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STRATEGIES FOR DEVELOPING LOGISTICS CENTRES: TECHNOLOGICAL TRENDS AND POLICY IMPLICATIONS

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ABSTRACT

Logistics centres are currently performing a key function in the development of countries through their ability to regulate goods, markets, and transport. This is shown by the infrastructure, cost, goods flow, and quality of logistical services provided by these centres. Nevertheless, in developing nations or regions with antiquated logistics infrastructure, conventional logistics centres seem to struggle to manage the volume of commodities passing through them, resulting in persistent congestion and an unsteady flow of goods inside these facilities. This issue poses a challenge to the progress of any nation. The emergence of new technology offers a potential avenue to solve the problems inherent in traditional logistics centres. Most prominently, four technologies (the Internet of Things (IoT), Blockchain, Big Data and Cloud computing) are widely applied in traditional logistics centres. This work has conducted a thorough analysis and evaluation of these new technologies in relation to their respective functions and roles inside a logistics centre. Furthermore, this work proposes difficulties in applying new technologies to logistics centres related to issues such as science, energy, cost, or staff qualifications. Finally, future development directions, related to expanding policies in technological applications, or combining each country's policies for the logistics industry, are carefully discussed.

Keywords: Logistics centers, logistics infrastructure, logistical services, smart technologies

INTRODUCTION

An important topic for the growth of the world's economy and contemporary society is digitalisation. Continual expansion and long-term welfare are cited as essential drivers of successful digitalisation efforts. Therefore, government programmes that seek to develop innovation capacity, increase productivity, decrease costs, increase revenues, improve preparation for the digital era, and strengthen competitive advantages are regularly used to promote digitalisation goals within businesses. The term 'Industry 4.0' frequently refers to a wide range of digitalisation methods, approaches, and technologies because it largely focuses on applications in the industrial environment. Because of this, the application sectors range from enhancing material flows to buildings, manufacturing, and product development. These programmes should help industrial organisations achieve their objectives, including higher competitiveness based on open processes, more agility, improved adaption, and increased flexibility.

The initial commercial practices and academic studies on disruptive technologies are still very much relevant in today's society. Disruptive technologies were also the foundation of modern business models like Amazon and Flipkart, since they outperform incumbent technologies, in terms of productivity, efficiency, and convenience [1]. The Internet of Things (IoT), for instance, completely replaced warehouse and inventory management through a precise combination of supply hubs, transportation, and customer handling system, which was a boost for e-commerce industries. As a result, IoT could offer more individualised, responsive, and novel or unconventional customer service, in addition to decreased operational costs [2]. The Internet of Things is anticipated to play a significant role in the logistics sector in the near future. It is also evident that many objects and items have already begun to carry or tag bar codes, RFID tags, and sensors, bringing geospatial data and allowing tracking of a variety of goods and merchandise through a single supply chain from any location [3]. Primarily, there are three schools of thought with respect to the IoT [4]: (i) Things oriented, which aims to improve things like object traceability and the ability to understand their current location or status; (ii) Internet-oriented, which seeks to improve network protocols like the Internet Protocol, which is seen as the network technology to connect smart objects all over the world; and (iii) Semantic oriented, which centres on issues of meaning and context [5]. In addition to IoT, other new technologies have also begun to become more prominent during this period, such as Big Data, Blockchain, AI, etc. Each technology has different functions that are combined in an industry, thereby helping the industry develop strongly in all respects [6][7]. The logistics industry is no exception to this development; hence, the use of 4.0 technologies has transformed logistics into a strategic tool for gaining a competitive edge, shifting its perception from a simple financial burden to a valuable asset [8]. Table 1 presents a comprehensive compilation of definitions of Industry 4.0 technologies that have been specifically implemented in industrial environments.

Tab. 1. Definition of outstanding 4.0 technologies [9]

4.0 Technology	Definition	Ref
Internet of Things (IoT)	The implementation of sensors and devices that are networked through wireless networks and Internet-based interaction with the objective of enhancing the value of products and processes.	[10][11][12][13]
Blockchain	The digital platform facilitates the safe storage and distribution of information across a collective of users via the creation of time-stamped, tamper-proof, and indefinitely lasting records. The system comprises decentralised ledgers that store transactions as data blocks, which are interconnected by a cryptographic pointer. The aforementioned system exhibits attributes such as distributed consensus, enhanced security measures, traceability, verification, and transparency of information.	[14][15][16]
Cloud Computing	The online service provides users with the ability to do rapid and streamlined calculations, without the need for establishing a tangible infrastructure. This technology facilitates the provision of computer resources, including networks, servers, storage, applications, and services, with the ability to access a network that is readily available, easily accessible, and beneficial. The outcome is a more economically efficient and expeditious resolution with regard to operational platforms, software, and infrastructures.	[17][18][10]
Big Data	The effective facilitation of decision-making processes is achieved via the management of a substantial amount of data, defined by its high volume, rapid velocity, and diversity. This is accomplished by using cutting-edge analytic approaches that are creative in nature.	[19][20][5]

The logistics industry is showing an increasing dependence on new technologies. Therefore, in order to fully capitalise on the potential of this industry, it is imperative to develop the 'Logistics 4.0' initiative, which aims to maximise the utilisation of cutting-edge technologies and implement innovative advancements in the logistics field [21]. Governments should aggressively push its 'Logistics Centre 4.0' strategy, starting with the logistics centre, which serves as the beating heart of logistics systems. As a result, the whole manufacturing sector, including its logistics, is transitioning to a paradigm that is more adaptable and agile, making room for Industry 4.0. According to Khatib et al. [22], the heart of Industry 4.0 consists of four primary enabling technologies that will increase the adaptability of manufacturing and distribution processes: robotics, Big Data, wireless networking, and inexpensive sensors. The interdependencies between the various 4.0 technologies are depicted in Fig. 1.

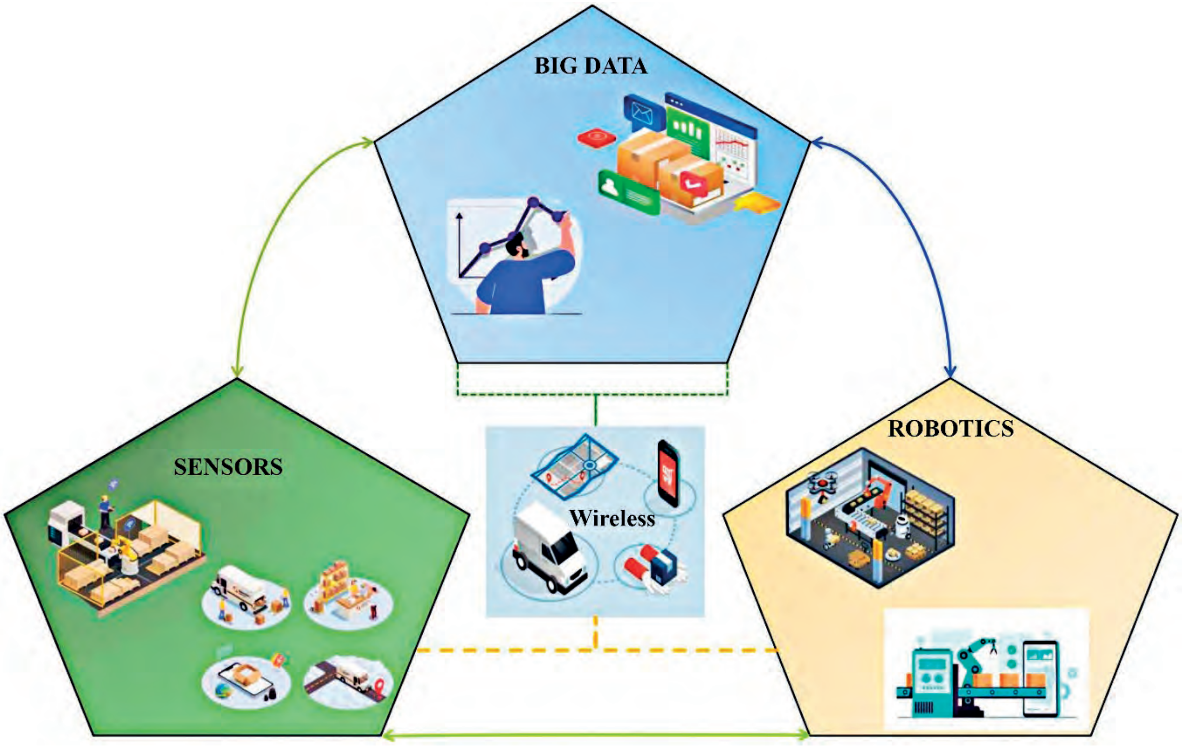

Fig. 1. Dependency between 4.0 technologies [22]

In the technologies mentioned above, IoT was acknowledged as one of the most significant fields of future technology and it is one of the key information and communication technologies (ICT). The IoT is quickly gaining ground in the context of contemporary wireless telecommunications, particularly with the rapid development of wireless communication technologies [23][24][25]. From an initial emphasis on machine-to-machine communication and applications in the 'ubiquitous aggregation' of data, the concept of IoT is continually changing. In other words, the IoT has generated vast amounts of data and various mathematical analytic methods can be used to continuously investigate the intricate links between the transactions represented by this data. Without a doubt, IoT would be crucial to the deployment of smart logistics [26][27], which would fundamentally alter the design of the logistics system and the logistical operation mode. These changes are very important in determining a company's competitiveness because logistics costs are seen as a significant component of overall production costs. Numerous businesses are thinking about how to operate their warehouses more cost-effectively and efficiently, especially in light of recent advancements in supply chain and logistics technology but there are also many businesses that are hesitant about applying smart technologies to a previously traditional infrastructure [28]. According to the public and academic literature, logistics centre management is a crucial component of the supply chain that has received increased attention, with the aim of meeting the rising freight demand and the increasingly high standards for logistics services [29]. In the last few decades, the warehouse and logistics centre business has experienced a remarkable development in major trading cities. Planners and social scientists have expressed concerns over the social and environmental impacts associated with this increase. Researchers have shown that transport infrastructure and links to supply chain partners are two of the most important factors in luring developers to an area [30][31]. Although the advantages of the effects and the role of digitalisation in logistics are still not properly recognised, it cannot be denied that digitalisation will be an essential step in the field of logistics [32][33]; this is reflected in transportation and warehouse activities [34]. As a typical example, in the past, real-time tracking of vehicles was performed using GPS systems. Then, with the advent of 4.0 technology and blockchain, real-time goods tracking systems using blockchain technology have been applied by many companies. From there, digital transformation frameworks are continuously being updated, based on emerging logistics activities. The research by Junge et al. [35] presented a framework for digital transformation in logistics, as demonstrated in **Fig. 2**.

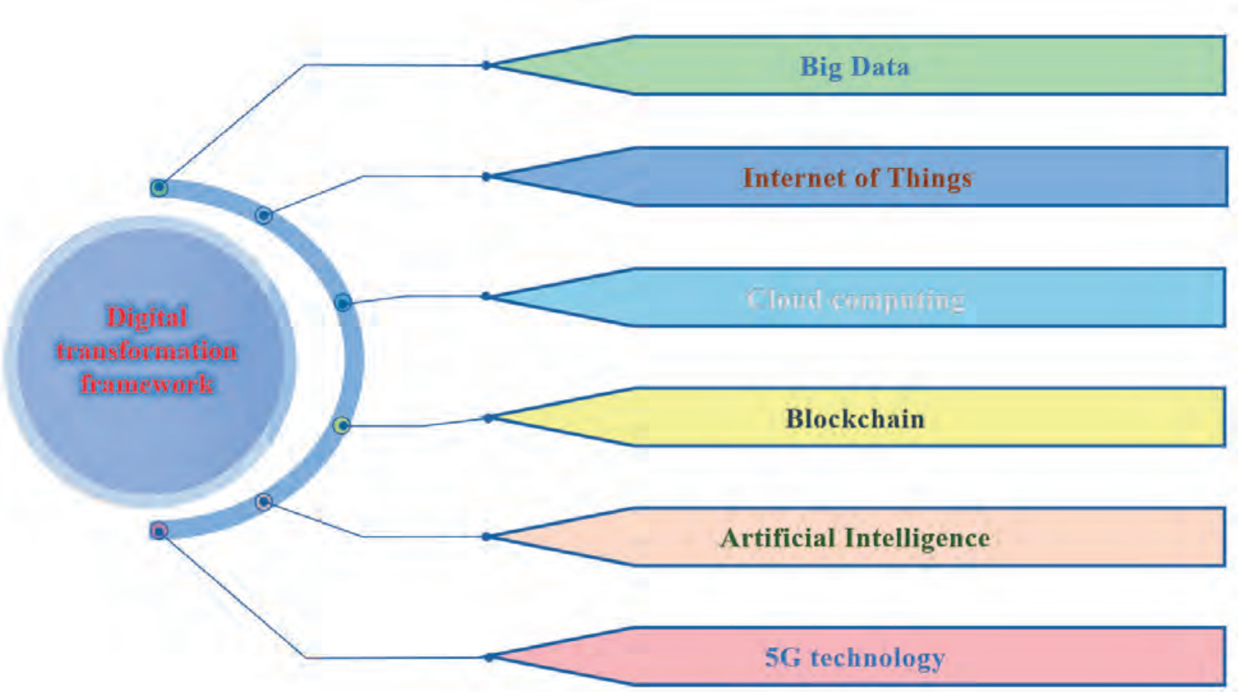

Fig. 2. The Logistics Digital Transformation Framework [35]

The next problem for the necessary development of 4.0 technologies is the e-commerce industry. The quantity of products that need to be handled in a logistics centre has grown over the past ten years, to meet the development of the e-commerce industry, making warehouse operations more complex. As a result, older manual methods are no longer sufficient or practicable to handle this enormous amount of activity [36]-[37]. From there, freight and logistics firms may encounter large delays between arrival and departure, as a result of poor management of the logistics centre [38]. Extra fees (fines for late transportation and additional expenditure for keeping the tractor-trailer driver on overtime) and orders being delivered late are the direct result of this [39]. Long lines of idle vehicles contribute to pollution [40]-[41], thus it is best to set up transport and storage facilities with standardised loading and warehousing efficiency. The primary objective of transportation and logistics centres is to minimise the overall costs associated with product transportation, while simultaneously increasing storage capacity through the implementation of short-term strategies and the use of technology. These elements play a crucial role in the efficient delivery of goods and enhancing transportation and logistics systems [42]-[43]. Moreover, the absence of cohesion in the managerial procedures within logistics centres leads to frequent instances of time wastage and mistakes in the tasks performed by personnel teams. Additionally, one company's barcode system will differ from their suppliers', leading to inconsistencies in the preservation of information about the items' features. This has long been a problem in conventional logistics centres, where it slows down the arrival of transporting vehicles and drives up waiting times and other expenses [44]. Because of this, the cost of logistics is consistently high in underdeveloped nations. Precisely for this reason, the Warehouse Management System was born to resolve the backlog of manual operations at warehouses and logistics centres. Warehouse Management Systems (WMS) evolved as a result of the emergence of increasingly complex tools and algorithms to run warehouses effectively in the 2000s [45]. A WMS has an information system that combines software programmes to keep track of, regulate, control, and manage inventory levels, and optimise warehousing choices. Order processing, order release, and master data are the three main WMS functions. In addition to the above functions, the additional capabilities of WMS include receiving (inbound), putting things away, and warehouse control [46]. However, WMS stopped meeting the needs of traditional logistics centres. For the e-commerce industry, specific characteristics related to the volume and quantity of goods still make it difficult for WMS to operate processing and storage.

By recognising the importance of technologies in applying the management of logistics centres to a smart environment, this work analyses and makes judgements of Industry 4.0 applications in the intelligent management of flogistics centres. Applications that reduce the number of pointless procedures can lighten the load in a logistics centre. Efficiency and operational productivity are then improved. These applications also pave the way for future studies in the field of smart logistics, where systems are combined with cutting-edge technology. However, there will be some notable obstacles, such as the cost of deploying the technology, the way in which the location of the logistics centre affects the environment, and the policies for applying these technologies; these will be of interest in future research.

LITERATURE REVIEW

LOGISTICS CENTRE DEFINITION

According to the European Economic Interest Group [47], a logistics centre is "the hub of a given area where all activities connected to transport, logistics, and products distribution both for national and international transit are carried out, on a commercial basis, by multiple operators". Facilities for storage, managing, clearing, reassembling, disassembling, inspecting quality, offering lodging, and providing social services are all found in logistics centres. Logistical activities are moving from urban to rural areas and using environmentally friendly modes of transportation, like electric vehicles. In the maritime field, the development of green solutions for ships and ports or green logistic centres is being considered as a priority, aiming to reduce carbon emissions and mitigate climate change [48]–[50]. In industrialised nations, logistics centres are crucial for sustainability and competitiveness, but they are also helpful for regional development in poor nations [51].

On the other hand, Uyanik et al. [52] asserted that an essential component of development strategy was the use of logistics centres, which were initially developed in Europe in the 1960s and were first observed in the US during the industrial revolution [53]. If such a centre was established in conjunction with combined and intermodal transport types, there would be innumerable advantages to doing so, including lower prices, reduced traffic congestion, lower environmental pollution levels, etc. However, the term 'logistics centre' was never defined in the literature. According to Higgins et al. [54] and Rimiené et al. [55], a number of terms implied a logistics centre, including distribution centre, freight village, dry port, inland port, load centre, logistics node, gateway, central warehouse, freight/transport terminal, transport node, logistics platform, logistics depot, and distribution park. Furthermore, Erkayman et al. [56] also published a concept for a logistics centre. National and international locations, known as logistics centres, are where various operators conduct all logistics-related activities on a for-profit basis, including shipping and forwarding, product distribution, material handling, storage, and other related transactions (such as banking and insurance). To carry out the aforementioned tasks, a logistics centre must be furnished with the necessary public amenities. These centres must be located near connections to highways, railways, airports, and seaports, as well as being located outside residential areas. Lastly, it has to be run by a single public or private organisation [46][57].

From the perspective of multimodal transport, according to Smail et al. [58], a logistics centre is a type of output point structure of the supply chain that includes stages like warehousing, distribution, and the provision of value-added services, and storage. According to Kaynak et al. [59], the logistics centre is a hub that combines various modes of transportation, almost performing like a multimodal transportation terminal, it is a crucial link in the multimodal transportation chain, and is a structure that serves as a hub for transportation activities among various modes of transportation. With the birth and evolution of the phrase 'supply chain management', the logistics centre concept has also altered and developed, much like the concept of logistics itself [60][61]. Nonetheless, it is most apparent that a logistics centre needs to have two main functions: shipping and warehousing. These are regarded as the two most crucial elements in setting up a basic logistics centre.

SMART LOGISTICS CENTRE

All facets of social life are being significantly impacted by the Industrial Revolution 4.0. Whether they want it or not, people are impacted by the revolution every single day. Automation, labour-saving production, lightning-fast product speed, and consistent quality are at the core of the fourth industrial revolution. One of the primary concerns is the use of automation as a means to effectively adapt to the strategic change that affects the national economy [62]. For logistics centres, the 4.0 revolution is bringing a lot of technology to support smarter and more flexible operations. New technologies are seen as a great support to meet the automation needs of logistics centres. Applying technology to logistics centres will help effectively manage the quantity, status, and flow of goods, in terms of time and cost.

The concept of 'smart logistics' has emerged in recent times, whereby advanced information technology serves as the fundamental basis for its implementation [63]-[64]. By processing information from all facets of logistics in real-time and thoroughly evaluating it, contemporary integrated logistics systems can be intelligently implemented. End-to-end visibility, improved transportation, warehousing, distribution processing, information services, and other aspects of smart logistics could all result in time and money savings. Additionally, it might be able to lessen the environmental damage that logistics causes. However, there are still difficult problems that must be solved before smart logistics can be implemented. One of the outstanding issues is the application of technology and connected activities in a logistics centre into a complete chain of activities, to overcome additional time and cost. In order to fulfil the needs of product storage, surveillance, safety, fire and explosion detection, and more, a smart logistics centre needs IoT equipment, such as IoT stacking shelves and an IoT inspection, as well as a monitoring system. The same degree of automation and network connectivity needs to be applied to machines and tools. It is obvious that IoT will play a pivotal role in the success of these modern logistics centres. These applications of IoT allow for the construction of a network-based cyber-logistics system that can be managed by humans. The incorporation of intelligence, automation, and automated choices of technology (IoT), elements of the supply chain, and logistics 4.0 are other important topics to explore in the Fourth Industrial Revolution [65][66]. A modern smart logistics centre, with intelligent goods arrangement and inventory management systems, is shown in **Fig. 3**. This is the result of the combination of many Industry 4.0 and Logistics 4.0 ideas, including driverless cars, digital connections, and information security, with the core functions of a logistics centre.

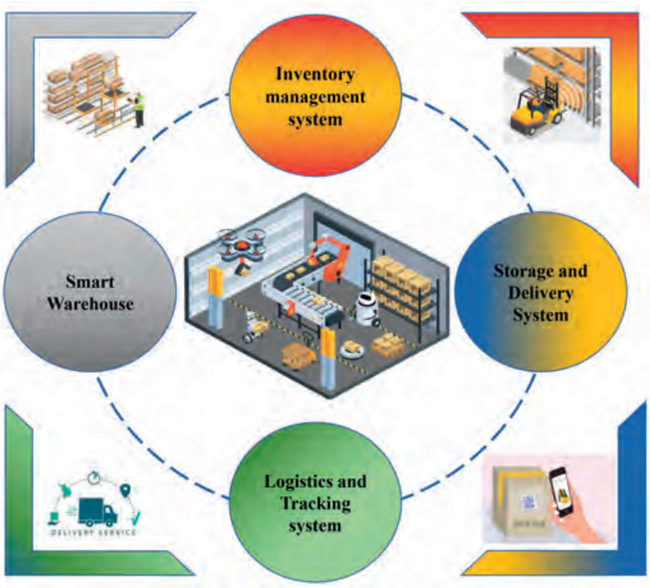

Fig. 3. Operations of a smart Logistics Centre [67]

To meet the needs related to the intelligence of a logistics centre, the study by Yavas et al. [68] focused their research on the transformation of logistics centres in industrial revolution 4.0 and identified key criteria for logistics centres in the new industrial era. The strategy was to look at the interactions between the operations of traditional logistics centres and then suggest a new framework for them. The four primary operations of logistics centres (handling management, information management, transport management, and warehouse management) were the basis for the twelve criteria for logistics centre 4.0 presented in this work. These criteria were acknowledged as the operational criteria at the logistics centre stated above and were linked to the four traditional criteria in the proposed framework [69], as illustrated in **Fig. 4**.

The operation of a smart logistics centre is based on the use of the latest technology, such as Big Data and IoT, to increase its operational efficiency. Through a decision support function based on logistics data, it also aids in the development of a managerial logistics operation plan. According to Cho [70], Logistics Centre 4.0 is based on IoT technologies. The data is collected and analysed using Big Data technology, the product is stored and transported based on the knowledge obtained through Artificial Intelligence, and a smart logistics centre system performs tasks automatically using robots. As the variety of items that need to be processed in a warehouse has grown over the past decade, conventional and manual techniques for warehouse management have proved to be unable to manage them.

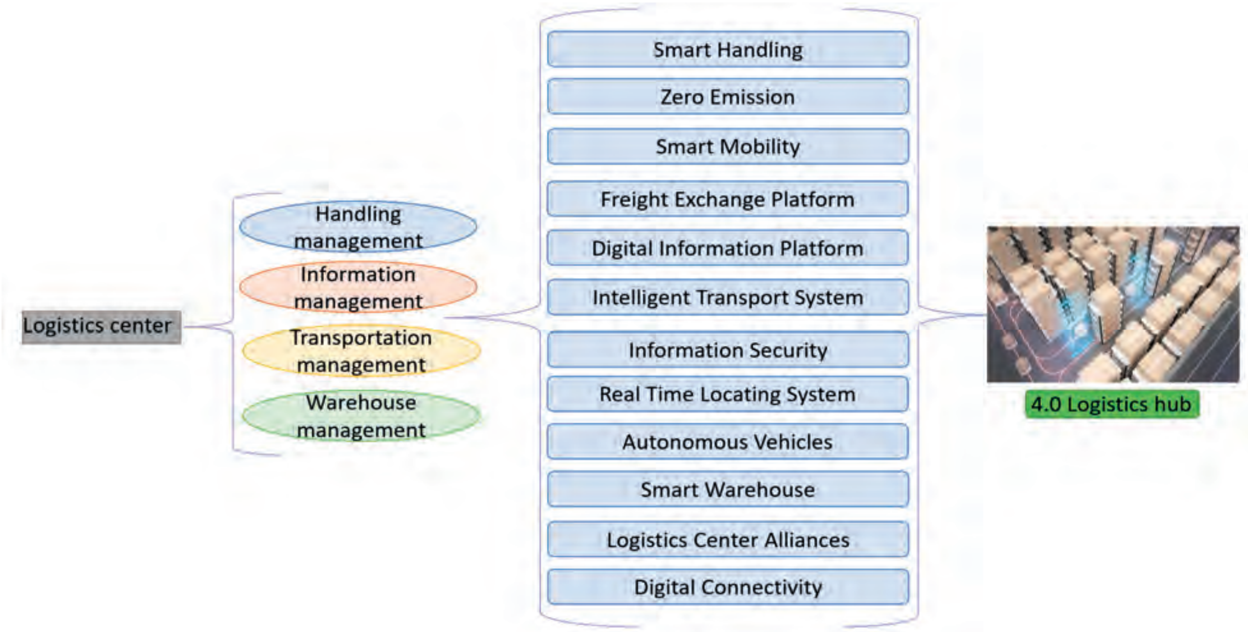

Fig. 4. A conceptual architecture for the 4.0 logistics hub [68]

This has resulted in a rise in the use of information technology to facilitate warehouse operations. The WMS has evolved as more sophisticated tools and algorithms for managing warehouses have been made available since the turn of the 2000s [45][71]. With the advancement of both technology and the marketplace, however, the manufacturing of products has shifted from make-to-stock (MTS) to make-to-order (MTO), leading to a dramatic rise in the number of commodities. As a result, new forms of warehouse technology are being integrated with existing warehouse management systems. In this article, a smart logistics centre is defined as having four 4.0 technologies: IoT, Blockchain, Big Data, and Cloud Computing. These technologies are applied for solving problems in logistics centres. In the next section, we analyse and review some applications that have been, and are being, applied at smart logistics centres. In addition, applicable policies, development possibilities, and future research directions will also be mentioned in this work.

APPLICATION OF 4.0 TECHNOLOGIES IN LOGISTICS CENTRES

The secret to creating a smart logistics centre is to use cutting-edge technologies to their fullest potential. Of these, IoT technology has emerged as a technology with outstanding data collection potential, helping managers to have a more holistic view of a logistics centre [72]-[73]. To facilitate data communication, exchange, and control among objects using distinct identifiers, a range of information sensing technologies are employed. These technologies encompass RFID, wireless sensor networks (WSN), and machine-to-machine systems. Additionally, embedded systems are also utilised, in conjunction with network communication technology, to achieve these objectives [26][74][75]. A sensor is apparatus that identifies and reacts to a certain kind of stimulus originating from the surrounding physical milieu. The input might include a range of environmental phenomena, such as heat, light, motion, moisture, pressure, or other factors. Alternatively, the data might be communicated by electronic means over a network, enabling remote access for reading or further processing [76]. The classification of sensor types is presented in **Table 2**.

Connecting and collecting massive amounts of data from sensor systems in logistics hubs is made possible by Internet of Things applications. This data can come from many different sources, such as product volume, temperature, humidity, shelf location, etc. According to Uckelmann et al. [85], the IoT is dedicated to connecting the physical world to the virtual internet and its primary drivers of development are object self-identification, information sharing, and interactive processing. Machine-to-machine and human-to-machine interactions are made possible by IoT applications [86]. The technological components of the IoT have been extensively discussed in Miorandi et al. [87], Mishra et al. [88], Ng et al. [89], Whitmore et al. [90], and Li et al. [91]. Despite the fact that several types of smart logistics exist due to different priorities, all of them rely on the use of ICTs. A new working concept of smart logistics is centred on the movement of goods, based on cutting-edge technology and intelligent management. Fig. 5 shows the concept map of a smart logistics centre with four technologies in the current industry 4.0 era: IoT, Big Data, Blockchain, and Cloud computing [92].

Tab. 2. Classification of sensors [77]

Type of sensor	Function	Ref
GPS sensors	The objective of this sensor is to determine the location of various components and to accurately detect and communicate the operational duration of equipment in the logistics centre.	[78][79][80]
Strain sensors	Quantify the instantaneous deformation experienced by structural components in a timely manner.	[81]
Accelerometer sensors	This particular sensor is capable of detecting changes in gravitational acceleration, enabling the measurement of tilt, vibration, and acceleration.	[78][79]
Barometric sensors	Barometric pressure sensors have been employed in many electronic devices such as smartphones, smart watches, and drones, to monitor air pressure readings and changes in altitude.	[78][79][82]
Wind-sensor, rain-sensor	The objective is to observe and measure the velocity of wind, as well as the amount of precipitation.	[83]
Fibre optic sensor	The automation of operations might be achieved by the activation of the reader for RFID and GPS detectors.	[84]
Laser sensor	The objective is to ascertain the duration required for the production process of the equipment.	[78]

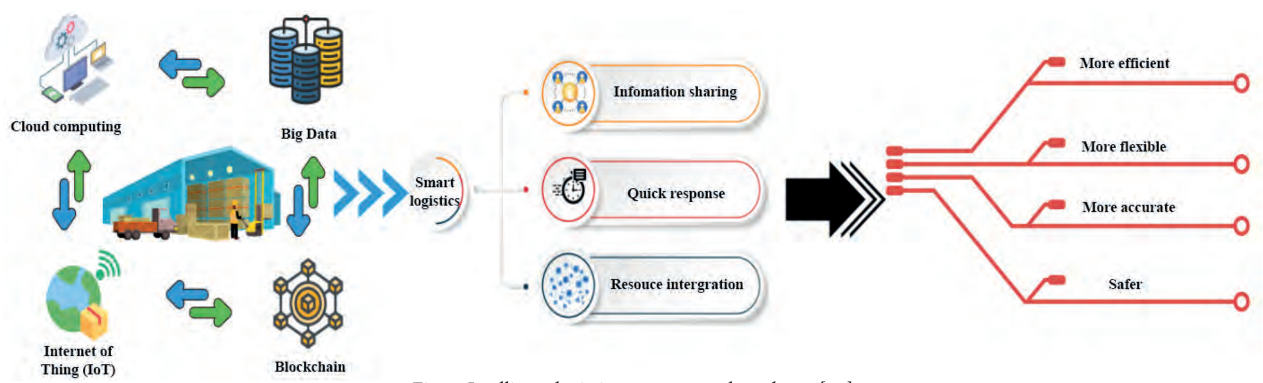

Fig. 5. Intelligent logistics: a conceptual roadmap [92]

INTERNET OF THINGS (IOT)

One potentially useful technology that might be included in a standard logistics system is the Internet of Things (IoT). Utilising Auto-ID methods, such as Barcode and Radio Frequency Identification (RFID), the IoT can accurately identify a wide range of things. The IoT would gather and record data in real-time from a wide variety of things, allowing for real-time visibility and traceability [93]. Data collected in real-time might be used for complex tasks like logistics route planning. The logistics sector has recently looked at wearable gadgets that combine IoT technology [94]. Logistics platforms have included state-of-the-art technology to allow for automated tracking of commodities and improved capabilities for logistics personnel [95]-[96]. With the help of IoT technology, a traditional logistics centre has the ability to connect devices and units, and manage those units within a network. **Fig. 6** shows the connectivity and management capabilities of IoT in a logistics centre.

Öner et al. [100] took a case study into account, for the application of RFID technology in the wool yarn sector. RFID is intended for the handling process, including receiving, picking, and shipping of semi-finished goods, as well as tracking work-in-progress, inventories, and stock levels. In order to accomplish this, an architectural framework for an RFID-based information system for the wool yarn sector was created and a cost-benefit analysis was carried out to determine whether the new system was cost-effective or not. Additionally, a risk analysis for RFID investments was performed. In the same study direction, a WMS was created by Tejesh et al. [101], based on RFID wireless communication technology. The IoT-based warehouse inventory management system is designed to track the products that are linked to tags and provide product information and their associated time stamps for additional verification. A server called Raspberry Pi would monitor and update all data. The entire system provides an archetype to match the material and information flow. The website is designed for ease of use and an interface

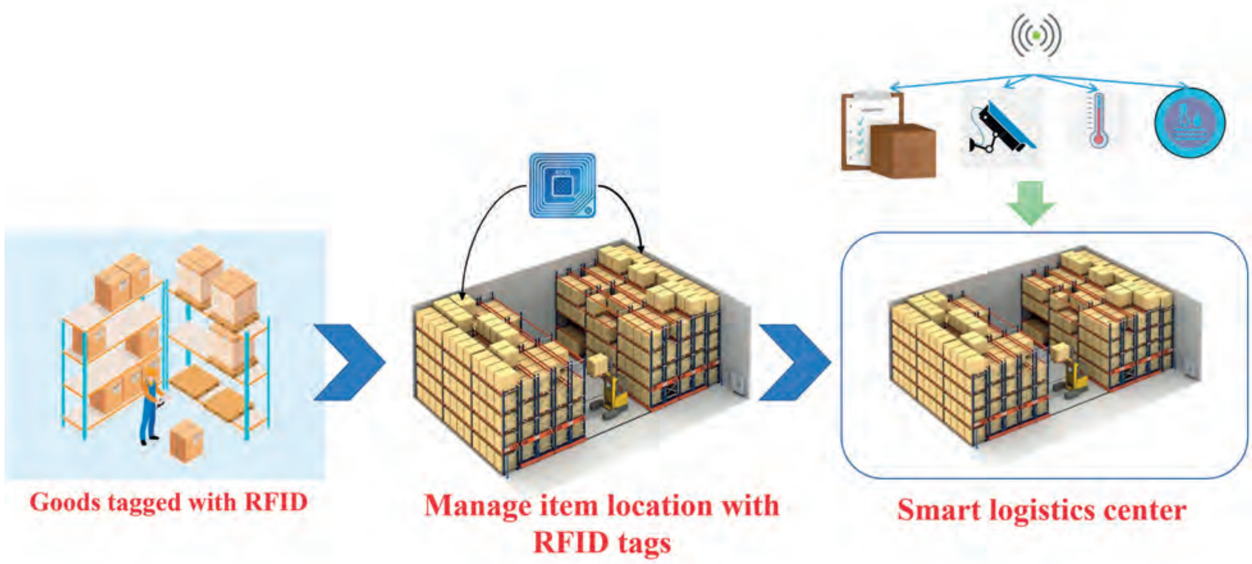

Fig. 6. IoT application in logistics centre management [97]

for the user to track the products in mind. Comparing the developed system to the already-used warehouse inventory management systems, it was significantly more affordable and operated dynamically.

In order to promote intelligent logistics for Industry 4.0, Lee et al. [98] suggested an IoT-based warehouse management system with an enhanced data analysis methodology, based on computational intelligence approaches. Data acquired from a case firm demonstrated that the suggested IoT-based WMS might increase warehouse productivity, picking accuracy, and efficiency, while also being resilient to order unpredictability. The authors also discovered that employing RFID might increase efficiency in order picking by warehouses, pickup time, and inventory accuracy. A smart WMS framework was announced by Hamdy and colleagues [99]. The warehouse manager could perform more real-time management and monitoring of the activities because of this solution. The adoption of WMS and IoT in warehouses was reviewed. The building components and levels of the IoT were also shown, carefully.

A logistics centre's facilities were connected to a cloud centre, gateways, fog devices, edge devices, and sensors in Lin et al.'s [102] investigation of the deployment of an intelligent computing system. This work established an integer programming model for deploying gateways, fog devices, and edge devices in their respective potential sites, so that the total installation cost was minimised under constraints of maximal demand capacity, maximal latency time, coverage, and maximal capacity of devices. The locations of the cloud centres and sensors were determined based on the factory layout. The system's deployment was simulated using a mathematical programming model, which chose the locations of the gateways, fog devices, and edge devices in the logistics centre, to minimise the overall installation cost while maintaining the system's maximum capacity for demand, latency, coverage, and device capacity. Two new paths in the study of the vehicle routing problem (VRP) in transportation management (under the umbrella of smart logistics) have emerged, because of intelligent technologies like IoT and ICT. First, studies on VRP began to focus on multi-objective models and enhanced intelligent algorithms for handling dynamic optimisation problems. Data-driven models and dynamic models with various objectives have drawn more attention from academics, in terms of model types, because they address real-time data updating and coordination amongst numerous transportation agents. Second, some researchers have shown that the use of Big Data and geospatial positioning technology enables smart logistics to perform activities like visualisation, prediction, control, and decision-making in VRPs [103].

For the purpose of organising fresh integrations of intelligent food logistics systems, Li et al. [104] presented a linear approach. The costs of overall production, inventory, and transportation were minimised, while average food quality was increased. Then, a fresh approach was created to resolve it by fusing the fuzzy logic method with constraint-based two-stage heuristics. One case study and 185 randomly generated cases, with up to 100 stores and 12 periods, were used to evaluate the methodology. The case study's calculation results showed that the suggested model and method could resolve a real situation involving 40 merchants and 7 periods. The authors' method could give decision-makers a selection of Pareto solutions and assist them in selecting a preferred alternative. Moreover, Zhang [105] suggested a path decision approach based on an intelligent algorithm, merging the Cyber-Physical System's characteristics with the existing logistical system. The equipment layer's connectivity architecture and data processing utilised the IoT and cloud platform data storage technologies, which were based on the Cyber-Physical System's logistics path decision model. The impacts of using ant colony, simulated annealing, and genetic algorithms on logistic path optimisation were thoroughly examined. It was determined that the ant colony algorithm had the best path optimisation impact in solving the logistics path decision, by comparing the shortest transport route and convergence rate under the three algorithm decisions.

BIG DATA

Data obtained from the market, such as consumer preferences and the experiences of logistics users, can be processed and analysed with the use of big data gathering technologies, allowing logistics firms to improve the quality of their services in response to client needs. Additionally, logistics firms can improve their overall competitiveness by collecting data about their target markets, such as logistical costs, basic pricing, and marketplace assets [106][107]. In order to improve supply chain management and logistics centre efficiency, Big Data analytics sparked a revolution in inventory monitoring, forecasting, and management. By analysing massive amounts of data, Big Data provided insights that would otherwise be impossible to reach, driving the warehouse closer to its full potential. In the study by Xie et al. [108], the researchers conducted a survey of companies, looking at how Big Data is being used in the management of logistics, and used logistics hubs as a case study for using time series models to predict cargo load capacity. The results showed how smart logistics built on Big Data may improve logistics in many ways, including efficiency, cost, and user experience. The authors also concluded that the leadership and making of decisions, customer relationship maintenance, and resource allocation of logistics firms would all greatly benefit from the judicious use of Big Data technologies. Wang et al. [109] also conducted research on the topic of locating logistics facilities through Big Data analysis. This issue was stated in the form of a nonlinear mixed-integer programme. The simulation analysed the effect of varying demand, distribution centre operating costs, international shipping, and client count on the optimal placement of distribution centres produced in random, massive datasets. The experimental data showed that the model provided was practical and stable. This case study demonstrated the practical use of Big Data in designing a distribution network by evaluating different potential network layouts.

Big data could be especially useful in inventory management, as mentioned in the study by Wang et al. [110], where it could aid the development of cutting-edge inventory optimisation systems, the forecasting of future inventory requirements, the meeting of fluctuating customer demands, the cutting of inventory costs, the attainment of a more complete picture of stock levels, the improvement of inventory flow and storage, and the reduction of safety stock. Big Data provided additional information about the logistics hubs that support certain industries. An advanced data mining strategy was presented by Vieira et al. [111], for an automobile sector firm based on their analysis of proof of concept Big Data in a logistics centre. Due to the dearth of pre-existing methods, the most cutting-edge one was employed. To better identify relevant data to assist decision-making, the suggested strategy focused on goals that were user-driven. Another shared objective was to facilitate communication and consensus during decision-making. In order to ensure that the proper replacement parts were available for the right equipment at the right time and in the right amount, Zheng et al. [112] proposed an intelligent system for managing inventory that makes use of cutting-edge technologies, such as the IoT and Big Data Analytics. The Singapore Economic Development Board anticipated that this approach would benefit the whole of the Singapore semiconductor sector in the future. The interactions between providers and consumers should be investigated further to find ways to improve openness, adaptability, and satisfaction.

Furthermore, Wahab et al. [113] set out to learn what variables in Malaysia's warehousing industry were slowing down the use of Big Data analytics. The theoretical underpinning was the TOE model (technology-organisation-environment). Partial least squares structural equation modelling was used to evaluate survey responses from 110 logistics firms. The empirical findings indicated that the level of adoption of Big Data analytics was influenced by relative advantage, technical infrastructure, absorptive capacity, and government backing, but that industry rivalry had little impact on noticeable gains. The results of this research should make it easier for warehouses to use Big Data analytics in the most effective ways possible. Big Data analytics are more likely to be adopted by warehouses that place an emphasis on operational excellence, ICT infrastructure, and the integration of new technologies.

The inclusion of Big Data in data collection in the warehouse is a very feasible option, making data reception more passive. In addition, the combination of Big Data and IoT is also a good technological solution for helping the logistics centre become automated. This was also a premise for conducting transport flow management outside the logistics centre. The combination of managing the flow of goods and motor vehicles in and out of a logistics centre would greatly help in reducing transportation costs, warehousing costs, and waiting costs.

BLOCKCHAIN

For IoT or Big Data, the application of these technologies in logistics centres mean exploiting and processing information to achieve optimal goals, as well as reducing costs. However, the major drawback of the above applications is their transparency, as well as the ability to protect data, and this is what blockchain can do. By using examples and frameworks, Ahmad and colleagues [114] explored how blockchain technology might revolutionise port logistics and operations. In addition, researchers designed permissioned architectures to draw attention to the numerous elements, participants, and deployment options of port logistics services, in order to automate these processes. The results showed that blockchain technology could render it impossible for theft to happen, with documents linked to data management and storage, fleet management, trade paperwork, as-set and crew approval, and tracking shipments. This made transactions go more smoothly and built trust between authorities, organisations, and other players in the logistics centre transportation environment. With RFID tags, the supply chain process was described from the raw materials to the consumer. Each step was recorded in the blockchain to improve transparency, in which the activities at the logistics centre would be recorded, see **Fig. 7**.

A paradigm for the combination of blockchain with the IoT was presented for a logistics centre by Aleksieva et al. [116]. This technology, which made use of smart contacts on the blockchain, might be used for the logistics of cross-docking warehouses and shipping. The model showed the ability to operate effectively when it was possible to classify items in a logistics centre very well, thereby increasing operational efficiency and reducing waiting times. Blockchain logistics 'apps' for the optimum placement of intelligent transport logistics centres were created by Chen et al. [117], to make use of the blockchain system's simplicity and IoT input devices. This strategy was used to monitor where goods were in the supply chain at any given time. Based on the results of the experiments, it was clear that the optimum location technique is superior to conventional approaches, in terms of the amount of computing required, the precision of the locations it produces, the total cost, and the ease with which warehouse locations might be determined. Applying an intelligent logistics system built on the IoT and blockchain technology helps businesses get a clearer picture of their stock levels and shipping progress in real-time. Thereby, it ensures the assets and capital turnover of the enterprise.

It is impossible not to mention the traceability of blockchain technology as, with this ability, many applications have been launched, e.g. product traceability. In order to reliably record airplane parts and improve traceability data (with organisation-wide consensus and verification), Ho and colleagues [118] suggested a blockchain-based approach that was constructed using Hyperledger Composer and Hyperledger Fabric. Blockchain was also used to keep track of inventories at distribution facilities, cutting down on inefficiencies in both time and money. Kurdi et al. [119] analysed data from a sample size of 303 respondents, using regression and hypothesis testing with ANOVA, to apply a descriptive, exploratory, causal, and analytical design. One particularly noteworthy finding was the effect that blockchain and smart inventory systems had on the efficiency of supply chains and logistics hubs. Future studies should expand on the number of sectors and building types studied by using the same amount of organised research. On the other hand, Lakshmi et al. [120] used QR codes and blockchain technology to create a system for trustworthy distribution and open

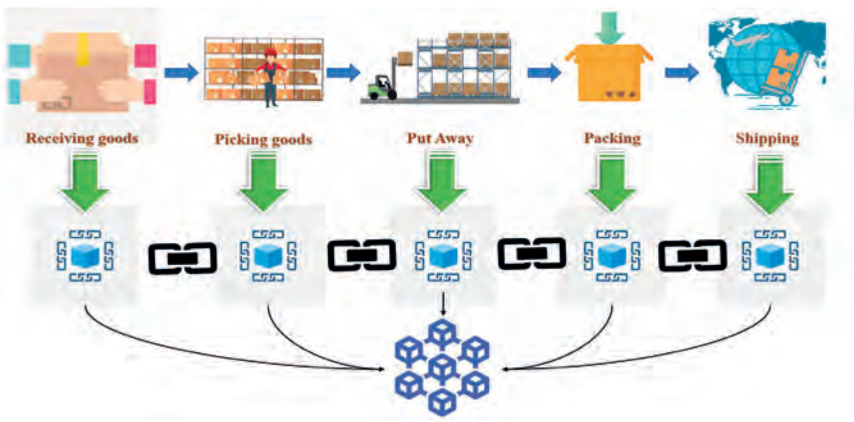

Fig. 7. The use of blockchain technology inside a supply chain framework [115]

inventory management. Distributors, retailers, suppliers, and manufacturers might all be linked via blockchain technology, with every transaction between them being permanently recorded. The use of QR codes helps the efficient management of this stock. Faster feedback loops mean fewer mistakes in inventory records and more reliable data for making well-informed decisions at review intervals.

CLOUD COMPUTING

The term 'cloud computing' refers to the delivery of computing resources and functions through the internet. The key features of cloud computing include on-demand service delivery, widespread network access, shared resource pooling, scalability, and use monitoring and control. Since a large number of users might share identical assets, cloud-based platforms automatically monitor and measure the usage of resources for each user [121]. This allows users to make as little or as much use of the system's capabilities as they see fit [122]. The most-mentioned advantages of cloud computing is that it reduces risks in the supply chain and limits the generation of waste. Supply chain risk might be mitigated and robustness improved in the same manner as cloud computing in logistics increases agility (by boosting speed, scalability, and visibility). In a poll by Accenture [123], 52% of supply chain executives claimed that cloud computing has helped them improve resilience. The executives also claimed a 26% improvement in the precision of demand projections as a result of using cloud computing. The effectiveness of supply networks in reducing waste and their long-term viability are under increasing examination. This was a major topic of discussion during COP26, held in Glasgow in 2021. Overall, 48% of supply chain executives polled by Accenture in 2021 [123] said that they had reduced waste because of cloud computing. Companies might use cloud computing to highlight waste and inefficiency in the supply chain and save costs, allowing them to make adjustments to reduce their waste. The cloud might assist businesses in reorganising their supply chains to improve efficiency, refine logistics and transport routes, and maximise resource use, all of which contribute to a smaller carbon footprint [124]. The application of cloud computing to each stage in the supply chain was an inevitable trend of businesses moving towards smart logistics. In the research by Jiang [125], the researcher took advantage of cloud computing to provide a strategy for determining the best geographical and transitable parameters for an international e-commerce logistics distribution hub. When micro-influences were taken into account, this model performed well. Transportation distances were stated to be reasonable, ranging from 3.5-7.5 km, when using this approach. Based on this technology, Zhang [126] also presented a two-layer unloading system for a railway logistics centre using cloud-edge communication technology. The simulation findings demonstrated that the discharging technique described in this research reduced the total time cost of unloading by as much as 40%. This technology's use also has the potential to expedite inter-device communication and enhance the efficacy of railway data transfer. Sharma et al. [127] illustrated research on how to leverage cloud computing to improve retail warehouse distribution and supply chain management through Microsoft Azure technology. Microsoft Azure is utilised in retailing, shipping, and warehousing, as well as supply chain management. The utilisation of this technology helps cost savings and eases administration, with more adaptability and better oversight. These are just some of the benefits of using this kind of technology in retail centre logistics. Gupta et al. [128] also confirmed that a suitable application created by cloud computing may greatly facilitate the simplification and automation of logistics centre management. Sivakumar et al. [129] investigated the storage facilities at Chennai Harbour. The warehouse management system for the Chennai Port Trust is hosted in the cloud, so that numerous people may use it from off-site locations. According to the findings of this study, warehouse operations benefit from cloud computing, which increases productivity and streamlines the workflow. Furthermore, Barreto et al. [130] noted that electronic contacts with customers, trade partners, and carriers may be handled by integrating warehouse administration and transportation administration using cloud computing technologies.

POLICY IMPLICATION FOR LOGISTICS CENTRE DEVELOPMENT

Smart logistics centres powered by the IoT, Big Data, Blockchain, and Cloud Computing would be safer, more accurate, and more efficient. Additionally, the warehousing procedure would be expedited, and resources would be utilised to their full potential. In a centralised warehouse management system, decentralised decision-making was possible using IoT. The hurdles for IoT-based smart warehousing still lie in the selection of a storage allocation strategy and the optimisation of indoor routing. The technical limitations of RFID, the IoT's limited technological capability, IoT standardisation issues, IoT data acquisition and processing issues, and IoT security and privacy concerns, are all obstacles to IoT-based smart logistics. IoT is unsuitable for sophisticated applications in logistics due to its constrained computing power and data processing capabilities. In transportation, IoT has a limited impact on cargo load optimisation and vehicle selection. IoT technology is unable to easily tackle the complicated problems of storage allocation and container/truck loading [131]. IoT could not be used to achieve the agile WMS [132]. Without the aid of an intelligent algorithm, IoT technology could not provide decision-making in truck route optimisation for the delivery of perishable goods [133]. IoT technology could gather large amounts of information about delivery resources and requirements [134][135], but it could not address how to improve the scheduling and use of delivery resources [20]. It is not sufficient to address the issues of resource waste and excessive cost in last-mile delivery.

Logistics become more difficult during the handling, palletising, and transporting of custom or limited-edition products [136]. The occurrence of eventualities modifies the demand for specific products quickly and calls for adjustments to the warehouse floor plan. Transportation scheduling changes at short notice also presents another difficulty for traditional logistics. In light of the transit stock being transported along the supply chain (and its scarcity, needs, and trends), the issues in current logistics centre on these factors [137][138], including spikes in the demand for otherwise stable products [139]. The desire to deploy Industry 4.0, according to Pereira et al. [140], involves a variety of technological hurdles with significant effects on many aspects of today's manufacturing industry. Therefore, before implementation begins, it is crucial to define a plan for all the actors engaged in the entire value chain and to come to an agreement on security-related concerns, as well as the appropriate architecture. Furthermore, a lot of scholars claim that putting Industry 4.0 into practice is a difficult task that would probably take ten or more years to complete. Adopting this new manufacturing method involves several factors and presents a variety of obstacles and challenges, including social, political, and economic issues, in addition to technical, economic, scientific, and energy hurdles. The gathering, processing, and presentation of manufacturing process data were three new, demanding activities that they should be able to test out using specialised Industry 4.0 technology [141]. Industry 4.0 has the potential to bring about significant changes in a number of areas that extend beyond the industrial sector and enable the development of new business models. With so much rivalry in today's market, businesses must constantly adapt to be competitive in terms of cost, quality, and turnaround time [142]. Due to global competition, businesses need to be quick to adopt new technologies and provide new items to the market [143]. Designing productive, efficient, and adaptable techniques is necessary to ensure process competitiveness throughout the value chain [142]. The integration of new technologies into manufacturing processes, goods, and machinery is crucial to facilitating rapid response to changes in the marketplace [144]. One of the main obstacles faced by different countries is the lack of policies that allow technology to be applied to the logistics sector. **Fig. 8** illustrates the relationship between logistics policy and governmental policies. It should be noted that logistics policy does not have a superior attitude toward other policies; rather, it implements some of these (such as security and transportation policies) and cooperates with others (e.g. industrial and maritime policies). Nonetheless, it should be considered in each area of its functioning, including in macroeconomic and detailed policies and (crucially) it should not be 'closed'. This phenomenon is closely related to the processes of globalisation and aims to create a 'no barriers' relationship between regions, states, and continents, in terms of logistics [145].

Fig. 8. Links between logistics strategy and other industries [145]

The use of 4.0 technology also requires ties with other fields and sectors within a nation. Furthermore, only a small portion of 4.0 technology is used in logistics centre management. Here, the focus is on building a nation's digital infrastructure and smart infrastructure. Although there are many questions about 4.0 technology's ability to safeguard information, its practical applicability, and the expense of doing so, this is thought to be one of its most risky. Theft, or the disclosure of user-data kept in databases, might compromise user privacy and impact the customer service of the logistics centre [146]. However, ensuring data privacy is just one of the obstacles to overcome; lowering operational expenses is also crucial [147][148]RFID (radio-frequency identification. Many questions have been raised about whether the application of these technologies in logistics centres would really cut or increase costs. As an added argument, applying technologies in a uniform way, or prioritising each technology applied in logistics centres, would also be a topic for future research. Therefore, in addition to the priority policies aimed at macro-development for countries, research directions for technology application should also be explored in future studies of logistics centres. Developing an acceptable application policy is a problem that requires further research.

CONCLUSIONS AND FUTURE PROSPECTS

Exponential growth in the number of products that are available has led to the persistent challenge of overload within logistics centres and freight operations in the logistics sector. Moreover, these activities not only result in the inefficient use of time and resources but also have detrimental effects on the environment. Hence, the use of novel technology arises as a viable approach to effectively address these issues in their entirety. The integration of advanced technologies, such as Big Data, Blockchain, Internet of Things, and Cloud Computing (commonly referred to as 4.0 technologies), has been extensively studied and applied in various domains. Through previous research and applications, this work has demonstrated the significant potential of these 4.0 technologies in enhancing the operational capabilities and efficiency of logistics centres, particularly in managing and controlling the movement of goods.

The primary uses of each technology are as follows: The Internet of Things (IoT) facilitates the collection of a substantial volume of data by using RFID tags affixed to individual packages and sensors installed throughout the whole of the logistics centre. The use of Big Data facilitates the processing of vast amounts of data in order to provide assistance for managerial decision-making. Blockchain technology in the logistics centre provides transparency across the whole of the workflow, including the arrival and departure of items. Cloud Computing facilitates the sharing of information while maintaining control, leading to continuous productivity improvements in logistics centres. The use of these technologies has the potential to enhance the intelligence and advancement of a logistics centre. In addition, it is recommended that future research is directed toward the development of a technologically advanced logistics centre that conforms to established environmental criteria. Hence, it can be inferred that the adoption of a green-smart logistics centre model will become an unavoidable trajectory in the future. This model would enable the systematic regulation of goods transportation to effectively cater to the substantial demand for commodities. Furthermore, these logistics hubs have the potential to function as seamless extensions of seaports, therefore mitigating congestion issues in port cities. Transportation operations within the logistics business are well acknowledged as being a significant contributor to environmental degradation. The escalation of congestion and prolonged waiting times at conventional logistics hubs and seaports has led to a significant rise in pollution levels, hence posing a substantial urban challenge. The use of 4.0 technologies enables the expeditious regulation of products inside centres, resulting in reduced waiting times and, subsequently, contributing to the mitigation of vehicle emissions. Hence, the establishment of a green and intelligent logistics centre emerges as a prominent research direction aimed at mitigating environmental pollution. Simultaneously, this development aligns with the evolving requirements of smart cities, which are experiencing rapid global growth.

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