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Review of RFID and IoT integration in supply chain management

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ABSTRACT

Supply Chain Management (SCM) is increasingly complex and dynamic. Radio frequency identification (RFID) and the Internet of Things (IoT) are expected to play a significant role in fulfilling customer requirements in the supply chain. In this work, the integration of RFID with IoT is called RFID-IoT. RFID-IoT strives to develop automated sensing, seamless, interoperable and highly secure systems by connecting IoT devices through the internet. In this paper, the authors have systematically reviewed the selected literature on the application of RFID-IoT in supply chain management. The contribution of this paper is to review the current state-of-the-art literature and potential trend on the application of RFID-IoT in SCM. There is a need for an in-depth, comprehensive analysis of up-to-date literature to help enhance the management system efficiency, maximize productivity, and minimize cost. This work also explores the current challenges of the reviewed papers in RFID-IoT implementation in the supply chain. The conceptual framework model has been conducted from four major critical SCM perspectives: product manufacturing, shipping and distribution, inventory and retail shop. In the future, this review's highlighted insights and recommendations will hopefully lead to increased efforts toward developing RFID-IoT technologies.

1. Introduction

RFID has gained significant interest from industry and academia in recent years, even though it has existed for a long time. The reason is the component of this technology have become miniature, less expensive and more effective, which makes it easier to implement in many applications. For example, the recent implementation of RFID in event processing in SCM has enabled the company to identify the process deviations and optimize the business operation [1]. RFID is a wireless communication that can be used as system inputs for sensing, detecting, identifying, tracking, and monitoring multiple objects in its simplest form. The RFID's advantage is it links physical space and information space and discovers the binding between physical space objects and information space objects [2]. RFID is part of Automatic Identification and Data Capture (AIDC) that utilizes wireless communication to read multiple RFID tags [4] simultaneously. Compared with other AIDC solutions such as Optical Character Recognition (OCR), RFID is more widely used in supply chain management due to its ability to read outside from the line of sight and is cost-effective.

The evidence of RFID advancements can be witnessed in the blooming integration of RFID and Internet of Things (IoT) technology. IoT constitutes Wireless Sensor Network (WSN) to form a complete IoT system. WSN is a technology that integrates multiple small and intelligent sensors and scales in a more extensive area for various applications, including retail, healthcare, agriculture, and military surveillance, to overcome the limitation of wired solutions [3–7]. Conceptually, IoT can be defined as a dynamic global network infrastructure where physical and virtual objects are seamlessly integrated based on standard and interoperable communication protocols [8]. RFID uses communication protocols such as Tag talk Only (TTO) protocol and Reader Talk First (RTF) protocol to connect every tagged object in the IoT network [9]. It is named RFID-IoT. RFID-IoT offers a new operating solution in the supply chain focusing on manufacturing, retail shops, inventory, transportation, assembly, asset tracking, location, and even environmental detection. From all the previous studies, the evolution of RFID-IoT will bring a significant impact to the revolution of Supply Chain Management (SCM) [10–15]. The adoption of RFID-IoT technologies improves operational processes and reduces SCM costs. This is because RFID and other IoT technologies can provide information transparency, product traceability, compatibility, scalability, and flexibility. With the ubiquitous interconnectivity offered by RFID-IoT technologies, each stage in SCM can be interconnected to ensure correct processes and products are delivered at the right time, at the right quantity, to the right places [16]. Previous research reveals that information sharing is essential to

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improve coordination among organizations in the supply chain, resulting in efficient management [17,18].

After surveying the literature, the scope of RFID-IoT in the supply chain has increased drastically as the company is looking at reducing the operation cost and automating the process, enhancing product quality and creating customer satisfaction. However, a focus on RFID-IoT in SCM context is still missing. To date, most recent review works have focused on RFID or IoT in the supply chain to serve as practical guidance for future research [19–23]. A systematic review of the RFID-IoT study, especially SCM, remains highly demanded by supply chain stakeholders such as suppliers, manufacturers, retailers and customers in Industry 4.0 [24,25]. This paper fills the gap by carrying out a systematic review on the integration of RIFD and IoT in terms of effectiveness, interoperability, scalability and compatibility in SCM. Additionally, the paper aims to investigate the advantage of RFID-IoT from the aspect of four main criteria as follows: 1) Effectiveness for the assigned task, workforce, machine/vehicle utilization, time and other resource costs, 2) Interoperability between raw material, product, pallet and container, 3) scalability of marketing strategy and data accuracy, and 4) compatibility to real-time data updates and security standard. With the continuing development of RFID and IoT, RFID-IoT has become crucial to automate supply chain management. There is still a lack of a comprehensive review that studies the state-of-the-art literature, investigates the challenge, and discusses the possible trends of RFID-IoT in the future. Thus, this paper will highlight the implementation of RFID-IoT from these points in recent works. This paper also focuses on the application of RFID-IoT by introducing the background of the technology, providing helpful insight and problems that existed in the anatomy of the previously proposed method. Since the RFID-IoT technologies are advanced, the paper highlights each article's feedback to provide a knowledge base overview for academicians and practitioners. The objective of the paper is as follows:

1 To study RFID-IoT technology's advancement in effectiveness, interoperability, scalability, and compatibility in SCM.
2 To investigate the challenges faced by the existing literature in SCM.
3 To discuss the potential future works based on the current development of RFID-IoT technology.

The remainder of this paper is organized as follows. Section II presents a brief description of RFID and IoT technology as well as how RFID-IoT is integrated to apply in SCM. Section III provides the step for implementing the systematic review methodology. Section IV surveys the solution of RIFD-IoT in SCM application in each stage of SCM. Meanwhile, Section IV also discusses the problem faced in each stage of SCM. Next, Section V discuss managerial implications, and Section VI reveals the current challenge and future potential works of RFID-IoT. In the last section, some concluding remarks and research perspectives are presented.

2. Brief introduction of RFID-IoT in SCM

Of late, RFID has drawn increasing attention in many fields, including defense, identification, environment, transportation, agriculture, banks, healthcare, security, and communications [26–30]. The three main essential components in RFID are the reader, antenna, and tag. The reader is also known as a transceiver. A Radio Frequency (RF) electrical wave is used to activate and power the RFID tags. The antenna converts the electrical wave to electrical flow via a coil. Then, RFID tags (e.g., passive or active) are attached to a physical object response by sending another electrical wave information back to the reader. The RFID tag has a part named the Electrically Erasable Programmable Read-Only Memory (EEPROM) to store information such as unique product ID, batch ID, product quantity and location. All the data will be stored in a computer database.

RFID monitors the dynamic changes of state, position, and other tagged objects' attributes. It can be divided into two major types: passive and active tags. A passive tag does not need an external power source. The tag is powered by the radio frequency energy transmitted from RFID readers. The active tag typically offers longer reading ranges with a limited lifespan than the passive tag with its built-in power source. The active tag works to track the object by providing real-time data continuously. In contrast, a passive tag works with many tagged objects to provide a more economical deployment cost. Both tags have their advantages. There are a few significant advantages of using RFID as a detection and identification system [11]:

1 Tag detachments are negligible as they could be disposed easily
2 Ease to implement and trace
3 The probability of missing and failure detection rate is reduced
4 The system is easier to develop and maintain
5 "Place and go" scenarios are fulfilled
6 Able to read multiple tags at once
7 Cost effective

The RFID classification is divided according to the frequency at which they operate and the application types. It is shown in Table 1.

The RFID's emerging technology has inspired IoT to link physical objects into an informative network to exchange raw data about the item location, statuses, movement, and process [8]. IoT is defined as a dynamic global network where each physical and virtual asset is individually identified with a unique ID, tracking physical status seamlessly [31]. IoT has made the devices to be remotely accessible to the user. Through IoT, RFID and sensor network technologies will meet new challenges in which information and communication systems are embedded in our daily lives. Interaction and communication among objects and machines allow them to respond autonomously. For example, the machine can make a decision intelligently through other machine inputs to solve a complex problem. Generally, IoT are divided into three primary layers: perception layer, network layer and application layer. Based on the study of [32], IoT system should include five type of layered architecture to relate RFID-IoT with business or management models. Five layered architecture consists of the perception, network, middleware, application, and business layers. It can be shown in Fig. 1.

The details of each layer are explained as follows:

1 Perception layer: Collect and identify information from various IoT devices such as RFID tags that stick on the product and other IoT sensors such as temperature, optical sensors, proximity sensors, accelerometers, and gyroscopes to indicate the product environment.
2 Network layer: Transmits information generated by IoT sensors into the server by utilizing a Wi-Fi network.
3 Middleware layer: Ingest, process and store data generated from the network layer according to the data format types.
4 Application layer: Analyze and visualize the collected data in SCM systems.
5 Business layer: Understand the data and change the business or management model according to the trend.

In SCM, RFID-IoT can automatically identify the status of an object, stock, equipment, machine and even workers by capturing the real-time data. For example, RFID-IoT can detect the start or finish of a process from the signal of arriving and leaving the RFID-IoT covered area. IoT is a prominent innovation that enables communication and interaction among different devices through the internet [34]. Objects are equipped with data collection and analysis automation, allowing them to react to real-world events and make predictions and decisions without human intervention. IoT can resolve many multifaceted problems that require sophisticated analysis and fast response in this ubiquitous computing environment. Real-world problems are solved using IoT devices and networks [35]. An example of application is driving assistance tools,

Table 1
RFID frequencies, characteristics and applications in SCM.

RFID operation frequency band	RFID properties	RFID frequencies	Read Range	Transmission rate	Applications
Low Frequency (LF) 30–300 kHz	Passive	125–134 kHz	Short	Slow	Manual warehouse and retail counting
High Frequency (HF) 3–30 MHz	Passive	13.56 MHz	Medium	Medium	Automated product counting
Ultra-High Frequency (UHF) 300 MHz-3 GHz	Passive	433 MHz and 865–956 MHz and 2.45 GHz	Long	Fast	Logistics tracking and progress updates for different location
Microwave 2–30 GHz	Active	2.45–5.8 GHz	Very Long	Very Fast	Real-time tracking such as asset tracking, worker tracking and Work In Progress (WIP) in real-time

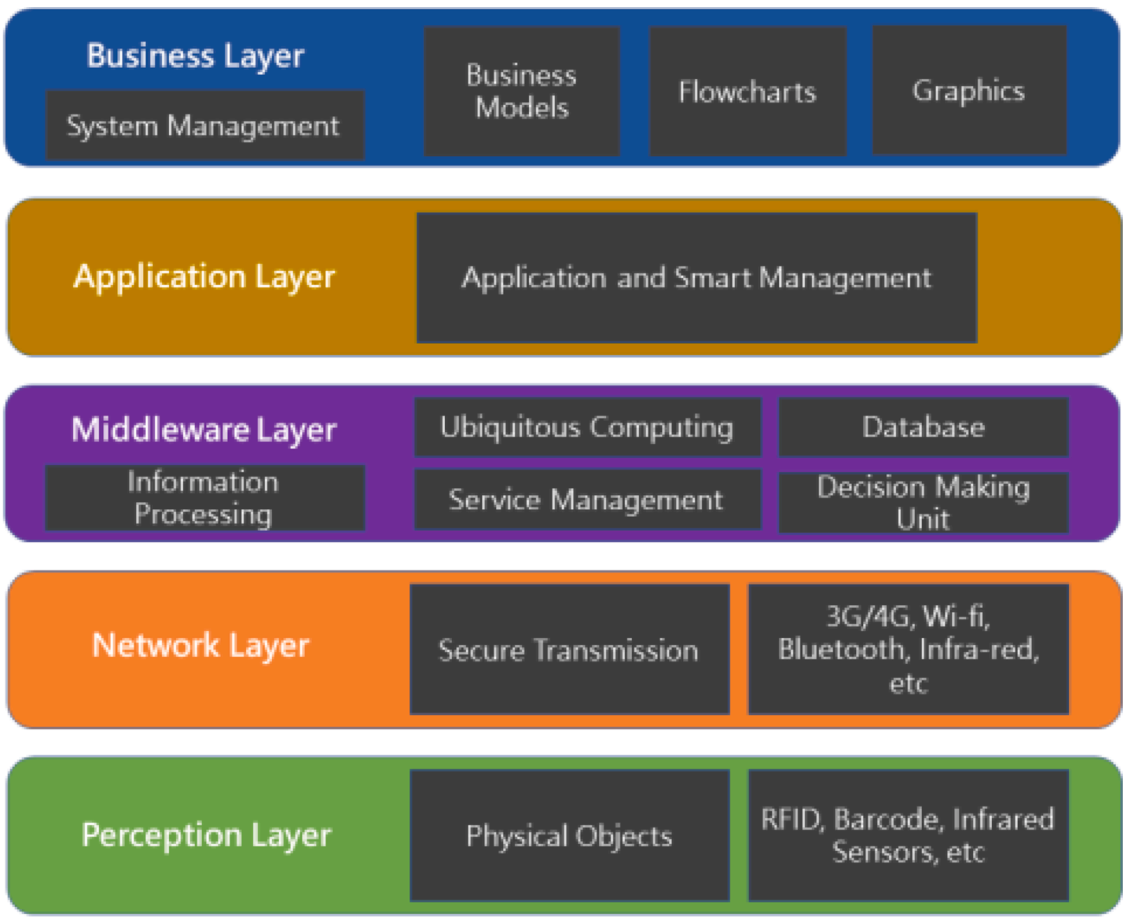

Fig. 1. Layered architecture of RFID, IoT and business model [33].

asset tracking, machine maintenance, process control, resource allocation and context-aware automation.

To this purpose, IoT can become an active participant in business management, automation, industrial manufacturing, intelligent transportation of people and goods. IoT provides a friendly environment to improve inventory management, data transparency, resource utilization and business insight. The combination of RFID and other IoT technologies allows the product to be tracked from manufacturer to retailer and cost-efficiently mitigate time and production. Also, intelligent supply chain management enhances brand protection, quality assurance and customized client preference. For example, consumers are more positive by-products because every ingredient, process, and status can be traced and verified. Since each process is complex and dynamic, it is hard to calculate the cost and time needed. RFID and other IoT technologies are necessary to track cost and time in the supply chain.

Fig. 2

3. Review methodology

In this study, the selection of literature was performed by systematically reviewing to avoid the reviewer's biases and discover the hidden structure and properties of research domains on the application of RFID-IoT in supply chain management. It started by searching for the combination of keywords such as RFID, IoT and Supply Chain Management. Note that resources from white papers, theses, book chapters and websites are excluded in this review. Also, only research articles published in the last 10 years on RFID-IoT applications in supply chain management are included in this study. Furthermore, the selected papers must be published in English and relevant to the title. After all the research articles were collected, papers were divided into four categories: product

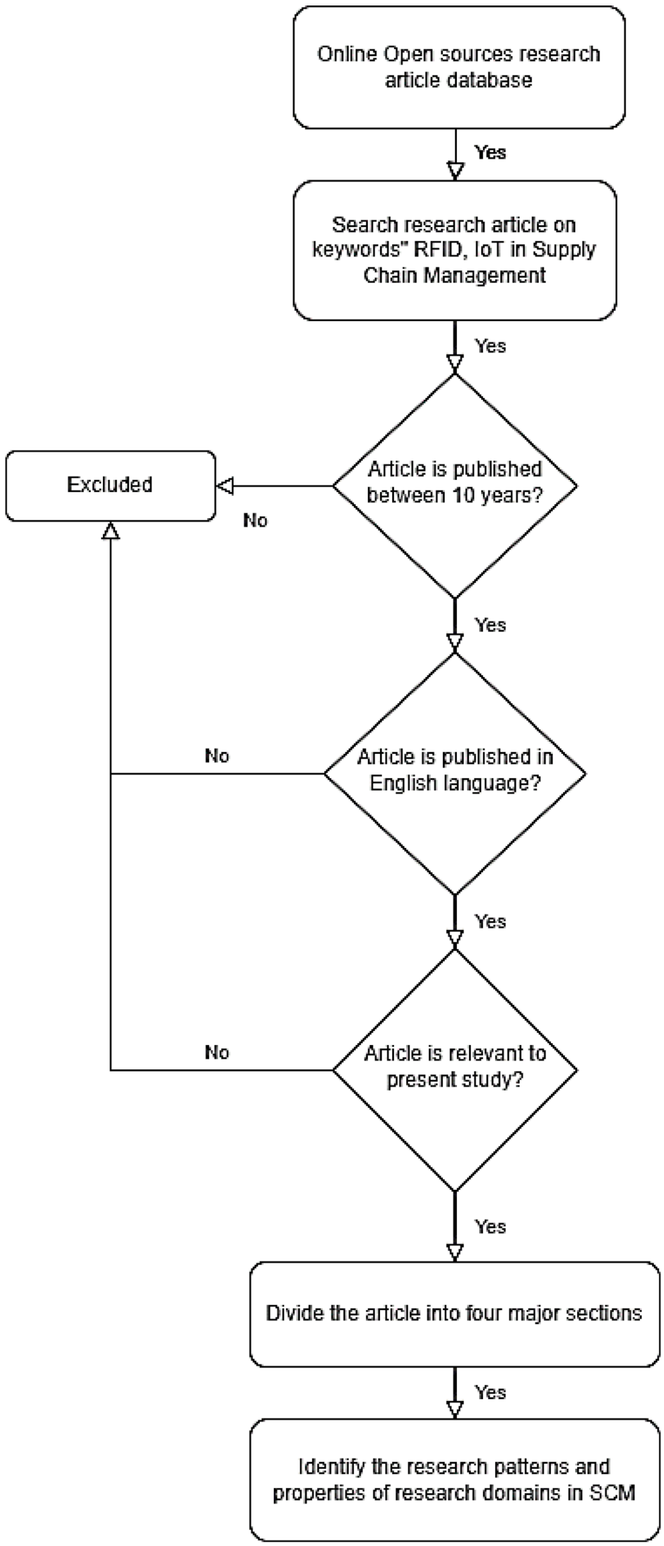

Fig. 2.. Article selection Methodology.

manufacturing management, shipping and distribution management, inventory management, and retail management. This is the adopted model by the author after performing a systematic review of recent literature. All the selected articles are studied thoroughly to identify the trends and properties of research domains in supply chain management. Additionally, a few more articles were used to support the study. Fig. 3 shows the article selection methodology used in the present study.

4. RFID-IoT system in supply chain management

RFID-IoT technologies, with their existing properties, such as automated product identification, pervasive network and real-time data transmission, contribute to the supply chain in various ways. The development of RFID-IoT can be observed through different supply chain management stages such as manufacturing, shipping and distribution, inventory and retail shop. The classification is motivated by a recent study that pointed out that many studies do not explicitly incorporate product shipping and distribution in their supply chain activities [36]. The undefined gray area of classification makes SCM process becomes uncertain and increases the cost and risk of the supply chain [36]. It is shown in Fig. 3.

Through these applications in the supply chain, RFID-IoT technologies can help product cost reduction, product quality, process improvement, and multiple-party communication and service. Sarac et al. [37] remark on the impact of RFID-IoT technologies deployment on the supply chain from analytic modeling, simulation work, case studies and experiments, and ROI analyses. From a substantial amount of RFID-IoT literature that has been surveyed, this paper aims to present the significant contributions of scientific articles from its methodology, design and applications in the supply chain based on four main categories.

4.1. Product manufacturing management

4.1.1. Overview

Manufacturers recognize that a shift of procedure and organization mindset is essential to succeed in the current market, especially in monitoring and managing raw material workflow. The development of this sustainable agile manufacturing supply chain can be assisted with the help of technology. With the sensory wireless network from RFID and ubiquitous data accessibility from IoT, materials or objects can be identified and streamed to the servers through the internet to provide real-time information. In other words, it also eases the complex process of assembly tasks by delivering the suitable material and accurate location (i.e., row and column of the shelves). Furthermore, the intervening RFID-IoT technology impacts high-efficiency labor work and cost-efficiency in manufacturing with less human error. Indirectly, this also solves high turnover rates in manufacturing companies by intervening with fewer workers in the overall process. At each stage of the supply chain, the authors assessed the advantage of the RFID-IoT application in terms of effectiveness, interoperability, scalability, and compatibility. The advantages of RFID-IoT are divided into three main categories: product and resource management, operational management and information management. At each stage, the advantages of using RFID-IoT are different. For example, in product and resource management, RFID-IoT plays a role in tracing the origin of the resource and tracking the product, machine and workforce to maximize the operation process. In contrast, in operational management, RFID-IoT is used to show the current status of the operational tasks to estimate the completion time, and RFID-IoT is used to further analyze the data for decision support tools in information management. By organizing the benefits of RFID-IoT in three main parts, it is easier for the stakeholders to see its benefits from a different point of view based on their requirements. Fig. 4 shows the advantages of RFID-IoT applications in product manufacturing management.

4.1.2. Applications in product manufacturing management

The authors [29] proposed an active shopfloor material handing based on multiple manufacturing data sources. The solution is conducted in real-time navigation. The proposed solution included a new allocation strategy to optimize the move task process, an intelligent trolley with sensing and automated ability, and transportation cost reduction. In order to optimize the overall workflow, the proposed solution utilized active sensing capability from RFID technology and

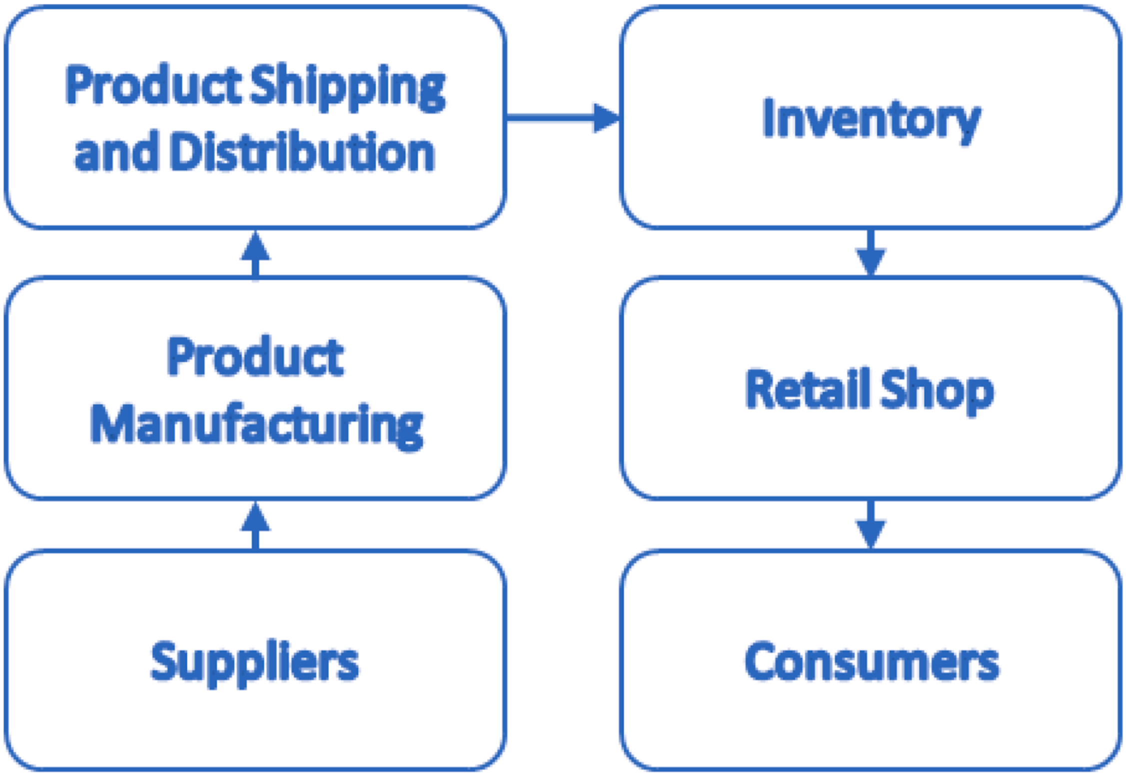

Fig. 3.. Stages of RFID-IoT technologies in SCM.

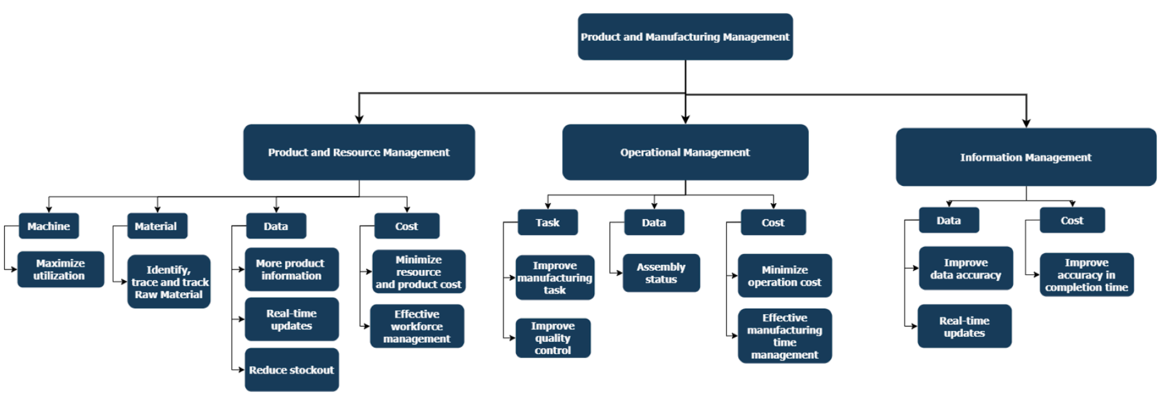

Fig. 4.. The advantages of RFID-IoT applications in product manufacturing management.

improved the process flow in dynamic material handling tasks in a real-time data-driven environment with IoT technology. With the proposed optimized strategy, bulk tracing and tracking efficiency is improved. Human handling errors mainly cause efficiency to be decreased with automated material handling with the optimal task in time, cost, quality, distance, priority, and volume. The overall transport cost is also reduced to meet the requirement of large-scale manufacturing using RFID-IoT technology. For advanced material handling, a more energy-efficient and cost-saving material involving cognitive computing is proposed to solve this problem [38]. This work focused on designing a high-performance cloud-based material handling system with various localization and mapping algorithms, notification services and decision-making mechanisms. This proposed system proved its viability and effectiveness compared with the conventional demand delivery method.

Other than that, RFID and IoT technology are also implemented to identify, trace, and track the process history of assembling automotive parts. It is designed to deal with processing defects and product recalls. Segura Velandia et al. [39] investigated the RFID system's flexibility and compatibility to track crankshaft workflow in manufacturing, assembly and retail processes. The proposed method focuses on designing a low-cost UHF RFID passive tag and optimizing the reader antenna infrastructure to be robust in metal environments. The solution can work under harsh operating conditions, and it is removable and reusable to other similar automotive components. With the integration of IoT, all the data from manufacturing, assembling, process, and environment is collected in real-time. All the data is streamed into the local server within the factory area. The paper claimed that the proposed RFID-IoT solution is more beneficial in lower-cost terms than other camera-based systems in assembling and manufacturing. The other solutions tend to have a relatively higher cost in terms of hardware, software, and development cost.

One of the focuses in manufacturing is the quality and safety of the material used. In this high visibility and data transparency, the consumer demands details on the material used. It includes ingredient description, ingredient amount, and even non-compatible ingredients, including chemical composition. Mihai et al. [40] proposed a food safety management system in manufacturing the product from raw material data like organic fertilizers, organic seed, growth process and environment. The purpose of this system is to monitor the overall food production ecosystem. Identification data was collected to trace and track the data from RFID tags and various sensors (i.e., IoT sensors). Then, the data is streamed to the data center with IoT technology. This process makes the traceability of raw materials convenient, automated, effective, and, more importantly, real-time. By doing this, the solution has increased the visibility of the product quality and ensured product safety. Overall, the food processing process and the amount of the ingredient have become more transparent than the primitive method (i.e., barcode technology). The shown information would convince the consumer that the proper process and the right amount of ingredients are labelled in the final product.

Other than barcode technology, the authors in [41] proposed to combine RFID and QR technology to develop an economical and effective solution for tracing and tracking prepackaged food in a real-time situation. This sensory technology combination is selected by considering the implementation cost in large scale manufacturing. This method is not only conducted by number counting; it can also detect excessive additives, unhealthy portions of multiple ingredients, and food expiration. In addition, validation and warning alerts identify the root cause and facilitate a timely response when food quality and safety issues happen.

Another important factor that always affects manufacturing efficiency is the work schedule. In a manufacturing factory, it is expected that various types of products are manufactured parallelly at the same time in the shared production line. Thus, it is essential to schedule the resources such as equipment, job tasks, machines, workers and materials to achieve effective productivity. Wang et al. [42] modelled a real-time IoT-enabled solution named Manufacturing Petri Net (MPN). This solution encapsulated various passive and active manufacturing objects with RFID tags and mapped them with an intelligent tool agent. Following that, a conventional metaheuristic method named Ant Colony Optimization (ACO) was performed to optimize the MPN model. The simulation studies were carried out to prove the proposed solution's outperformance in solving the search stagnation of the schedule and increasing the workflow's efficiency. Also, Zhang et al. [43] presented an integration architecture for the internet of manufacturing things (IoMT) to provide a real-time information acquisition process. Under this framework, manufacturing data from machines, operators, pallets, materials, and operations embedded with sensors is connected in dual-way communication among enterprise, factory, and even machine layers.

In an ideal pervasive manufacturing environment, real-time production scheduling is always demanded. Production scheduling allocates the right manufacturing resources to the plan's set of manufacturing processes [44]. Zhang et al. [37] utilized the multi-agents method to control and plan the overall workflow to achieve real-time production scheduling. This work proposed agent models to demonstrate the result in a simulation work example by utilizing various technologies such as wireless sensors (i.e., RFID), information network (i.e., Zigbee) and communication (i.e., IoT) technologies. Four main agent models: machine agent, capability evaluation agent, real-time scheduling agent, and process monitor agent models are presented to optimize production management.

Another notable article was proposed by Chen et al. [11] to introduce a new design concept and system architecture of RFID and IoT-enabled solutions in the semiconductor manufacturing industry. Manufacturing Execution Systems (MES) collected RFID data into the database instead of RFID memory (i.e., EEPROM). This key process is to avoid the failure of reading and data updates. This design has changed the manufacturing operation flow, especially in improving reading quality to fit the characteristic of IoT at a lower cost. However, despite RFID-IoT technology's benefits in solving the fast reading and updating rate of data, the proposed solution needs the collected data to be formated in a small size.

4.1.3. *Problem faced in manufacturing management*

There are always new problems as the manufacturing industry changes rapidly due to fast technology transformation. Based on the previous subsection, a considerable amount of literature has been published on designing a new manufacturing industry system from the material used, complex assembly tasks, agile manufacturing processes, product quality, and even worker's efficiency. However, many articles still do not consider dynamic events of manufacturing resources, which makes most of the proposed methods are limited to simulation or laboratory work. For example, factors such as battery life, operating frequency, feasibility, and size need to be considered and tested in real-world situations [45]. In addition, the aspect needs to be compromised upon to fit the stricter requirement of a live system.

From a technological aspect, the adoption of these technologies is still challenging. The manufacturing industry's key challenges can be mainly listed as follows: system architecture, scalability and compatibility, and decision-making mechanism. Most of the time, software consultants design a system according to the main requirements of manufacturers. The problem comes when integrated with existing systems like MES and the production scheduling system. Challenges like communication bandwidth, data ingestion from batch processing and real-time data and database management require many optimizations to minimize system latency and downtime. Many proposed solutions work well in simulation, but they fail to work when deployed in actual manufacturing. The reason is that the problem faced in the real world could have different. Communication between the consultant and the domain expert is necessary. Other than that, the mechanism involving more relevant data collection, data analysis and prediction model building (e.g., machine learning) is always neglected. This key process is vital to provide more business insight and help to make more decision-supporting tools. According to the previous section, all the problems are depicted in Table 2, according to the reviewed papers.

4.2. *Shipping and distribution management*

4.2.1. *Overview*

In today's world, shipping and distribution management plays a vital role in many companies. A well-managed company in shipping and distribution can increase its ability to compete and profitability from cost and time. Shipping and distribution management provide product movement and storage from sources of materials to the end-user and consumer. Usually, this process involves many parties such as manufacturers, transporter, storekeepers and even consumers. Effective coordination is hard to be achieved due to inconsistency and fragmentation that occurred in the process. With the seamless ability of RFID and IoT, it is easier to connect multiple parties in the same platform where each party can access the information they want at any time. For example, when the product is transferred from one place to another, all the involved parties' locations could be accessed to better plan and prepare to receive it or send the next batch. Such a system will significantly reduce shipping and distribution costs and effectively handle mass orders despite its customized product. Fig. 5 shows the advantages of RFID-IoT applications in shipping and distribution management.

4.2.2. *Application of shipping and distribution management*

A vast amount of literature focuses on automation shipping and distribution applications. However, given the complexity of the processes involved, this industry still lacks identification, tracking, real-time data streaming, resource management, and operations compatibility. This weakness has affected the dispatch and arrival time of the product and mitigated the overall process's efficiency.

Qiu et al. [48] designed a public logistic system to increase inter-company collaboration by increasing visibility and transparency of the assets and statuses. This solution highlighted a new business model

Table 2.
Problem description in product manufacturing management.

Article	Year	Research object	Problem description
[46]	2015	Manufacture distribution tasks	• The integration of the proposed solution with the existing system (i.e., production scheduling system or MES), particularly in agile software and hardware technology. • The system architecture can be further optimized. • Costly solution, especially in large scale deployment. • The scalability and compatibility of the system should be further evaluated with more real-life cases.
[38]	2018	Manufacture distribution tasks	• Cloud technology is not fully utilized. • The integration of the proposed solution with the existing system (i.e., production scheduling system or MES), particularly in agile software and hardware technology. • The scalability and compatibility of the system should be further evaluated with more real-life cases.
[39]	2016	Automotive part, Crankshaft	• RFID solution needs to be customized, which then increase the implementation cost. • The integration of the proposed solution with the existing system, particularly in agile software and hardware technology. • Traditional Business Intelligence (BI) analysis is limited to product, process and workforce. • Domain expert knowledge is lacking from the proposed solution. • The costly solution, especially in large scale deployment. • The system architecture can be further optimized. • The scalability and compatibility of the system should be further evaluated with more real-life cases.
[40]	2015	Food	• RFID solution needs to be customized to fit the requirement of the autonomous sensor structure. • Redundancy data • System latency due to big data processing • The system architecture can be further optimized. • Domain expert knowledge is lacking in the proposed solution. • The solution is costly, especially in large scale deployment.
[41]	2017	Prepackage food	• System security should be enhanced. • System latency due to big data processing. • The system architecture can be further optimized. • The decision-making mechanism should be enhanced. • The solution is costly, especially in large scale deployment. • The scalability and compatibility of the system should be further evaluated with more real-life cases.
[42]	2016	Manufacture process	• The scope of dynamic events is limited. • More IoT devices should be added. • System latency due to big data processing. • The scalability and compatibility of the system should be further evaluated with more real-life cases.
[43]	2015	Real-time data acquisition in manufacturing	• The integration of the proposed solution with the existing system (i.e., production scheduling system or MES), particularly in agile software and hardware technology. • The system architecture can be further optimized. • The solution is costly, especially in large scale deployment. • A decision-making mechanism should be added. • System security should be enhanced. • The scalability and compatibility of the system should be further evaluated with more real-life cases.
[47]	2014	Real-time production schedule	• Real-life use cases should be implemented. • System complexity should be evaluated. • The system architecture can be further optimized. • A decision-making mechanism should be added. • The scalability and compatibility of the system should be further evaluated with more real-life cases.
[11]	2020	Manufacture process	• System security should be enhanced. • System latency due to big data processing. • The system architecture can be further optimized. • The decision-making mechanism should be enhanced. • The scalability and compatibility of the system should be further evaluated with more real-life cases.

in industrial parks by supporting real-time information of the assets using RFID sensing and IoT's pervasive computing capabilities. Since the proposed business model involves multiple parties, especially manufacturers, tracing and tracking the assets and services plays a vital role. With that, procedures such as check-in and check-out, real-time route, vehicle status and resource utilization can be monitored and optimized. The system infrastructure design aims to be flexible, easy to use, easy to deploy, and simple data exchange using Extensible Markup Language (XML) format. Besides road-based vehicle tracking, the vessel's demand in inland waterways is also required despite the water-based service still being largely disorganized [49]. Conventionally, the vessel is mounted with an Automatic identification system (AIS), which disadvantages time delay in data exchange. This delay makes it hard to monitor and communicate across the area. The new system can achieve low latency with real-time visibility and communication to each stakeholder by integrating RFID, wireless sensor networks (WSN), cloud, and IoT technology,

Rescheduling commonly happens in the shipping and distribution process, resulting in the waste of vehicle loading capacity, error in loading tasks and low-efficiency logistic delivery. To encounter rescheduling, real-time information update and effective route optimization are essential. Liu et al. [50] suggested a framework of IoT installed with RFID tags, readers, sensors and actuators that provided reliable real-time information from multiple parties. The real-time information, including vehicle's paths, road conditions, logistic resources and additional task requests, optimizes vehicle routing problems. According to the driver's requests, all real-time information can be visualized in a software dashboard to offer the optimal routing service. This proposed method has improved vehicles' utilization and reduced resources, particularly in providing optimal vehicle routing in fuel

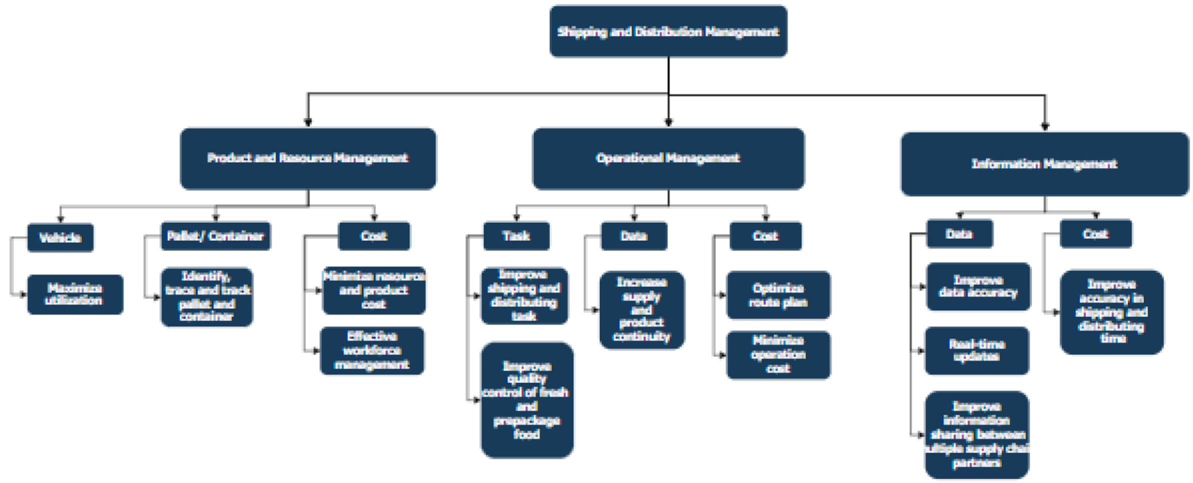

Fig. 5.. The advantages of RFID-IoT applications in shipping and distribution management.

consumption. The scheduling and routing network model is proposed [51] in work with RFID and GPS to manage the supply chain. Based on the real-time information from RFID reading GPS units, supply chain managers can plan, monitor, and adjust optimal routes and schedules based on their experience.

Besides the mobile app, Ding et al. [52] remark that transparency of inter-enterprise transportation is vital for logistic service providers to provide a smooth and reliable system. With RFID and IoT technology, the proposed method offers two main functions in shipping and distribution: real-time transportation status monitoring (RTSM) and integrated production and transportation task dispatching (IPTD). Furthermore, IPTD is optimized with improved teaching-learning based optimization (TLBO) to minimize production and transportation costs. Specifically, this work integrated real-time production and transportation data to monitor task progress and status. It also provides more automation tasks, including decision support tools on production schedules and order management. The authors also claimed that the proposed solution would react to the dynamic decision for inter-enterprise transportation tasks. The designed software integrated system used a Web-based application (WebAPP) because of its autonomy, scalability, and easy reconfiguration. This work provides a comprehensive solution by considering production process monitoring, machine status monitoring, historical tasks and current task and machine workload analysis graph. A previous study used a collaborative cloud-based platform with core technologies such as RFID, IoT, GPS/GPRS and cloud computing to facilitate the pallet and container transportation flow and information sharing [53]. The proposed system used the Google cloud SQL platform to store a relational database schema. The advantage of using Google Cloud Platform (GCP) is that Google will handle replication and path management and ensure performance from scalability and availability.

Pal and Kant [54] reviewed the potential to enhance sensor-based infrastructure (i.e., RFID-IoT) to reduce food waste and keep fresh food in good condition until it reaches the end consumer. The proposed mechanism, which is aided by centralized data collection and analytics via cloud computing, can reduce food waste, improve transportation and distribution processing, and quick detection of contaminated food and spoiled food along the supply chain. To enhance the efficiency of food traceability, the authors utilized a machine learning model to identify the direction of tags on receiving and shipping through RFID gate and IoT in perishable foods such as meat, ice-cream, milk and prepared products [55]. All the data is stored in the MongoDB database. Five tag movements were classified to train the machine learning model, XGBoost, to identify the product distribution process (i.e., shipping and receiving). Five different tag movements included moving through the gate, moving out of the gate, moving close to the entrance, turning-back movement, and static tags. This proposed system aims to track product movement and monitor food products' humidity and temperature to ensure food quality and safety. To handle data mining problems such as missing sensor data from hardware and networking problems, Alfian et al. [56] suggested a multilayer perceptron (MLP) neural network model to predict missing sensor data. Missing sensor data such as temperature and humidity data is anticipated to handle missing data problems to monitor the food (i.e., kimchi) quality and safety.

In 2020, the shipping and distribution of food were enhanced by tracing and tracking various food conditions. The authors combined temperature sensors into RFID tags and interconnection IoT services to evaluate food conditions like pumpkin and orange in real-time [12]. The proposed system integrates multiple systems into the same platform by addressing the different software providers' interconnection problems. The proposed solution utilized an RFID subsystem and cloud computing to form a scalable solution for the user. To perceive the proposed solution's return of interest, the authors proposed to charge the solution service as data as a Service (DaaS) scheme, where users pay based on the data they consumed instead of installed equipment.

4.2.3. *Problem faced by shipping and distribution management*

Shipping and distribution are the most challenging part of the supply chain as they act as an intermediate medium for suppliers, manufacturers, retailers and consumers. Based on literature reviews, most applications focused on detecting and identifying vehicle location, task status, data streaming in real-time, food quality examination, shipping schedule, and route optimization. However, many applications have difficulty ingesting the data continuously due to the moving and dynamic situation in shipping and distribution management. Moreover, there are some rural areas which are not covered by internet connectivity. The adoption of these technologies requires more investment and involvement from multiple parties. Factors such as the return of investment, development cost, deployment cost, scalability, feasibility, and future potential are considered to maximize the company's profit. Since many existing problems remain unsolved, there is a lack of a decision support mechanism in assisting shipping and distribution in the supply chain. Conventionally, shippers and carriers aim to minimize their costs to increase profitability. However, more recent focus has been shifted toward system-wide cost reduction to maximize the overall profitability [34]. A comprehensive system enables accessible communication, effective coordination and efficient management involving shipments from manufacturers through shipping and distribution centres to customer retail shops. It is difficult to find a comprehensive system to meet all the requirements from multiple parties. All the challenges are listed down in Table 3.

4.3. Inventory management

4.3.1. Overview

Inventory tracking is a crucial aspect of modern supply chains. It plays a vital role in the success or failure of businesses. An inventory's primary function encompasses receiving, storing, order processing, and dispatching based on customer orders. The inventory needs to be adaptive to production rate by optimizing three target customer demand services: inventory cost and operation cost. Customer demand services are kept highly responsive while inventory and operation costs are minimized. Conventionally, inventory management faced a problem in handling heavy workload and constant demand on product diversity. Innovation in RFID-IoT development has inspired many applications in inventory management. It has included product identification and tracking, equipment maintenance date, inventory space optimization, environment identification and workforce management. Fig. 6 shows the advantages of RFID-IoT applications in inventory management.

4.3.2. Applications of inventory management

Inventory management has drawn much attention due to the need to store the ready product, real-time sensory data streaming inside the warehouse, and space utilization according to different product requirements. In [41], the authors developed a low-cost solution to detect, identify, and monitor the product using Raspberry Pi as a central server. This work claimed that RFID is more compatible in warehouse management due to its wireless sensory ability in a dynamic environment such as inventory. A passive tag is employed in the proposed system due to its negligible interference effect and lower maintenance cost. Using an open-source IoT platform named NodeMcu with ESP8266–12e Wi-Fi module, sensor connectivity and data acquisition are connected to form a highly effective inventory management system. A web page is built to monitor the product information such as tag number, storeroom location, time, and description in a table. To ensure the proposed solution works in a dynamic event-driven environment, Qu et al. [57] presented a comprehensive solution that involves a real-time execution management system in internal and external warehouses. Traditional manual resource management has been replaced by a cloud-based resource management platform using sensing RFID, IoT and cloud manufacturing technology. The system can perform in real-time feasibility based on dynamic adjustments to activities. Therefore, this gives a better measurement of forklift utilization, shipment rate, total work overtime and inventory space utilization rate.

In inventory management, one of the common challenges is space utilization. Product is required to be stored correctly based on classes to ensure the safety assurance of the product. A previous study in the field proposed a safe and secure product storage management system based on its compatibility and availability [58]. The classes are divided into multiple categories such as flammable, explosive, oxidizing, health hazardous, toxic, harmful, and corrosive based on their chemical substances. After the product class is determined, a set of compatibility rules are conducted to prevent any incompatible products from being stored together, resulting in an accident. For example, chemical and explosive products should be stored in different areas to reduce accidents. RFID and IoT integration into the system, object, machine, and physical environment can facilitate the process. Besides rules, this work also presented a dynamic mathematical calculation on product class and compatibility. This space utilization strategy and class partition strategy are simulated with NetLogo's modeling platform using multi-agent entities such as product, resource, storage, and obstacle agents. Considering further space utilization, Zhou et al. [59] proposed a feasible solution in inventory by integrating a new fluid warehouse concept, movable shelves, as one of the trackable items. Instead of just storing the product in a specific location, this work built a dynamic and flexible warehouse scenario where the product can be dropped off and picked up

Table 3.
Problem description in shipping and distribution management.

Article	Year	Research object	Problem description
[48]	2015	Transportation in supply hub	• It takes time for a company to accept this idea. • More IoT devices should be added. • System latency due to big data processing. • The deployment work is difficult since the internet does not cover many areas. • Development and deployment are challenging to reconfigure based on the need of multiple stakeholders. • System security should be enhanced; especially it involves many platforms. • Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[49]	2011	Inland shipping	• The deployment work is difficult since many areas are not covered by an internet connection. • Development and deployment are challenging to reconfigure based on the need of multiple stakeholders. • System security should be enhanced; especially it involves many platforms. • Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[50], [51]	2019	Schedule and Transportation route optimization	• Resource allocations need to be optimized to achieve optimal management. • System complexity especially involves many platforms. • The system architecture can be further optimized. • Development and deployment are challenging to reconfigure based on the need of multiple stakeholders. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[52]	2018	Production and Transportation tasks	• System complexity especially involves many platforms. • Development and deployment are challenging to reconfigure based on the need of multiple stakeholders. • System security should be enhanced; especially it involves many platforms. • System latency due to big data processing. • The system architecture can be further optimized. • Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[53]	2015	Pallet and Container transportation	• Workflow management can be enhanced in terms of optimization, coordination, and quality of service. • Decision-making mechanisms should be included.

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Table 3. (*continued*)

Article	Year	Research object	Problem description
			• System complexity especially involves many platforms. • System latency due to big data processing. • A real-world use case could be added.
[54]	2018	Fresh food transportation	• Unreliable data were collected due to highly dense and dynamic in real-world logistic operations. • Faulty modules. • Patchy cellular communication due to unstable internet connection. • System complexity, since it involves many platforms. • System security should be enhanced; since it involves many platforms. • The system architecture can be further optimized.
[55]	2020	Perishable food transportation	• Faulty reading can cause the wrong detection. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios. • System security should be enhanced, especially in reader, tags and IoT sensor. • The system architecture can be further optimized.
[56]	2017	Perishable food transportation	• System security should be enhanced, especially in reader, tags and IoT sensor. • The system architecture can be further optimized. • Scalability and compatibility of the system should be further evaluated with more real-life cases.
[12]	2020	Fruits transportation	• Memory is too limited to store more data. • No warning system is proposed. • System complexity especially involves many platforms. • System security should be enhanced; especially it involves many platforms. • The system architecture can be further optimized. • Decision-making mechanism should be included.

from anywhere to achieve the most productive process. This step is handy, especially in handling heavy items. Based on the inventory capacity and shelves location, RFID-IoT based tracking system form a machine to machine (M2M) network to optimize the warehouse configuration based on location, capacity and routing in real-time. This work helps to save a lot of trip costs, space utilization and lead time especially in large and complex inventory environment. Other than that, the previous work also suggested to optimize the inventory space by measuring the stock control from multiple parameters [60]. To manage the inventory in the most effective way, parameters such as minimum stock level, stock review, reorder lead time, dispatch and arrival time, economic order quantity and batch control are assessed. The connectivity of the product status using RFID and IoT is essential to ensure this management system works in real time to prevent any faulty or inaccurate information flow. It helps to cope with high volatile customer demand while maintaining the process in inventory in optimal situation. The data exchanging is formed using cloud technology which is scalable to large scale production system.

In [45], the authors remarked on inventory management's importance in handling Returnable Transport Items (RTI). This paper presents an RFID-IoT peer-to-peer system for the packaged gas cylinder with the benefits of less cycle time, flexible capacity expansion, automation, and reduced cost of asset loss. The objectives of the proposed solution are divided into three categories. First, the solution needs to identify the cylinder with information, test schedule, and delivery date. Second, the gas cylinder's location must be tracked accurately to avoid misplacement and missing items. Third, the state of the gas cylinder needs to be accessed via environment or internal condition evaluation) to provide valuable data for business and customer purposes. In [46], the authors consider reusable containers part of the whole supply chain. Based on RFID and IoT technology, this work can acquire the returned item's recovery information (i.e., food container) in one period of time. Considering the utilization rate, status, return time, and quantity can effectively manage the inventory. Simulation works, including long-term average cost saving environment, and inaccurate information are conducted to ensure the proposed solution's reliability. It is critical to convince multiple companies to adopt this technology by providing long-term goals, particularly cost-effectiveness.

To provide secure, intelligent inventory management with identification process of products, trace and track products, information transparency, reduce time and cost, and customer satisfaction, the author in [61] presented a framework from RFID and other IoT technologies through a designed website. The proposed work analyzes cause and effect interrelationships among various criteria to develop a secure supply chain system. The requirements include dependability, service, network, and privacy analyzed based on the correlation matrix. Each

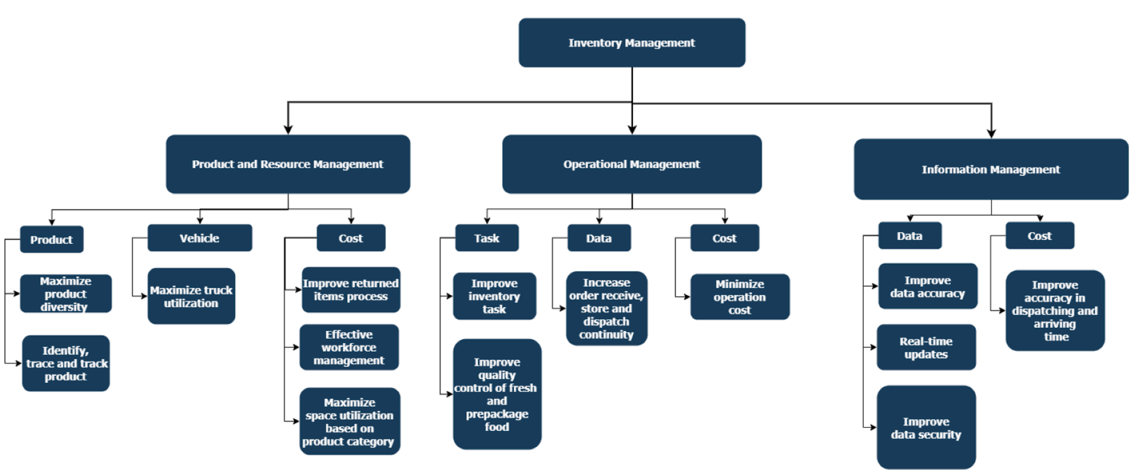

Fig. 6.. The advantages of RFID-IoT applications in inventory management.

criterion is calculated by weight to solve uncertain and incomplete information for prioritizing some requirements effectively. A previous study mentioned a secure and efficient end to end authentication protocol to mitigate security risk in the inventory management system, especially in RFID technology and information flow through the internet [62]. Mutual authentication between the tag-reader, reader-cloud server, user-reader, and the user-cloud server ensures the item's availability. Conventionally, the inventory management system utilizes an encryption method to ensure the sensed data is securely transmitted to the server (i.e., cloud server). However, the encryption method is computationally intensive and unsuitable for the RFID system due to the tag memory size and processing ability. The session key is generated during the authentication phase has proven to achieve a secure system with less computation and communication cost. Notice that the proposed method is also available to track the object in transit.

4.3.3. Problem faced by inventory management

An ideal inventory management system can deal with the erratic supply of the product to the inventory. However, inventory often faces difficulty handling volatile customer demands from their choices and preferences in the current era. This problem affects the strategy of each inventory planning accordingly. Based on the literature reviews, some systems advanced their solution with analytics models to forecast demand. Nevertheless, the analytic model still lacks real-time data, which can enhance the forecasting result in real-time. In terms of qualitative and quantitative analyses, inventory management always lacks comprehensive results and discussion, convincing parties such as small-medium enterprises to adopt the technology. This difficulty has restricted the continual development of this sector. Furthermore, some parties prefer to store their server and database instead of using cloud technology. The main reason is their company policy and their reliability on old technology. Having their server and database has indirectly increased the cost of developing and deploying any newly proposed solution and deteriorating innovation ideas. All problems are listed down in Table 4.

4.4. Retail management

4.4.1. Overview

Retailing is the last supply chain process before it is sent to the end-user. With the increased use of intelligent devices such as smartphones and tablets, the retail industry provides multiple solutions that bridge the gap between retail shops and end-users by automating product searching based on customer needs. This implementation requires a seamless retail tracking environment for any product placed in the shop. Retail management aims to enhance the customer shopping experience, improve profit margin, and lower operating costs. The enhancement in the customer shopping experience includes increasing multiple product varieties from different manufacturers, visibility of the product and product accessibility from the explosive growth of e-commerce. The profit margin of a retail shop strongly depends on product demand and supply. A successful retail shop can deal with seasonal and trend-based product demands and supplies. When a product is in high demand, a seamless and pervasive retail solution is crucial to increase the supply so that customers can get their product on time and vice versa. Besides, an excellent retail solution should maintain the product's quality regardless of the number of orders. Product hygiene has become a severe retail shop issue under the norm of the covid-19 pandemic,. This process has increased the operation cost, especially when this operation needs a lot of manual labor. Therefore, optimizing retail management to ensure the overall workflow is clean and safe while mitigating the operation cost is advised. Fig. 7 shows the advantages of RFID-IoT applications in retail management.

4.4.2. Applications of retail management

This section will focus on retail management applications in a

Table 4.
Problem description in inventory management.

Article	Year	Research object	Problem description
[63]	2018	Inventory management	• Microcontroller limitations – Memory, Ethernet, and processing power. • More quantitative analyses should be conducted. • System security should be enhanced. • Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[57]	2016	Dynamic inventory tasks	• More quantitative analyses should be added. • More value-added tools/information could be provided. • Task priority could be added to enhance the system efficiency. • System security should be enhanced; especially it involves many platforms. • Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[58]	2018	Product storing and space utilizing	• Inventory path optimization. • Workforce factor could be added. • Task priority could be added to enhance the system efficiency. • System security should be improved; especially it involves many platforms. • Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[59]	2017	Dynamic inventory environment	• The system can be further adjusted according to supply and demand trend. • More decision-making mechanisms can be added based on analyses of the trend of supply and demand. • System complexity since it involves many platforms. • System security should be enhanced; especially it involves many platforms. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[60]	2019	Space utilization in smart inventory management	• More quantitative analyses should be conducted. • System security should be enhanced; since it involves many platforms. • Decision-making mechanisms should be included.
[45]	2012	Explosive product inventory management	• Hardware limitations such as battery life, RFID operation frequency and size. • System security should be enhanced; especially it involves many platforms. • Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[64]	2018	Returned item management	• More value-added features could be added. • Necessary restriction rules could be listed.

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Table 4. (*continued*)

Article	Year	Research object	Problem description
[61]	2018	Secure inventory management	• Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios. • More comparison results could be added. • Integration with more systems should be enhanced.
[62]	2019	Inventory data security	• Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios. • More quantitative analyses should be conducted. • Security and risk assessment assistance tools should be added. • Scalability and compatibility could be enhanced with more cloud technology IoT features.

connected network of identified objects using RFID and IoT technology. The extensive set of applications of RFID-IoT is implemented to support streamlined retail management based on the challenges. The advent of RFID-IoT technology has inspired many retailers to explore the demand side of digitalization and automation in supply chain management.

Intelligent retailing is always in demand as many consumers face many bad real-life purchasing experiences, both physically and virtually. Part of the causes is the ineffective communication and tracking of products. The problem becomes prominent when the sales amount and customer requirements increase. Apart from product availability, customers require product information such as expiry date, price, nutrients, manufacturers, discounts, and other descriptions. Using RFID-equipped with interconnected IoT tools, the authors in [65] proposed a mobile device application (i.e., Android) that helps consumers shop with a better experience. Each product is tagged with RFID to store product information and connect data to the mobile application through IoT and cloud technology. This application is conducted economically as an android phone is commonly used now.

An interesting study on customer purchasing behaviors in retail shop is being investigated [66]. This work used multiple sensing devices such as beacons (i.e., RFID active tags) and Near Field Communication (NFC) to track the store's customer activity. The fuzzy logic model based IoT data is proposed to analyze customer purchasing intentions for a better shopping experience. The factors such as engagement time in the shop, similar product selection, and the number of the picked products are considered to build the membership function in a fashion retail shop. This intelligent fuzzy screening model can be developed to personalize apparel collocation based on customer preference [67]. Knowing consumer trends would enable technologies to benefit business decision-making and proactive individual marketing strategies.

To enhance the customer shopping experience, Verdouw et al. [68] suggested an information application system architecture that involved shipment planning, shipment planning, transport planning, and product tracking status in monitoring the fresh food supply chain more effectively. For example, booking cancellations from consumers can be prevented as long as timely product tracking information is provided. This virtualization is crucial to meet the requirements such as food perishability, safety, and sustainability in the fresh food (i.e., fresh fish) supply chain. Furthermore, this usage of this virtualization application could be powerful to enable decision-making tools with unpredictable supply variations such as refrigerator breakdown and limited supply from the daily supply. Technically, this work used software as a service (SaaS) approach by taking into consideration in providing an affordable solution for Small-Medium Enterprise (SMEs)

In [69], RFID hardware limitations are enhanced with printed Van-Atta reflectarray structure to design ultralong-ranger multi-sensor chipless RFID implementation. Van-Atta reflectarray is constituted of an array of antennas interconnected in symmetrical pairs. With its unique properties, RFID's ability is enlarged with ultralong range interrogation angles, which saves high costs in RFID implementation, especially in large retail shops. Xiao et al. [70] enhanced RFID design by focusing on cost-effective and low metal inference screen printed passive Ultra High Frequency (UHF) RFID design using electronic manufacturing method. Knowing that most retail shops consist of metal shelves, this work emphasizes designing a high-quality RFID antenna by formulating high conductive ink for screen printing techniques. This work is tested with several electromagnetic interference scenarios to prove its robustness and potential use in the presented analysis's retail environment. Another low-cost and inkjet-printed UHF RFID tag work was studied in the following year on metallic cans' item-level tagging [71]. This work is tested on retail shops (i.e., refrigerators) with the newly designed RFID tag integrated with IoT on its efficiency and compact size in a real-world application. The result showed that it is a cost-effective and eco-friendly solution by recycling empty beverage cans. These works significantly impact the future implementation of RFID-IoT technology as it is feasible for large and diverse retail applications.

A secure and safe authentication protocol is considerably desired between the RFID reader and tags in RFID-IoT applications other than

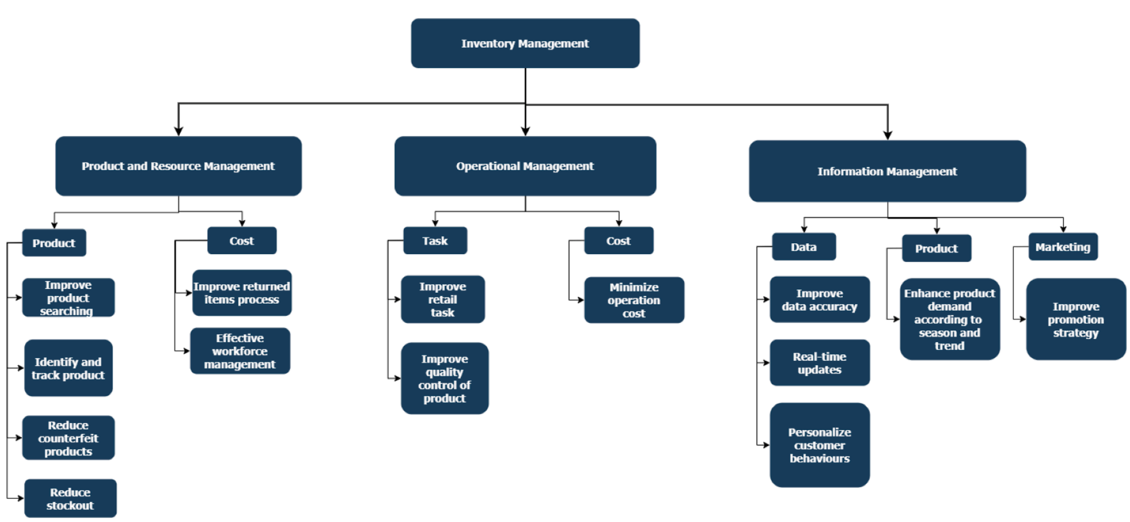

Fig. 7.. The advantages of RFID-IoT applications in retail management.

RFID hardware research. It is focused on [72]. This work employed basic bitwise XOR and left-rotation logical operations to produce an ultra-lightweight protocol for mutual authentication purposes. The computation, storage and communication are also considerably low. For example, factors such as data confidentiality, integrity, attacks, RFID tag anonymity and resistance to tracking are considered during its design. This design is required in retail management as a retail shop is one of SCM's most exposed places. This innovative work brings consumers' confidence when they intend to use a networked RFID-IoT system in their retail shops.

Dynamic pricing and promotion strategies have been a continual challenge for retail shops. In [73], the authors focus on fresh and perishable items by using RFID-enabled functionality to monitor product quantity in-store, product sales volume, expired date, and product replenishment to set up the volatile market price and promotion planning. The authors share the RFID tag placement method, RFID antenna placement based on product category, IoT data storing pipeline to interpret RFID's product movement, and streamline business operations for better supply chain visibility. This study highlighted the collaboration among retailers and suppliers is crucial to implement successful supply-demand tactics using communication technologies such as RFID and IoT.

4.4.3. Problem faced by retail management

Retail management is at the forefront of embracing RFID-IoT. It is mainly focused on enhancing customer shopping experience. A significantly rising number of retailers are receiving profit from operational and financial aspects, primarily through item-level tagging and live data streaming. The customer's behaviors are continually evolving, and it is essential to give insights on how technology can help improve the retail market requirements. The traditional store is hard to fully satisfy customer needs as the difficulties in locating the item, out-of-stocks, lack of sales assistance, and extended payment time. Most proposed methods are limited to live data and more quantitative results based on literature reviews. Owing to lacking data, this eventually restricted innovation invention of decision-making tools. The RFID hardware should increase tag readability, accuracy, and data security. In addition, the scalability and compatibility of the proposed method in various applications would be considered. All problem descriptions of the listed articles are tabulated in Table 5.

5. Managerial implications

RFID-IoT is positioned at the intersection of several disciplines of particular relevance to sensory, signal, connection, and communication systems. The underlying objectives focus on sensors' receptiveness, the effectiveness of the signal transmission and the ability to connect through network or internet between four SCM management stages: product manufacturing, shipping and distribution, inventory and retail. This study reports the findings of various research papers on effectiveness, interoperability, scalability, compatibility in supply chain management. The research problems, objectives and significant factors influencing on the problem encountered were included in the study. It is noted that the study not only inspires stakeholders to understand the challenges and potential works of RFID-IoT but also consumers as the study discussed how the evolution of this technology is critical for individual and social development. More importantly, better exposure to the current technology, knowledge, and experience can bring out a good result that helps develop RFID-IoT research. In addition, with the improvement of RFID-IoT technology, society is expected to get a good quality of products at much lower costs. The organization will also be able to achieve higher profitability.

6. Current challenges and future potential works of rfid-iot

Supply chains have evolved from detecting, identifying, tracing, and

Table 5.
Problem description in retail management.

Article	Year	Research object	Problem description
[65]	2017	Retail shop application	• Live data is limited. • Data security and reliability could be enhanced. • Decision-making mechanism should be included. • Compatibility of the system should be analyzed with more real-life cases.
[66], [67]	2018, 2015	Customer behavior in the retail shop	• Rules of fuzzy interference engine must be updated regularly. • Dependent on human logic and expertise. • Live data is limited. • Data security and reliability could be enhanced. • Decision-making mechanism should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[68]	2016	Food retail shop	• Lack of willingness to share information from consumer. • Data security and reliability could be enhanced. • Uncertainty of the impact on current business models in terms of cost and return of interest.
[69,70, 71]	2016, 2018, 2019	RFID design in retail management	• More analyses on readability accuracy should be conducted • The lifespan of the new RFID design should be computed • Middleware component (e.g., buffer mechanism) should be added • System infrastructure should be included • Decision-making mechanism should be included • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[72]	2017	RFID authentication protocol in retail management	• More quantitative analyses should be added to the proposed method. • System infrastructure should be included. • Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.
[73]	2012	Dynamic pricing and promotion strategy	• Customized RFID-enable service to improve the percentage of readability. • Infrastructure and development costs should be analysed. • Middleware component (e.g., buffer mechanism) should be added. • Decision-making mechanisms should be included. • Scalability and compatibility of the system should be further evaluated with more real-life scenarios.

tracking objects by passive and active RFID. Tracing determines the upstream path of the origin and characteristics of a product. Simultaneously, tracking refers to the ability to follow the downstream path of a product along the supply chain [12]. Then, the exploration of RFID is further developed into intelligent sensor networks with the integration of IoT. Indirectly, it challenges highly complex value network problems by connecting the environment to the machine, machine to machine, and machine to humans. RFID-IoT technology has become a concern for competitive advantages among suppliers, distributors, manufacturers, retailers, and consumers. The current system infrastructure is still not an optimal solution for complex tags. Previous studies have proved that, despite many systems that have been proposed, it remains challenging to form a versatile and compatible SCM system. The SCM system is expected to ensure the quality of the raw materials, maintain the product's transparency along the chain, manage space occupancy, and enhance the customer's buying experience. The following paragraph will list numerous potential challenges faced by the previous literature reviews. Researchers have proposed multiple approaches to tackle inventory accuracy, process status, vehicle route optimization, product quality, customer requirement, solution feasibility, and even returned item management. However, there are many problems regarding adopting RFID-IoT technologies that remain unsolved. This study focuses on four significant challenges for the supply chain when RFID and IoT are combined. These challenges include technical issues faced by current RFID-IoT technology, standardization, security, privacy protection, cost and efficiency problems.

RFID-IoT can automatically detect, identify and connect the data through the internet. However, it is usually restricted by hardware and software design. Hardware design is generally affected by the working environment. For example, metallic items and shelves in the retail shop have significantly affected the RFID tag signal, and hardware design is the only option to reduce the interrupt signal. A highly feasible, sensitive, and adaptable hardware design is always desired to form a scalable solution in a real-world problem. The lower cost installation, energy consumption, maintenance, and RFID hardware size are still big topics to be studied. A good design in RFID hardware, especially in tag, processor, storage and computing compatibility, can improve the readability and avoid miss read data. In terms of software design, system architecture, including data ingestion, storage, latency, scalability, and maintenances, are concerned. Many systems, especially in the industry, have their on-premises server to ensure system efficiency, reliability, and scalability. The database and modules are designed to serve the needs of the large organization regarding the business model. The development of on-premises required highly skilled workers and computing power for installation, enhancement and assessment to maintain the system infrastructure.

Moreover, there is a lack of flexibility in system integration as the information flow may be impractical. For example, the existing SCM system's inability to integrate with the retail payment subsystem may deteriorate its management flow. The challenge becomes more significant when the data is collected and streamed in real-time to provide a timely decision [21]. Many proposed systems are only designed for specific supply chain applications. It is hard to reuse, rescale, and customize other supply chain applications, eventually leading to the loss of resources and time. Besides that, most of the proposed systems still lack decision-making or automated support tools. Four main factors mainly cause it. First, most of these decision-making tools or systems need significant data to develop while these big data is still under collection. Second, the collected data is raw, making these analyses require expertise in data cleaning, mining, transforming, and extracting useful information to help the business model. The extensive knowledge of an expert in this data field is hard to find, and the hiring cost for a team usually is high. Third, these decision-making tools usually rely on stable communication models to avoid multiple miss-read and missing data. It is to ensure the collected data is of good quality. Finally, these decision-making tools usually require high computing power, such as the Computer Processing Unit (CPU) or Graphic Processing Unit (GPU).

Most of the literature discussed the implementation of RFID-IoT refers primarily to simulation settings or laboratory works. One of the major concerns is standardization. In existing proposed models from literature, most RFID-IoT solutions built all components from scratch, starting from hardware devices to the relevant on-premises services or cloud-based services. As a result, there is a lack of consistency and standardization among different IoT solutions. As the supply chain industry is evolved, there is a need for a standard model in RFID-IoT technologies such as IoT platforms, connectivity between RFID and IoT, application and even business model. IoT platform comprises front-end and back-end tasks such as User Interface and User Experience (UI/UX), system pipeline in processing, storage and firmware updates. Next, the standardization of connectivity including RFID tags and IoT devices is important to avoid human error and information flow. Generally, International Organization for Standardization (ISO) has established ISO for several RFID applications, such as animal tracking (ISO 11,784 and 11,785), contactless payments (ISO 14,443), vicinity cards (ISO 18,047), testing conformance (ISO 18,407) and performance (ISO 18,046) of RFID tags and readers [74].

Nevertheless, this standardization still varies from country to country due to the lack of government regulations and global collaboration. Many companies have developed their own supply chain applications. However, it is not easy to integrate their system with other systems when there is a need to collaborate with other parties to achieve the highest efficiency in the supply chain. A unified application is needed to monitor the object, collect the raw data, and analyze it to improve the business. Lastly, a more result-oriented standard business model would be appreciated to ensure its investment is worth it. This new standardization model makes RFID-IoT applications more interoperable, feasible, compatible, and manageable.

Commonly, RFID-IoT technology's utilization brings out the resistance in security and privacy issues due to the technology's continuously tracing and tracking capabilities. Although some systems have proposed mutual authorization in RFID systems to solve this issue, RFID technology is still perceived as a threat and an insecurity for SCM. Thus, it is important to design an embedded RFID system protected from interruption and interception from other unauthorized systems [14]. Besides the RFID system, it is crucial to have a security mechanism for the vulnerable IoT system infrastructure. A secure mechanism in IoT is essential as it compromises data privacy, such as confidentiality, integrity and availability. While security and privacy issues are concerned, the system's deployment needs to form a data-driven environment in the real world. As IoT is rapidly emerging, a data-driven environment is always desired to collect accurate data.

The result is always inversely proportional between these two issues considering the cost and efficiency. The initial price of an SCM system development is considerably high where hardware and software infrastructure is necessary. These hardware and software infrastructures are usually quite expensive. SCM hardware such as RFID tags, readers, computer hardware, and various mechanical systems are combined with software infrastructure such as database, software and applications for system installation, configuration, testing, and even licensing to set up a complete system. The current system practice depends on multiple technologies such as SQL and NoSQL databases, cloud technology and IoT platform have increased the setup cost.

Furthermore, the setup cost is high when significant data analyses are implemented with powerful computing power. The operation cost of integrating the existing system with other systems is equally high, mainly because of the incompatibility of the system pipeline. Hence, a thoughtful awareness of the cost and improvement of the system efficiency should be clearly defined to support the organization.

The rise of RFID-IoT has come a long way over the years. Besides fulfilling customer requirements and fast-changing in managing the supply and demand, several factors need to be considered before RFID-IoT in SCM can be scaled to a newer dimension. Company size, product profit and customer requirements are required to analyze the achievable profit to make a wiser decision. It can be seen that most of the existing literature has been focused on achieving operations in a closed-loop system without considering the scalability and feasibility of the system. According to one recent study, IoT, coupled with RFID and cloud technology can improve the tracking, data storing and system transparency in every stage of SCM [15]. The study pointed out the difficulty in merging the preferred transporters, multiple levels of inventories and cloud techniques used in the supply chain as it involves machine learning techniques. The study proves that the machine learning technique in SCM implementation remains unmatured at the current stage. The number of experts should be increased to handle the cloud tools as cloud technologies continue to develop rapidly. Although some systems implement cloud technology, the scalable nature of cloud computing services makes it sometimes difficult to predict quantities and costs [75, 76]. Multiple companies have multi-cloud hybrid technology strategies to optimize performance from the survey. Still, cloud service providers are unable to match the user requirement in real-time monitoring. It would be expected that cloud service providers will improve their technology in microservices, security, and extensive data analyses to ensure cloud business benefits will far outweigh the challenges. The adoption of cloud technology is becoming a strategic business approach, especially in fast development. In the future, the cloud may introduce a new industry standard that will help set up the necessary regulatory, management and technological matters.

Additionally, to persuade business owners, especially SMEs, to adopt RFID-IoT technology, it is essential to analyze the proposed system's pay-off time further and return on investment to have a cost-effective solution. The RFID-IoT's value in SCM could be additive primarily due to its transponder cost and uncertain value gain in the long term [77]. In fact, the price of passive tags dropped by 80 percent between 2003 to 2010. Other costs include middleware, system integration, the optimal number of readers, and reader placement to create an effective communication environment [77].

In 2020, the COVID-19 global outbreak changed supply chain management in many ways. Companies tend to work in a more agile environment to meet customer needs while maintaining their business market. This pandemic has motivated many companies to invest in technologies such as RFID, wireless sensor networks, IoT, cloud technology and many more to fit into the new norm. For example, many inventories have strategized their business model in "buy online pick up in-store (BOPIS)" to reduce human interaction. Such a strategy requires accurate stock and order information to prevent inefficiency, resulting in a bad customer experience. It is critical to provide complete inventory visibility using RFID tags' automation and transmit IoT technology capabilities.

Another deserving area of attention is the emerging of 5 G technology. The combination of 5 G and RFID-IoT technologies significantly makes the intra-connection and inter-connection faster, more visibility, higher efficiency and more accessible to be implemented. For example, real-time product scheduling and monitoring, which requires pervasive computing and agile response, is plausible for integrating 5 G technology. Notice that the higher number of sensing devices, the more processing power they consume. Further studies on integration between 5 G with RFID-IoT technology are needed to solve the complex network problem while providing faster data transfer, lower latency, and better reliability. Furthermore, this integration enables various application scenarios such as manufacturing, warehouse, and transportation by enhancing supply chain transparency. Ultimately, the supply chain can be an autonomous, self-adaptive system in which smart objects can operate, control, and decide without human intervention. From the analytic data perspective, there are a few aims where advanced data analysis could take place. The potential of data analytics work in warehouse management are as follows:

1. Decision support tool on enhancing the asset management in a large-scale warehouse
2. Data analytics to improve the efficiency of warehouse operation
3. Tactical/Strategic recommendation on system implementation
4. Fault analysis based on warehouse data
5. Stock replenishment forecast based on the monthly demand
6. Warehouse risk management including pre-, during- and post-order collection

7. Conclusion

This study presents a comprehensive literature review on the concept of RFID-IoT in supply chain management. The term RFID and IoT have been described thoroughly with their evolution from time to time and integrating both technologies to enhance SCM. The paper was organized into four major discussion topics: product manufacturing, shipping and distribution, inventory and retail shop management, aiming to provide an overview for academicians to establish new research domains and practitioners to consider RFID-IoT adoption to solve the real-world problem. From reviewed papers, the limitations of the existing literature have been identified as follows:

I Many academicians have discussed the application, problem, and challenges in adopting RFID technology, but most of the studies are conducted without relating it with IoT technology.
II There is a lack of studies on supply chain management using RFID-IoT technology against high implementation cost, effectiveness, interoperability, scalability and compatibility.
III Most of the studies have analysed the challenge of RFID, but none of them relates RFID to IoT, especially considering the system's dynamics.
IV There is a lack of studies that specify the changes required in supply chain management to adopt RFID-IoT in the future.

Furthermore, this study has provided a more in-depth insight into various application areas of RFID-IoT, highlighting the author's viewpoint on the problem faced along with the proposed methodology. Various problems were identified to evaluate each article as to how the proposed method tackles the specific application. Prior to this study, overall challenges and future research work have been discussed, and several key findings/gaps have been identified for future works. In conclusion, the study aims to encourage academics and industry researchers to emphasize core applications for RFID-IoT and continue developing more innovative solutions to impact the SCM industry.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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