LATEST ADVANCES IN INVENTORY MANAGEMENT SYSTEMS: A REVIEW

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Abstract: Inventory is perhaps the most researched topic of production and operation management since it immensely affects the lives of all and sundry. Inventory management systems (IMS) come in various forms and are evident in the various aspects of society: household, social and business inventory. This work provides an overview of manual and automated inventory management systems based on traditional and ultra-modern state-of-the-art technology. It investigates the usage of IMS and its associated technologies in some key sectors such as the aviation sector, warehouse industrial sector, telecommunication sector, health sector, automobile sector, and highway sector. Findings from the literature reveal that almost all industries have benefited from the use of inventory management systems most especially through savings in cost and time, but a lot still needs to be done in integrating two technologies for an optimum inventory management system.

Keywords: Inventory management system, Technology, RFID, IoT, AI

Introduction

Recent technological advancements have significantly impacted the field of inventory management due to their ability to provide increased flexibility and reliability. Since their renaissance, advancements in these technologies including radio frequency identification (RFID) (Ozguven & Ozbay, 2013), internet of things (IoT) (Choi *et al.*, 2017), cloud-based solutions, artificial intelligence(AI) (Preil & Krapp, 2022), Unmanned aerial vehicles (UAV) *(She et al., 2014; Wawrla et al.*, 2019), robotics, blockchain (Song *et al.*, 2019), automation (Madakam *et al.*, 2019), and big data (Tiwari *et al.*, 2018) have streamlined inventory management system. The control of movement and storage of goods, as well as keeping track of all information relevant to the flow of the goods are essential for the efficient operation of industries. Manual inventory management techniques have been used to achieve these tasks before inventory management became automated. There are many challenges associated with the manual techniques including inaccuracy, labour intensiveness, higher expenses, lack of centralisation, lack of scalability, and poor record keeping (K. Ahmed *et al.*, 2020). These challenges lead to the automation of inventory management systems to various degrees utilizing various technologies. Automated inventory management is implemented based on technological advancements to easily and efficiently keep track of all important information for the flow of goods. IMS is a set of techniques, methods, and technologies for managing and controlling inventories. IMS reduces manual work, human mistakes, and manual delays while simultaneously speeding up the processes (Varalakshmi & S, 2021).

IMS has a wide range of applications, such as monitoring the storage of products (Oluwaseyi *et al.*, 2017), tracking and tracing aircraft spare parts (Ho *et al.*, 2021), ensuring the minimum display of inventory at stores (Hassan *et al.*, 2018; HR *et al.*, 2020), and minimizing the cost of treatment and wastage of resources in a healthcare system (Saha & Ray, 2019). A lot of research works were conducted to develop IMS for varying applications. The model-based approach could also be used for the implementation of inventory management systems. Recently, the inventory managing community has witnessed exponential growth in the number of state-of-the-art-based techniques for developing intelligent inventory management systems. It is getting increasingly difficult to keep pace with the recent progress due to the influx of new techniques from various diversified fields of technology. As such, a survey of the existing techniques from these diverse technological fields is timely to provide a comprehensive account of new methods. In this paper, a holistic overview of both old and emerging inventory management techniques is presented, with the hope that this work can provide a roadmap for researchers to explore the field further. The major contributions of this paper include:

- A detailed coverage of the field by categorizing the papers based on their applications in inventory management as depicted in Figure 1. For each of these applications, the specific challenges are highlighted and insights provided about solving them based on the literature reviewed.
- A critical discussion was provided on the current state of inventory management as a whole, including identifying key challenges, highlighting open problems, and outlining promising future directions.

The rest of the paper is organized as follows: In the second section, a background of the field with a focus on salient applications is reported. From the third section to the seventh, a comprehensive discussion on the key inventory management applications is provided. Section 8 covers key challenges, problems, and future directions for inventory management. The last section is the conclusion and recommendations.

Figure 1 Applications of Inventory Management

Related Works

The advances in information & communication technology (ICT), which includes improvement in the efficiency of the internet and other services associated with it have highly affected the business and service delivery models of the nowadays global environment. Businesses and organizations are striving for the development and enhancement of their operations in an endeavour to increase the productivity and quality of performance of their work processes (K. Ahmed *et al.*, 2020). The digitization of the IMS increases flexibility, reliability, smart storage, resource utilization, and easy access to product location and warehouse management (Yuvaraj *et al.* 2020). Generally, to solve inventory management issues, both manual and automatic techniques have been deployed. Table 1 describes some of the manual and automatic IMS that were implemented in the literature. In manual inventory management, the use of the theory of constraints was proposed by (Chou *et al.*, 2012). They were able to come up with the root cause of inefficiencies in the inventory management of the aerospace industry. They designed a tree to depict the current and the future inventory management protocol for an optimized system.

The model-based approach could be used for the implementation of IMS. In (Kobbacy & Liang, 1999), a knowledge-based inventory management system was developed using visual basic programming language to use historical data in the stored inventory databases, and the recognized demand patterns were utilized to make decisions using mathematical inventory models. The work by (Yuvaraj *et al.*, 2020) proposed a way to overcome challenges in the traditional method of inventory logs, such as human mathematical ability, paper upkeep, and untidy editing process. Using Tkinter and SQLite platform, they were able to develop an inventory management system. They claimed their developed system saves a lot of time using a structured language SQL. Table 2 summarizes different methodologies/Technologies that were utilized in the development of IMS for different application

Table 1. Technologies used in the Development of IMS for Different Applications

Authors	**Methodology**	**Remarks**
Manual IMS (Chou *et al*., 2012)	The theory of constraint was used to manage inventory in the aerospace industry	A guideline for inventory management was designed
Automatic inventory MS (Balali *et al*., 2015)	Computer vision was used to analyze google street view images for road transport traffic sign inventory management.	An improvement to sign classification was achieved. They reported a sign classification accuracy of 94.63%
(Chila & Susi, 2019)	Deployed a web-based radiology IMS	This was based on a case study of a health care facility
(Tejesh & Neeraja, 2018)	Designed an open-source framework that utilizes IoT and RFID for inventory management of warehouse	The technology resulted in better warehouse inventory management
(Branson *et al*., 2018)	Developed an automatic tree detection and species recognition inventory management system	There was a significant improvement in species inventory management
(Atieh *et al*., 2016)	Developed an inventory management software for a service provider of telecommunication SIM cards and prepaid recharge cards with information on processing, receiving, and the supply of the products	Only a prototype was developed

Table 2 summarizes different Methodologies/Technologies that are adopted in developing Inventory Management Systems for different applications.

Table 2. Technological Advancements in the Development of IMS

S/N	Reference	Technology/Methodology	Application
1	(Tejesh & Neeraja, 2018)	RFID and IoT with a user interface to track products	Warehouse
2	(Al-momani *et al*., 2020)	Customized Microsoft Access 2016 packages to support the on-time availability of products.	Inventory of spare parts
3	(Ho *et al*., 2021)	Blockchain-based system	Inventory of spare parts
4	(Perez *et al*., 2021)	Reinforcement learning	Inventory Management Optimization
5	(Shuai *et al*., 2021)	Heuristic and Exact method	Spare parts inventory management
6	(Kobbacy & Liang, 1999)	Mathematical inventory models	Inventory management system
7	(Kritchanchai & Meesamut, 2015)	Vendor-managed inventory (VMI) system using passive policy	Hospital drugs
8	(Ozguven & Ozbay, 2013)	RFID integrated with multi-commodity stochastic humanitarian inventory management model (MC-SHIC)	Humanitarian inventory management system for disasters
9	(K. Ahmed *et al*., 2020)	Software Development Life Cycle (Iterative Model)	Pharmacy
10	(Rezwan *et al*., 2018)	Internet of Things (IoT)	Kitchen
11	(J. Lin *et al*., 2020)	Machine Vision	Warehouse (Automobile)
12	(Yang *et al*. 2020)	IoT (RFID)	Dental Laboratory
13	(Ozguven & Ozbay, 2013)	RFID	Disasters
14	(Atieh *et al*., 2016)	Business Process Modelling and Notation (BPMN)	Warehouse
15	(Sylvester & Paulina 2016)	United Modelling Language (UML)	Pharmacy
16	(Ivgantius & Andry, 2019)	Extreme Programming	Warehouse (Bio-Fertilizer)

Inventory Management System for Different Applications

This section will give a detailed discussion on the various IMSs that are developed for the enhancement of the different sectors.

Aviation Inventory Management

Due to the necessity for a stronger forecasting strategy to combat demand inconsistencies for aircraft maintenance repair components, airline operators experience forecasting issues (Ghobbar & Friend, 2003). As a result, airlines must have the most accurate short-term part demand prediction available. Ghobbar and Friend developed a forecasting assessment model that compares and assesses forecasting approaches based on their factor levels when faced with intermittent demand. This led to the need for airlines to know the short-term part demand forecast with the highest degree of accuracy. The work presented by Tracht *et al*.,(2013) was on a spare part inventory planning method that calculates cost-optimal inventory levels for warehouses in a two-echelon supply chain for aviation spare parts supply and takes into account various input and output planning parameters, such as budget and inventory level limitations. To perform sensitivity assessments and validate the calculated inventory levels, a simulation model was employed. Rao & Nayak,(2017) investigated spare part inventory procedures in the aviation sector. The purpose of their study is to assess inventory level strategies for helicopter spare parts utilized in production. They analysed 677 helicopter spare parts manufactured by a company in Thailand to calculate the most efficient spare parts to use for a specific spare parts change that can minimize cost and at the same time give the best quality in use. Their main objective is on optimized selective control rather than treating all spare parts as same. They reported that this approach ensures an holistic selection of the best spare part fit for each specific parts to be replaced.

Inventory management systems have a high maintenance cost due to their intricate design, which necessitates regular costly upgrades; In military aviation inventory management systems, improving fleet readiness, aircraft availability, and serviceability while lowering operating costs is critical (Al-momani *et al*., 2020). Al-momani *et al*.,(2020) study presented a high-quality, economical, dependable, and adaptable inventory management system for the military aviation sector that maintains and improves inventory. The Microsoft Access 2016 application was utilized to design a local IMS that effectively manages databases for personal and business use. The system generated high-quality reports that aid enhances supply chain management, as well as procedures that help collect maintenance, supply chain, and logistics information to keep stock to a minimum. This leads to better components, enhanced serviceability, availability, and dependability, lower costs, and fewer airplanes on the ground.

Due to the high cost of replacing components in airplanes, most airline fleets still operate manually and on paper, and poor historical data causes significant issues. (Ho *et al*., 2021) suggested a novel blockchain-based system that used Hyperledger Fabric and Hyperledger Composer to provide a managerial platform for correct recording of spare parts traceability data with organizational consensus and validation. Based on the current aviation spare parts inventory management (ASPM), a data model was developed to ensure information integrity throughout transaction operations. The improved blockchain-based inventory management system has the potential to develop aviation's digital twin as part of Industry 4.0 in the future.

Warehouse Logistics Inventory Management

In the Warehouses, users find it difficult to locate a product, because it involves a detailed search and requires a lot of user effort. Therefore, warehouse IMS is required to maintain detailed product information. Tejesh & Neeraja, (2018) integrates RFID with IoT to track products or items attached to the tags with product information in a precise span of time in two stockrooms, the system also incorporated Raspberry Pi 3 in developing a database to be displayed in a user-friendly web page (user interface).

Alawneh & Zhang (2020), developed a multi-item inventory model for emerging dual-channel warehouses to fulfill both online and offline orders, the inventory control model for the dual channel warehouse determines the ordering quantities and reordering points for both offline and online channels due to warehouse capacity constraints, demand, and lead time uncertainty. This aid in increasing space utilization, reduction in operation costs, and fulfilling orders quickly and reliably in the manufacturer's warehouse to enhance security and quicker handling in the supply chain (Atieh *et al*., 2016).

Kumar & Mahapatra (2021) suggested a hybrid optimization algorithm; and improvement of their Rain Optimization Algorithm (ROA) be developed in the future for more accurate results in the actual problem of warehouse inventory management. They applied their proposed algorithm on the footware inventory management and based on their Simulation results, their ROA minimizes total cost by 12.26% of Manta-Ray Foraging Optimization (MRFO) Algorithm, 16.07% of Equilibrium Optimization (EO) Algorithm and 22.47% of Black Widow Optimization (BWO) algorithm. Also, with ROA, they reported 2418.34 as total profit for 5 different items which is 0.725% more than MRFO, 1.37898% higher than EO and 13.55% more than BWO algorithm. They concluded that the high convergence rate of ROA significantly improves the performance of whole system. while (Alawneh & Zhang, 2020) recommend future research to consider investigating the warehouse layout in each stage and its effect on the total cost. Wawrla *et al*., (2019), classify indoor drone applications in warehouses into three different application areas: inventory management, indoor intra-logistics, and inspection/surveillance. Their analysis shows that using drones for inventory management applications has the highest potential in warehouses as they can be used for automatic inventory management.

Impact of Information Technology on Inventory Management

Information technology (IT) involves all software and hardware solutions that enable companies/business enterprises to collect, organise and analyse data that will help them make informed decisions to achieve their desired goals. IT has over the years revolutionized inventory management and is one of the important elements of every business plan in the contemporary world. Information technology has had a noticeable impact on inventory management in terms of its efficiency, data accuracy, and easy accessibility to data (Arslan, 2017). Inventory management is becoming more and more intelligent and informative through the use of information technologies such as barcodes, radio frequency identification, electronic data exchange, global positioning system, and robotics (typically for warehouse management in tasks like sorting and moving goods). According to (de Barros *et al*., 2015; Zou *et al*., 2018), IT has many impacts on inventory management including Flexible structure, Cost reduction, Compact storage space, Short response time, Flexible throughput capacity, Differentiation of products or services, Integration and collaboration, Quality, reliability, and accuracy of the information and Operational efficiency and process improvement.

Inventory strategy is the process of determining whether the available and current inventory is appropriate and will meet downstream demand. Chuang & Oliva, (2015) and Tian & Wang, (2022) pointed out two reasons why IT has a positive impact on inventory strategy. One is that IT helps in the optimization of warehouse layout which in turn optimizes operations. the other reason is that using smart devices helps avoid the effects of human factors such as fatigue and slack in inventory management.

Chuang & Oliva (2015), revealed that full-time and part-time workers have different effects on the problem of inaccurate inventory records. According to Turban *et al.*, (2018) effective inventory technologies have the following features: Scalability, Realtime updates, Ease of accessibility, and In-depth reporting.

Evolution of IT techniques includes Punch Cards **(**Technique where holes are punched on cards to reflect cataloged inventory. This information is used to update inventory records using specialized card readers); Barcodes (Introduced around the 1940s and used to record information about a product such as a type, price, location, origin, and other information about the product. The barcode is read using specialized scanners to retrieve the stored information in form of light-sensitive ink imprinted on the product packaging); Radio frequency identification **(**A small microchip that holds key information about a product placed on its package. A special barcode reader scans the chip retrieve and automatically updates network databases).

Medicine Inventory Management System

Deals with the monitoring of the quantity as well as the quality of the medical-related materials in hospitals, pharmacies, and laboratories (Scott *et al*., 2021). Pharmacists find it very tedious and difficult to handle a very large pharmacy in keeping track of the inventories concerning the available drugs in the pharmacy as well as in the store and the expiry dates of the available drugs (K. Ahmed *et al*., 2020). It is a common problem in hospitals that the medication distribution systems are inefficient due to the variety of medications that are in the pharmacy and the store at a particular time (Sylvester *et al*., 2016). A large number of personnel need to be hired to solve the above-mentioned problems and that will lead to the addition of cost in the process. An automatic Inventory Management System needs to be developed so that the cost will be reduced with the increased efficiency (K. Ahmed *et al*., 2020; Sylvester *et al*., 2016).

To solve the various inventory management issues in medicine, different approaches have been taken. The goal of the work of Chila *et al*.,(2019) was the development of an efficient IMS infection control and management of medical supplies that have expired. To counteract the paper record in filling cabinets, (K. Ahmed *et al*., 2020) developed a drug inventory management information system (DIMIS) software, Software Development Life Cycle (SDLC) was adopted to design the software application. The system was developed to manage all the information so that the pharmacists will perform their jobs efficiently. The system was able to find and check a large number of drugs and their expiration dates in purchase and delivery records.

In (Kritchanchai & Meesamut, 2015) their objective was to reduce the total medicine inventory costs of the most consumed medicine while keeping safety of patients in high priority. The medicines that have a high consumption value by a vendor-managed inventory (VMI) system was utilized for hospital drug management with a passive policy, where the historical demand was classified by the drug characteristics in terms of clinical importance (VEN categories), consumption value (ABC categories) and demand characteristics. Their study revealed that a single inventory management system is not sufficient for an efficient inventory management. Sylvester *et al*., (2016) developed a system to improve pharmacist efficiency and drug dispensing accuracy. They developed and modeled an Integrative computerized pharmacy inventory system for improving patient care by promoting medication dispensing accuracy which enables pharmacists to spend more time on patient care duties. A sensing system was developed by Yang *et al*. (2020) based on the Internet of things to collect information on cobalt-chromium disks both in the storage room and manufacturing area of the Dental laboratory, and an intelligent system was developed to automatically conduct inventory management based on the established rules.

Highway Inventory Management

In general, to obtain highway inventory data for repair or maintenance, different methods have been used which include: Aerial photography, video/photo logs, geographic information system (GIS), manual field inventory, a global positioning system (GPS), image from satellite, light detection and ranging (LiDAR), laser scanner and others. The most widely used method of inventory data collection is video/photo logs, GPS, aerial photography, images from satellite, and GIS. For managing highway inventory, software such as MicroPAVER and geographic information systems (GIS) has been reported to show satisfactory results.

Table 3. Highway Inventory Roadmap

Author	Focus Area	Remark
(Jalayer *et al*., 2015)	Highway video and photo tagging geospatial inventory data collection	Based on their study, they recommended that the video/photo tagging method of highway inventory data collection is optimal for cost saving and implantation.
(Seboru *et al*., 2016)	Highway road construction material procurement and its performance based on its inventory in Kenya due to Highway Road dilapidation giving rise to traffic congestion and consequently economic loss via loss of productivity and high fuel consumption	They recommended a statistical techniques to weigh in on which construction materials to procure. Based on their analysis, they reported that proper inventory of the required materials for highway road repair or construction has a significant influence on the road repair/ construction performance
(B. Lin *et al*., 2017)	The optimization of inventory management of high-speed train spare parts maintenance	0-1 programming for optimization (for comparing the temporary order policy and advance order policy for rail, land, and air transport), a method for demand estimation, spare parts shortage time was developed in PERT,
(Henry Kipkurui & Obura, 2018)	Studied the correlation between road inventory management and road performance	They reported that the road inventory management was tied to the Kenyan road agency management performance
(Hasan *et al*., 2020)	Inventory management for Highway pavement maintenance and upgrading in Iran	For managing pavement inventory, Micro PAVER software was used to analyze pavement conditions index and budget analysis for either maintenance or upgrading for appropriate action. They reported that the PAVER out performed other methods in terms of effectiveness, quality and more economical

Automobile Inventory Management

An inventory management system (IMS) is a system that keeps track of the supply and availability of goods for proper decision-making in the industry. Being an industry that involves the design, development, maintenance, and selling of vehicles and their spare parts, the automobile industry is one of the major sectors that hugely depends on IMS to effectively perform its operations.

Several systems were developed to manage and control automobile inventory. An automatic spare parts IMS was developed to compute the economic order quantity of each part; keep track of spare parts transaction records; and notify the user to purchase more spare parts at the appropriate time (Mohd-Lair *et al*., 2014). The IMS, whose software was developed using Microsoft visual studio, was compared with existing manual methods. Although the automatic software IMS outperformed the existing manual method when zero opening balance was considered, the manual method provided better performance when the current opening balance is taken into consideration. This is as a result of the increase in data and observation time required by the automatic method to reach its steady state. Hernández-Rodriguez *et al*., (2016) proposed a system that recommends the selection of appropriate indirect materials for the development of automobile parts. The recommender system, which has proved to be useful in industries where there is frequent change in staff and in situations where the standard model for developing the spare parts is not available, is based on a non-personalized approach that takes similar order circumstances into consideration.

Estimating the demand for spare parts and other production components is an essential attribute of automobile IMSs. An enhanced fuzzy neural network (EFNN) IMS that considers global decision factors—which is a limitation of conventional approaches—was developed to manage automobile spare inventory in a central warehouse (Li & Kuo, 2008). The EFNN system upgrades traditional neural networks on different fronts to enhance the forecasting accuracy of the demand for spare parts. Furthermore, the comparative analysis showed that the developed management system outperformed five similar models in stock measures and fill rate. In another study a recurrent neural network/ long-short term memory (RNN/LSTM) with a modified Adam optimizer was proposed for forecasting the demand for automobile spare parts (Chandriah & Naraganahalli, 2021). The weights generated by LSTM were optimized with the modified Adam algorithm. Their proposed method Obtained results showed that the proposed method provides estimation with less error when compared to other methods such as: Croston method, Simple Exponential Smoothing (SES), Syntetos-Boylan-Approximation (SBA), Teunter-Syntetos-Babai (TSB), and Modified SBA, and it is appropriate for forecasting automobile spare parts demand. Copeland *et al*., (2011) developed an inventory management model to estimate the production and within-model-year pricing of automobiles. Using monthly transaction prices as input to the model, a 9% annual rate was predicted for prices to fall over a year. Furthermore, the model estimated that 40% of the price decline over a year is due to the automobile industry's build-to-storing management policy.

Comparative studies were conducted to examine the impact and the level of accuracy of various inventory management systems. A comparative study of a general import model, a database management system (DBMS) based import model and a principal standard model was carried out on some automobile industries to ascertain their effectiveness (Tamang & Paudyal, 2015). The DBMS model—which takes warranty, clipping, sales, and data demand to predict the cost of transport, demand, and import time information—was found to provide better performance than the other two. Furthermore, the developed software for the DBMS model was found to be reliable and user-friendly. However, for the model to be effective, its inputs should be available. In (Vargas & Cortés, 2017), several time series methods for forecasting the demand for automobile spare parts were compared. The artificial neural network (ANN) model, autoregressive integrated models of moving average (ARIMA), ARIMA-ANN hybrid models, and the classical methods of moving averages were all compared in the study. Although ANN provided good performance, ARIMA was generally better due to its superiority in post-sample periods.

Li, 2020 worked on enhancing the effectiveness of automobile spare parts inventory control so as to solve the issue of low satisfaction encountered in automobile spare parts maintenance in warehouses using a distributed multi-level spare parts algorithm that is based on a centralized control. The algorithm was used to estimate inventory cost and functions related to inventory cost. The experimental results obtained indicated that inventory management optimization was achieved with the aid of the algorithm. Ugaya & Walter,(2004) performed a life cycle inventory analysis to observe the use of international and national data relevant to the utilization of steel in automobile industries. The analysis, which involves scope and objective definition, inventory analysis, and interpretation, was conducted on three phases of the life cycle, namely: automobile use, steel manufacturing, and disposal. Obtained results from the study showed that materials manufacturing and automobile use account for the majority of resource and energy consumption. Also, the study noticed significant differences between national and international data, which indicated the requirement for enhancement in the environmental database.

Radio frequency identification (RFID) technology is used in inventory management systems for the automatic recording of detailed data relevant to supplied goods. The major components of the technology are the RFID tag which contains the needed information from a good; an RFID reader for collecting the information stored in the tag; and an application system which serves as an interface between the RFID reader and a user's main monitoring system to supply appropriate information that would aid in proper decision making. RFID technology has been used in automobile industries for various purposes such as good tracing, protection from theft, and monitoring the availability of required parts on the assembly line (Chen *et al*., 2014).

Maritime Inventory Management

There are many businesses whose products sail the seas, and whose fate may be accomplished or improved by the use of RFID. There are three (3) main related RFID maritime applications.

Shipment Tracking

Tracking a container from source to destination is one of the most difficult tasks in supply chain management. A study conducted by Fan *et al*.,(2015) indicated that products can be tracked from point of manufacture through the distribution chain and down to the retail level using RFID technology. The significance of this technology to the maritime industry is that the sensors can automatically detect missing shipments and raise alerts thus increasing the granularity of supply chain visibility. It also can scan entire pallets at strategic locations like warehouse dock doors without human involvement. Moreover, increased visibility allows manufacturers, distributors, and retailers to maintain lower inventory levels thus making the system more receptive. Furthermore, over time, numerous accidents at sea have occurred and many lives perished. RFID technology was used by Andreadakis *et al*.,(2021) to record the number of passengers during lifeboat embarkation and relevant passengers and crew data upon their boarding on a designated lifeboat to save lives and properties.

Yard Management and Container Security

A research was conducted by Hakam & Solvang,(2012) to provide solutions due to the complex processes and systems that involve both human resources and artificial systems. The RFID system was deployed to improve clearance speed, reduce cost and administrative burden and allow for traceability and monitoring of containers from point of origin to destinations. The technology also keeps track of the temperature and humidity level of the vessels.

Managing Inter-Modal Shipping and International Trade Regulations Compliance

According to Papadimitriou *et al*., (2012) RFID Technology helps in directing and tracking containers. It also aids in transfer between modes through the port. The technology enhances authentication/matching shipments with transfer and transfer/shipping instructions and tracks the process. It sends the status as work is completed, and the date/time stamp of a shipment as it leaves the port. The tracking was done by mobile readers as well as by GPS. Also, RFID tags are placed in the containers or pallets to keep track of containers. In this study, the potentials of RFID tags which usually contain significant data on shipment together with link to the network application was reported. This usually contains the appropriate shipping information database.

Other Inventory Management

A method that characterized carbon management and joint product recovery under a cap-and-trade scheme was proposed by García-Alvarado *et al*., (2017). The study indicated that inventory management plays a significant role in the impact of industrial companies on the environment. The study showed that carbon emission, which affects climate change, could be reduced by reshaping industrial inventory management. Ozguven & Ozbay,(2013) proposed a comprehensive methodology for developing a humanitarian emergency management framework based on real-time tracking of emergency supplies and demands using Radio Frequency Identification Devices (RFIDs) technology integrated with a multi-commodity stochastic humanitarian inventory management model (MC-SHIC). The MC-SHIC model was approximated using a functional approximator based on simultaneous perturbation stochastic approximation (SPSA). The impact of unforeseen disruption was minimized by an online inventory control of humanitarian emergency management based on the real-time tracking of emergency supplies and demands to determine the optimal emergency inventory levels.

An IoT-based smart kitchen inventory management system (SIMS) software was developed by Rezwan *et al*., (2018) which conceptualizes the idea of connecting and remotely monitoring real objects via the internet. The system reminds users of their existing inventory and places orders for additional products automatically when the quantity gets low. To reduce time spent searching for compounds over an extended period, Qin *et al*., (2021), developed a systematic approach to inventory management. The system is built around a low-cost Raspberry Pi that was linked to a touch screen and a barcode scanner. Heuristic methods are used when problems have high computational complexity and exact methods can find optimal solutions or bounds on optimal solutions to optimization problems, both methodologies are majorly implemented in spare parts inventory management (Shuai *et al*., 2021). An algorithmic approach (machine learning) was used to address an inventory management problem where the reinforcement learning model proved more resilient to network disruption by creating more balanced inventory policies in making decisions at each time step (Perez *et al*., 2021),. In (Demey & Wolff, 2016), a semantic inventory management system was developed to estimate the position of lost items on the international space station. The system works with a model-based searching strategy that makes its estimation based on three contextual features: human, temporal, and spatial. Furthermore, other components of the system are machine learning algorithms, ontologies, ubiquitous client applications, and databases.

Conclusion

In this work, recent works on traditional and automated inventory management systems were reviewed. Essential aspects of IMS including the definition and methodologies used for the development of IMS were discussed. The numerous advantage an optimized inventory management can have on a field cannot be over emphasized. The challenges faced in inventory management includes slow response to taking advantage of more solutions such as artificial intelligence. A lot of authors have argued that inventory management is not a one size fix all, solutions needs to be developed based on the system requirements and better system has been realized with combining more than one type of inventory management solutions. Moreover, this work has demonstrated the technological advancement in the development of IMS and its applications in vital sectors of the society. Future research will look at the implementation of enhanced technologies in the advancement of IMS utilizing two or more inventory management solutions.

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