Internet of Things (IoT) Driven Logistics Supply Chain Management Coordinated Response Mechanism

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***Abstract*—This study explores the development of an IoT-driven logistics supply chain coordination and response mechanism aimed at achieving real-time information sharing, precise forecasting, and rapid decision-making among supply chain nodes. By employing a hierarchical system construction method, SQL database techniques for data management, and an evaluation model combining AHP and entropy methods, the study proposes a robust framework for improving supply chain efficiency and adaptability. The results demonstrate that IoT technology significantly enhances supply chain transparency, resource allocation, and operational efficiency while reducing risks and costs. The proposed mechanism facilitates dynamic adjustments to market changes and unexpected disruptions, fostering a resilient and collaborative supply chain network. This research provides a foundational basis for the integration of IoT in modern supply chains and offers insights into advancing intelligent logistics systems, with implications for improving global competitiveness in the evolving digital economy.**

***Keywords*—IoT; logistics supply chain; management coordination; response mechanism**

I. Introduction

In the new post-epidemic normal, the manufacturing industry urgently seeks to accelerate its digitization process and smart warehouse and logistics upgrades in light of the continued climb in market demand for smart warehousing and logistics [1]. In the ecology of logistics and supply chain, the efficiency of the warehouse and logistics system, service quality, and operating costs constitute the core considerations. By optimizing the intelligent warehousing and logistics system, enterprises can effectively speed up the logistics process, ensure efficient resource deployment and management, and then cut costs and improve overall performance [2]. In the construction of intelligent warehousing, promote the level of informatization of warehousing and logistics to enhance the irreversible development trend in the field of intelligent manufacturing.

In recent years, with the deep penetration of Internet of Things (IoT) technology in the industrial sector, the Industry 4.0 era has witnessed an increasing convergence of technologies [3]. This cutting-edge concept is gradually attracting the attention of the industry, which is dedicated to the comprehensive digital mapping of physical entities, empowering the intelligent design, manufacturing, commissioning, and full lifecycle management of physical equipment through data access and model-driven. Specifically, the application of digital technology in the field of warehouse logistics, embodied in the construction of digital subsystems to provide intuitive monitoring and predictive maintenance services, at the same time, it also helps the simulation and pre-commissioning of industrial equipment in the virtual environment, to provide a virtual test platform for the development of the production plan, to effectively assess the feasibility of the production process, the initial cost can be reduced, and production efficiency has been significantly improved [4]. On the other hand, in real production environments, manufacturers often need to integrate different industrial equipment from multiple suppliers, and the diverse communication protocols and interfaces between these devices often become obstacles to the efficient collection, transmission, and processing of data, which exacerbates the difficulty of data sharing [5]. This phenomenon, the so-called "knowledge silo", is gradually evolving into one of the challenges in promoting the digital and intelligent transformation of production [6].

This research aims to explore and construct a set of logistics supply chain coordination response mechanisms based on IoT test the constructed platform to a certain extent, and evaluate the IoT platform according to the test results and subjective and objective factors to explore the level of logistics supply chain management coordination response in China.

II. Background of the Study

As a key pillar of the national economy, the logistics industry is of strategic importance in shaping the framework of the modern cycle, driving high-quality development, and building a modernized economic system [7]. In 2022, the General Office of the Government issued a five-year blueprint for the development of modern logistics, which is the first five-year planning document for the development of modern logistics in China [8]. The blueprint specifies the core tasks for the next five years: to enhance the innovation driving force and market competitiveness of logistics enterprises, to optimize the quality and efficiency of logistics services, and to build a hub network operation system and a modern logistics and distribution network to flexibly respond to changes in domestic and international supply and demand [9]. At present, China has jumped to the top of the global logistics market, carrying more than half of the world's express parcel volume. However, despite the huge scale of logistics, its comprehensive strength has yet to be strengthened. Therefore, accelerating the construction of a modern and efficient logistics system, and realizing the leap from "big" to "strong" has become a key mission to improve logistics quality, cut costs, and enhance efficiency, which is particularly urgent in the five-year planning period [10].

Logistics companies need to have a forward-looking vision, advance insight into industry trends, carefully plan the future path, and continue to innovate and optimize, to better meet the challenges and achieve sound management and long-term development [11].

The continuous prosperity of the logistics industry has prompted intelligent logistics to become an increasingly critical growth trend. This trend not only can effectively deal with the information asymmetry, lack of transparency inefficiency, and other constraints in the logistics industry, but also greatly improves the efficiency of logistics operations and service quality, accurately meeting the expectations of both the logistics industry and consumers, and gives the logistics experience better, faster and more convenient characteristics [12]. In addition, intelligent logistics is accelerating the digital transformation of the logistics industry, helping the logistics supply chain synergy and fine-tuned operation, and realizing the double benefits of economic and social growth [13]. Given the rapid progress of artificial intelligence technology and its in-depth penetration in various fields, the vision of "comprehensive monitoring, seamless links, intelligent supply" is gradually becoming a reality. To achieve integrated management and intelligent strategy development in logistics operations, IoT technology and data analysis means that the nodes in the logistics planning network can instantly capture, receive, and transmit real-time data to the core command system, realizing a seamless flow of data. This has undoubtedly strengthened the foundation of intelligent logistics and significantly enhanced its market competitiveness [14]. It is worth noting that road transportation dominates China's cargo transportation pattern, accounting for 73.8% in 2020, so it is urgent to build an IoT-driven supply chain to serve road transportation.

Therefore, to improve the quality of logistics services and transportation efficiency, in the layout of intelligent logistics, it is necessary to make use of advanced tools such as Internet of Things (IoT) technology, data analysis means, and optimization algorithms to solve a series of key technical difficulties [15]. The application of these technologies shows great potential in enhancing the real-time monitoring capability of logistics services, intelligent identification accuracy, and promoting the synergistic optimization of various links [16]. Therefore, for logistics planning and decision-making, in-depth exploration and application of these technologies have extremely important research significance and practical value.

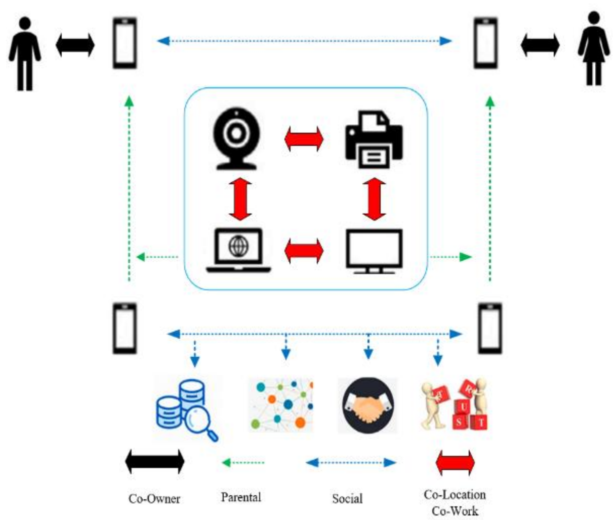

Fig. 1. Correlation of traditional IoT technologies.

III. Research Methodology

A. IoT Theory and Technology Foundations

At the heart of smart logistics is the efficient use of cutting-edge technology, with IoT dominating the logistics sector and being widely used. IoT, as a unique and recognizable network of "things", is centered on the identification and aggregation of personalized information about "things" through sensors/controllers connected to the Internet. IoT, as a unique and recognizable network of "things", is centered on the personalized identification and aggregation of "things" through sensors/controllers connected to the Internet, a process that integrates electronic devices, Internet connectivity, and multiple devices such as sensors [17]. These integrated devices can interact with infrastructure such as cloud servers and respond and operate quickly to dynamically changing environments and situations. The IoT architecture can be subdivided into four layers: sensing, transmission, processing, and application layers. The sensing layer, as the core layer of IoT devices, is responsible for capturing and quantifying the physical characteristics of various types of objects and is composed of diverse sensors, RFID tags, and other sensing networks [18]. This layer captures data from the sensors directly associated with the objects and subsequently converts this raw data into digital signals and passes them to the transmission layer [19]. The transmission layer, on the other hand, plays the role of a bridge, using a variety of digital communication methods such as Bluetooth, ZigBee, 5G, etc., to receive and transmit these data signals from the sensing layer. The traditional IoT technology is known as SIoT technology and its IoT technology correlation is shown in Fig. 1.

IoT system integration not only covers the functions at the basic data level but also provides data processing services and support for specific application requirements. Based on the organizational structure of the enterprise, it flexibly provides diversified business support services [20]. Its building blocks include hardware platforms such as cloud services, big data technologies, artificial intelligence, and advanced algorithms, as well as a series of middleware (e.g., sensor network gateways, sensor network security middleware, embedded M2M middleware, etc.), which together weave a powerful technology network [21]. For example, the mid-tier capabilities of intelligent computing are fully utilized, while cloud services are transformed into a hub for remote data storage and processing, greatly facilitating the process of accessing, storing, and processing data.

B. Key Technologies

In the field of identification technology for LoT, Radio Frequency Identification (RFID) technology occupies a dominant position. This technology relies on radio waves for data collection and identification and constitutes a unique identification system. The system consists of an RFID tag, a reading device equipped with a transmitter, and an interface to the target system. Specifically, the RFID tag has a built-in microchip and antenna assembly; when the tag enters a specific magnetic field, it receives a frequency signal from the reading device. The microchip on the tag serves as the core of data storage, carrying relevant information about the target object [22]. The antenna acts as a data transmission medium, enabling the microchip to pass information about the object to the reading device. The reading device then converts the RFID identification data into a format that can be easily processed by a computer, allowing the user to easily identify a specific object or individual.

Io Big Data enables flexible access to a diverse set of computing resources - servers, network architectures, storage, applications, and services - that are widely accessible and on demand. Such resources can be rapidly provisioned into place with minimal control and interaction between the user and the service provider, aiming to maximize data processing efficiency and capacity [23]. This model contributes significantly to the efficiency of data processing and computing. On the other hand, the big data technology system focuses on the all-round processing and insight of large-scale data sets, covering data collection, storage, refined processing, information extraction, and visualization. This process empowers users to dig deeper into the value of massive data, revealing the valuable information hidden behind the data. Through in-depth analysis and application exploration of big data technology, we can more thoroughly understand big data-related devices and their practical scenarios, which in turn will promote the performance leap and continue to optimize the user's interactive experience.

The technique of processing and analyzing real-time large-scale event streams can be called integrated event processing [24]. This process involves searching and organizing basic events to construct more complex and advanced events. Streaming analytics enables users to instantly monitor and analyze input data to dissect the causal chain of events and derive conclusions based on specific complex events. Low-level events are either manifested as a series of activities within a timeframe or as a bridge between events from different sources, and these elements are synthesized from a variety of data sources to shape complex event models that can be used to predict, manage, and regulate potential events, scenarios, and biases. At the core of CEP (Complex Event Processing) technology is the uninterrupted processing and profiling of massive streams of high-speed data (e.g., RFID data), which are combined with a variety of data streams, and are analyzed uninterruptedly. The core of CEP (Complex Event Processing) technology lies in the uninterrupted processing and analysis of massive high-speed data streams (such as RFID data), which are fused with decentralized data to enable immediate monitoring and response to critical business scenarios[25]. The efficient Complex Event Processor can react quickly to hidden patterns, correlations, and data abstractions between apparently unconnected events based on predefined rules. It can be viewed as a continuously operating intelligent application designed to maximize the overall value of challenging events, provide immediate decision support for diverse event scenarios, and enhance overall situational awareness and understanding.

C. IoT Heuristic Exact Algorithms

The solution of numerous complex optimization challenges often relies on metaheuristic algorithms that are viewed as efficient tools. These algorithms can be strategically differentiated into individual solutions for a single case and generalized solutions that are universally applicable. Among them, innovative practices in individual solving encompass unique strategies such as large-network search (LNS) and adaptive large-network search. Population-based metaheuristics, on the other hand, have the core goal of breeding novel solutions by integrating and adapting existing solution sets, or by promoting synergies between solutions in the learning process [26]. Among the many heuristic algorithms inspired by natural biological processes, genetic algorithms stand out for their generality. In each iteration, the algorithm selects two pairs of parents from the population based on the principle of fitness and generates new solutions (i.e., "offspring") by merging their characteristics through a mechanism that mimics the "crossover" mechanism of biological interbreeding. In addition, to ensure the diversity of solutions in the population, the genetic algorithm introduces a "mutation" procedure as an effective means of facilitating the algorithm's exploration of the unknown solution space.

Eventually, the selected optimal solution is set as the dominant strategy in the next iteration loop. The family of swarm intelligence algorithms includes two members, Ant Colony Optimization (ACO) and Particle Swarm Optimization. Within the framework of these algorithms, ACO algorithms are often complemented with local optimization strategies to solve problems based on a predefined graph and a probabilistic mechanism for deciding their routes. On the other hand, particle swarm optimization algorithms envision a population of many "particles", each of which migrates from one place to another during the exploration process [27]. In this algorithm, the record of the optimal positions of individual particles and the optimal solution for the whole swarm of particles act as guiding factors that influence and shape the trajectory and direction of each particle.

A meta-heuristic local search strategy examines the current state of a solution and promotes the transition from the current solution to a neighboring new solution that shows potential [28]. Taboo search (TS), a widely used algorithm, is rooted in the strategy of continuous exploration, which does not stop searching even when a local optimum has been reached. Even if the objective function is relaxed, the rheology guarantees the validity of the current solution. Another strategy is the Large Neighborhood Search (LNS), which is known for its ambitious search landscape and shows remarkable search patterns by partially dismantling existing solutions through the removal operator and then restoring them with the reorganization operator [29]. Adaptive SPS strategies are similar but are unique in their ability to dynamically adapt and select the most effective operators in each iteration according to the search process. To avoid the pitfalls of local optimality, guided local search (GLS) broadens the search boundary by imposing constraints on the objective function, thus expanding the exploration domain. In addition, meta-heuristic techniques such as Variable Neighborhood Search (VNS), Stochastic Greedy Adaptive Search Process (GRASP), Simulated Annealing (SA), and Iterative Local Search (ILS) are also focused on the optimization of local search, aiming to jump out of the limitations of local optima [30]. These algorithmic architectures not only serve the direct solution of the problem but also play an important role in constructing the initial solution of the heuristic algorithms, which lays a solid foundation for finding more optimal solutions.

Actuarial algorithm generation process for IoT:

$$\min \sum_{j \in J} c_j x_j \tag{1}$$

$$s.t. \sum_{j \in J} a_{ij} x_j \geq b \tag{2}$$

$$x_j \geq 0 \tag{3}$$

In this case, both Eq. (1) $c_j x_j$ unknown x and constant c are considered to be summed. Eq. (2) $\sum_{j \in J} a_{ij} x_j \geq b$ are constraints, and Eq. (3) both determine the positive and negative values of each variable of the function of x.

$$\xrightarrow[C_j]{} = \min c_j - \sum_{i \in I} \pi_i a_{ij} \tag{4}$$

$$E_i = e(w_{id}, r_{id}, t) \tag{5}$$

In Eq. (4), consider the variable in Eq. (1) as a constant 1 for $\min c_j$, and consider π as a constant variable; in Eq. (5) consider w, r, and t as natural variables.

To assess the positive expectations of the current solution, perform an accounting of the price subcategories and ensure that at least the negatively corresponding columns are included in the updated RMP solution set. An optimal solution is considered to have been reached only if the price analysis does not reveal any unfavorable test results. For RMP problems, the new variables introduced during each iteration are intended to optimize the current set of variables and their corresponding pairwise optimal solutions, thus ensuring the optimization of the overall solution.

D. Definitional Approach to IoT

The most common means to solve global design challenges and many combinatorial optimization problems is with the help of branching strategies and their associated algorithms. Branching algorithms traverse the entire search domain, identify potential solutions, and select the optimal solution. This process relies on the structure of the search tree for partitioning and definition. A solution tree covering all potential solution paths is constructed, where the root node summarizes the global search pattern and pre-lists possible initial solutions. Each subroutine corresponds to a node presentation in the search tree. The decentralization technique, on the other hand, partitions the solution space into smaller blocks that can be recursively refined, aiming at generating children of unexplored nodes and eliminating suboptimal search patterns that may be confirmed during the partitioning process [31]. After completing the scrutiny of the entire tree structure, the searched optimal solution is fed back to the solution endpoint.

IoT delimitation was originally designed to meet the challenges of various types of constraints or variables. It incorporates a combination of different branching strategies, related algorithms, and column-generation techniques. Similar to the linear relaxation branching method, the original problem is depicted by a Dwolfe distribution. This process first splits the primal problem into a master system with several sub-systems, followed by a consistent path to solving the currently limited master system problem and passing the corresponding binary variables to each sub-category. For each subcategory, a column generation technique is then employed to solve its linear relaxation constraint set. It is worth noting that although the column generation algorithm plays a key role in estimating the node lower bounds, the practical application of the branching strategy is carried out after the linear relaxation solutions are obtained. In addition, it is possible to divide a series of potential primal solution candidate sets into subsets and apply recursive constraints with branching to each subset. In the branch-and-bound framework, the relaxation problem at each node is solved directly while the branch-and-bound pricing process is optimized using a column generation algorithm. By solving local problems iteratively, a series of problem sets optimized in the sense of linear relaxation can be identified. If a linear relaxation problem reaches an optimal state, the optimal solution can be further verified to satisfy the condition of an integer solution. During branching iterations, each new branch introduces unique constraints, resulting in the derivation of new subcategories that are again solved with the help of the column generation algorithm. This process continues, introducing new columns (i.e., variables) into the linear relaxation model until a globally optimal solution to the original problem is found.

The IoT delimitation method is carried out utilizing the branch pricing algorithm, in addition to the main process, where column and integer solutions are examined at the nodes respectively, as shown in Fig. 2.

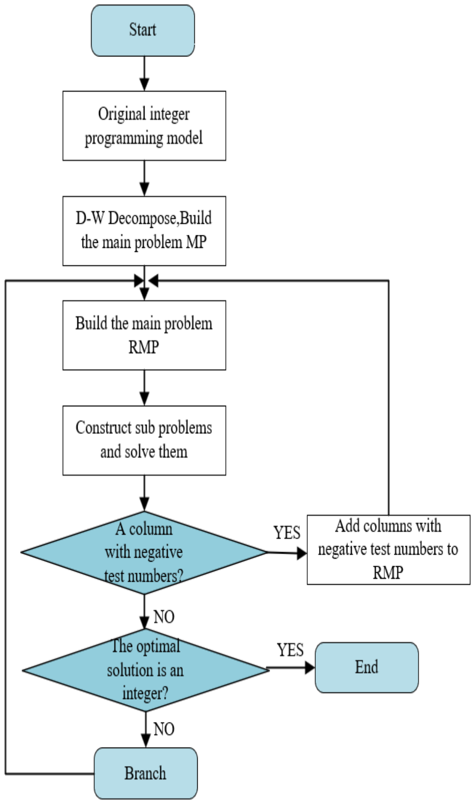

Fig. 2. Branch pricing algorithm flow.

The set of cut strategies constitutes a solution methodology for universal design challenges. The core idea is that multiple linear programming paradigms can be nested within the planning framework, which together portray multiple faces of the same set of integer solutions through a system of transformed linear inequalities. When dealing with a linear relaxation problem and obtaining a fractional, and then additional solution, one realizes that the current scheme is not rigorous enough linear inequality constraints need to be added, aiming at eliminating unrealistic floating-point or generalized solutions, and progressively approximating the globally optimal integer solution. This process is a way of pinpointing the poles of the optimal numerical solution that can be easily solved outside of the widened linear relaxation domain.

The dyadic principle of linear programming, on the other hand, breaks down the complex overall design problem into a series of asymptotically accurate local linear programming subproblems, with each round of solution pushing us closer to the ultimate solution. In the execution of the tangent algorithm, the first step is to solve the base problem with boundaries on all original variables, and then move to the relaxation problem [32]. The algorithm is terminated if a no-solution situation is encountered in the process, or if the best solution presents a generic characterization as non-integer. Instead, an additional linear boundary called a "cut" is introduced, which is designed to precisely cut out the non-integer solution space that has not yet been covered and integrate it into the current relaxation model to exclude the validity of the current solution, which is then resolved based on the updated model. This process is repeated until all solutions for all basic variables meet the integer requirements.

The delimitation of IoT should also consider the interaction flow between the front and back end, to consider the request to send Axios to start, through the control, service, data, and entity four levels to reach the end of data persistence, as shown in Fig. 3.

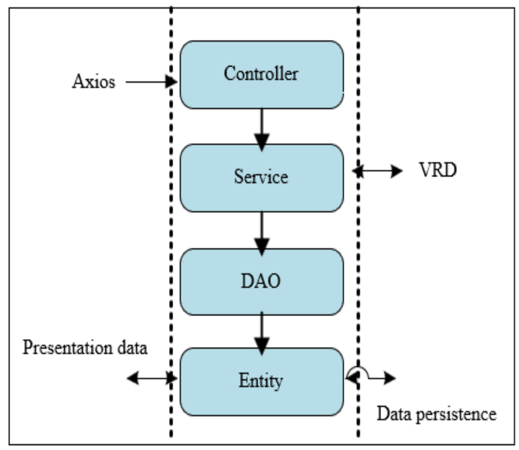

Fig. 3. IoT front and back-end interaction flow.

IV. Results and Discussion

A. IoT System Architecture

Using the system structure hierarchical construction method to build an IoT platform and commissioning system, the initial intention of building an industrial IoT platform and virtual commissioning system is to rely on a cloud platform to realize instant remote monitoring of the status of each device in the industrial production chain [33]. In addition, the cloud data-driven remote storage line virtual debugging mechanism effectively shortens the on-site troubleshooting cycle and significantly improves the maintenance efficiency and performance during the various stages of production line debugging.

The construction of the IoT platform and debugging system is divided into five layers from the "virtual device layer" to the "virtual simulation debugging layer", as shown in Table I.

The experiments for IoT were divided into 30 sessions, and the number of debugging system fluctuations for the IoT platform is shown as a folded line in Fig. 4 (right axis), and the IoT latency test points are shown as squares in Fig. 4 (left axis) as the summation of the values on the major latency nodes (3, 5, 6, 15, 20, 22, 23, 25, 27, 28, 29, and 30). The IoT platform debugging system fluctuation and delay test results are shown in Fig. 4.

TABLE I. CONSTRUCTION OF IOT PLATFORM AND COMMISSIONING SYSTEM

Virtual Device Layer		**Equipment communication control layer**	**Data Storage Layer**	**IoT cloud platform layer**	**Virtual simulation debugging layer**
ABB industrial robots	PC-SDK	Data acquisition	Data management	Data monitoring	Data Mapping
Youao Industrial Robot	TCP/IP		Data subscription	Command parsing	Motion driven
Siemens PLC	S7	Data parsing	OPC UA	OPC UA Client	collision detection
KEBA PLC	TCP/IP	Data display	Real-time	MOTT	Visualization
AVG	REST	Data control	HISTORICAL DATA	data display	
RFID	Serial port		MySQL	Command Control	Unity 3D

The communication management layer architecture adopts a separated front and back-end design mode, and its core system module relies on Java and Spring Boot framework to build and realize efficient data interaction and persistence with the database by integrating a hybrid programming paradigm and MyBatis technology. This layer focuses on data processing logic planning and communication protocol management at the virtual device level. The front-end display layer is crafted using the Vue.js framework, focusing on the smoothness of user interface interaction and the flexibility of data configuration. In contrast to traditional project architectures, the UI code is often tightly coupled with Java Server Pages (JSPs), which are located in the backend of the server. In this model, the UI browser needs to retrieve HTML, CSS, and JavaScript resources from the JSP for data visualization and page presentation. This process is accompanied by a large amount of interactive data transfer, resulting in a lengthy and inefficient analysis and processing process, which in turn hinders the long-term maintenance and iterative development of the project. On the contrary, after the implementation of the design principle of separating the UI from the back-end logic, the UI layer actively disengages from the role of direct control of the browser page and focuses on the serialization of data (e.g., JSON, XML, form data, etc.) and recovery work. Front-end pages are loaded independently, which significantly reduces the number of communications between the front and back ends, greatly reduces the complexity of data interaction, effectively reduces the business processing pressure on the back-end server, and thus realizes a significant improvement in the overall performance of the system[34]. Therefore, the specific embodiment of the robustness of the Internet of Things logistics for the first high, then low, and then high, its horizontal axis is the number of iterations, the vertical axis is the robustness, that is, the performance of the performance due to the increase in the number of communications to deteriorate, but also because of the iteration and the enhancement of the process of the number of Internet of Things iterations and the linkage of the robustness, specifically as shown in Fig. 5.

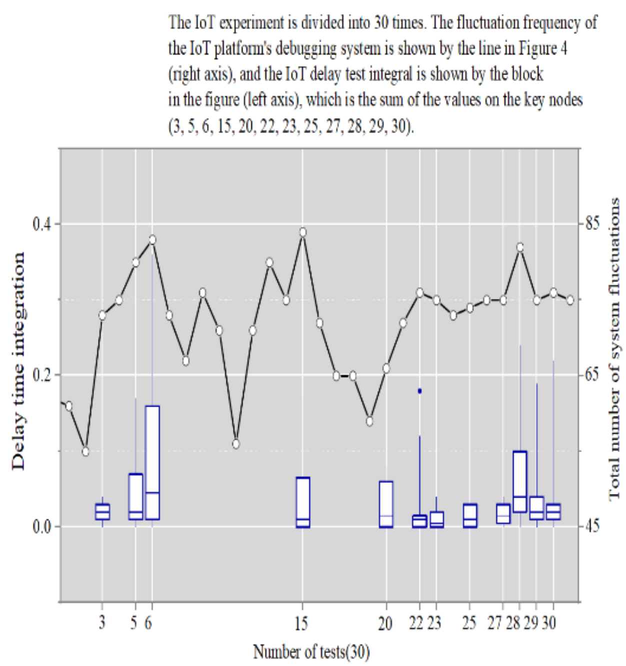

Fig. 4. IoT platform debugging results.

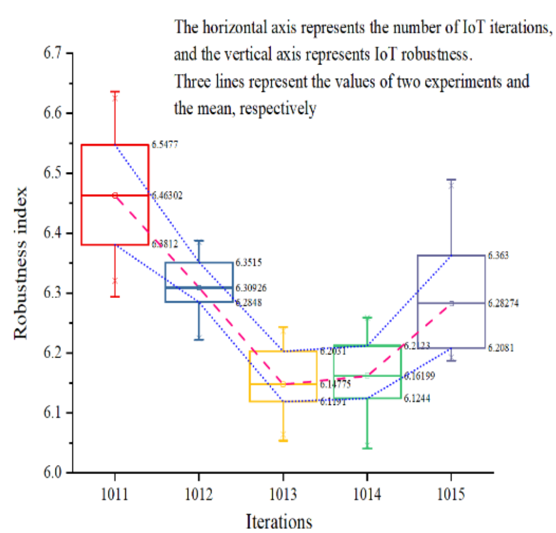

Fig. 5. IoT iteration count and robustness linkage.

In the heuristic algorithm mentioned in 3.3 above, the heuristic actuarial algorithm columns are generated in such a way that firstly the first row generates a column Ω 1, followed by the algorithmic disaggregation using Do and while as shown in Table II.

TABLE II. HEURISTIC ACTUARIAL ALGORITHM COLUMN GENERATION

column generation
Generate an initial set of columns Ω 1
Do
Calculate the answer MP
Γ : New columns obtained from sub-problems
Ω $_1 \cup \Gamma$ While $\Gamma \neq \theta$

The core concept of microservices architecture is to refine the huge software system into a series of independent, different functions of the service unit, the collaboration between these units does not interfere with the integrity of the business logic. Spring Cloud is the Spring ecosystem for the development of microservices framework, and support for the integration of Spring Boot Starter to enhance the scalability of the system. It provides a complete set of components, covering service registration and discovery, service consumption, maintenance, disaster recovery, API gateway, distributed tracking and monitoring, distributed configuration management, and other key aspects.

The development of communication layer systems and devices is rooted in the Java programming language, which is widely used in web server construction and big data processing because of its reliability, security, cross-platform compatibility, and superior performance. In industry, the construction of hardware operating systems and external communication libraries often relies on languages such as C++ and Python. Similarly, industrial simulation devices utilize virtual device technology on diverse simulation software platforms, relying on their core systems to provide communication protocols and library support. To achieve robust communication and efficient data processing, the debugging system has to cross the Java boundary and adopt hybrid programming and integrated programming strategies, which invariably exacerbates the complexity of the communication challenges among different programming languages. To address this challenge, the Hybrid Programming course will focus on exploring new ways to skillfully blend the strengths of each language through advanced integration techniques. Specifically, the extension session aims to integrate functional modules from languages other than Java, and realize seamless collaboration between modules through careful design and development; while the integration process involves configuring the parsers of other languages to execute in the Java Runtime Environment (JRE), thus expanding the capabilities of the system and achieving a leap in functionality.

In the construction of the communication layer system of IoT, it is found that the bands of centralized interactive data transmission are mainly concentrated in the following four bands "57~61", "73~76", "81~83", and "08~12". ", "08~12", therefore, the evaluation of the four bands of the communication layer system, column thickness indicates the level of expectations, the ability of interactive data transmission for the curve, which is concentrated in the range of 2.5T~13.5T, as shown in Fig. 6.

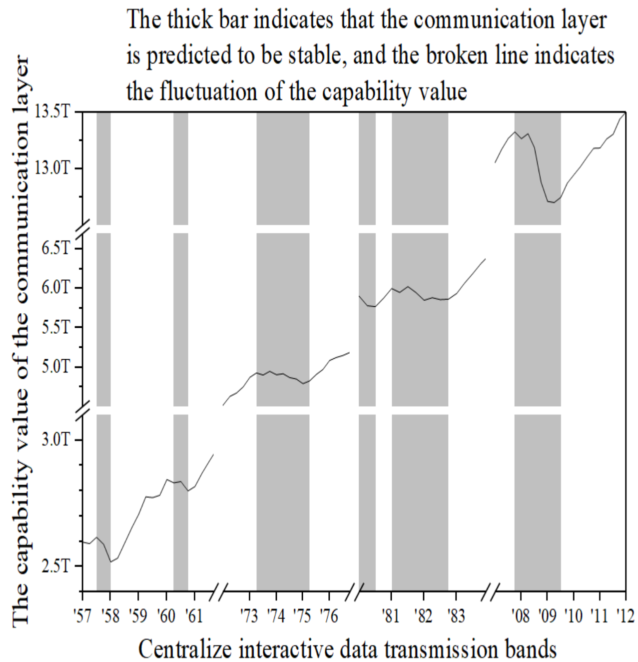

Fig. 6. Communication layer assessment for centralized interactive data transmission bands.

In the IoT communication architecture, the system integrates the Java Native Access (JNA) library, which is seen as an optimization and enhancement of the Java Native Interface (JNI) mechanism. When it comes to Java's Dynamic Link Library (DLL) calls to C++, JNA provides a more straightforward approach: it is assumed that you have already done the corresponding adaptation work, which constitutes one of the application scenarios. It is worth noting that the calling mechanism of the generic DLL follows the data structure specification defined by Sun, rather than directly adopting the data structure of the C language, to achieve access to functions within the established DLL. Ultimately, the process consists of downloading the shared Java library files and embedding them in the linked library system as function proxy service components.

B. Platform Construction and Testing for IoT

The database used to retrieve the data for this study is MySQL, which as a relational database management system has significant advantages in terms of its openness (open source), superior computational performance, and broad support for multiple platforms and applications [35]. In contrast, MyBatis is known for its lightweight, as an open-source database interaction manager, it is embedded in the essence of traditional JDBC (Java Database Connectivity) technology. Through the integration of global configuration data and mapping files, MyBatis can flexibly map the database table structure to the system-level classes and property blocks, this process cleverly circumvents the database driver registration, connection setup, and centralized SQL management of cumbersome configuration. Integrating MyBatis into the Spring Boot framework not only simplifies dependency management but also makes it more straightforward and efficient to write query statements and manage database tables at the system data access object (DAO) level. This integration strategy promotes development efficiency and enhances application maintainability and scalability.

In the selection of MySQL to be centralized interactive data transmission band database validation, the band stability structure determination found that the purple for MyBatis, green for MySQL, and orange for the traditional other vb databases, found that the green MySQL peak band is similar to the interactive data that is, in the "57 ~ 61 ", "73~76", "81~83" all have better stability, most in line with the idea of this study, therefore, MySQL was selected as the tuning database, Fig. 7 horizontal axis is the band, the vertical axis is the stability. Specifically shown in Fig. 7.

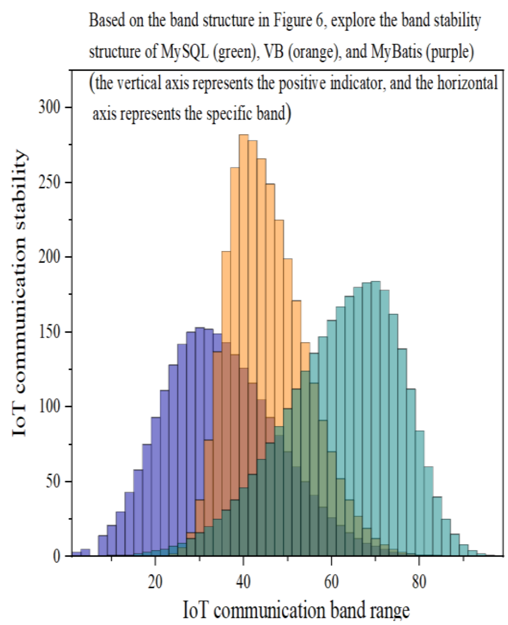

Fig. 7. Database selection test.

In the construction of the database, the IoT model is used to construct the data fields, the specific types of fields required such as demand, time, order details, storage information, etc., as shown in Table III.

TABLE III. FIELD TYPES REQUIRED FOR ORDERS

Field Name	Field type	Can it be left blank	explain
Bill_id	Int	NO	Order number, self increment primary key
Cargo_name	Int	NO	Name of goods
Demand_num	Int	NO	Quantity demanded
Demand_time	Int	NO	Requirement time
Cargo_id	varchar	NO	Customer ID
Creat_time	data	NO	Table record creation time
Description	varchar	NO	Order Description

The virtual commissioning system not only builds a bridge for communication and connecting information but also successfully meets the challenges of integrated management and unified storage of heterogeneous data from industrial equipment. In the face of complex industrial environments containing massive parallel, heterogeneous, and multi-source data, OPC UA technology is regarded as a powerful assistant for industrial IoT data management, helping the debugging work of virtual modeling. In this framework, Kepware, the preferred OPC UA server, is widely used as an industrial communication server software for controlling industrial automation equipment and associated industrial control programs. The process of initializing the server involves configuring communication addresses and ports, deploying channels on the KEPServer EX platform for the virtual system device hierarchy, adding analog devices, designing tag groups and tags based on the database table structure, and creating the corresponding nodes in the address space of the OPC UA server. Subsequently, the server control configuration table is optimized, and the OPC UA client service is constructed based on Spring Cloud microservice architecture, focusing on communication and hardware management functions.

In addition, the client can use the push mechanism to track the data changes from the server node, once the data is updated, the server will quickly analyze the host data and instantly send the host ID and attribute data back to the client, which effectively avoids the resource consumption of the client due to frequent polling of the server. Therefore, the three major systems in cloud services, i.e., IoT, Cloud Computing, and Edge Computing are evaluated for Data Return Resource Consumption where the results of the W1, W2, W4, W6, and W8 phases are shown in the following figure, and it is found that the average Data Return Resource Consumption rate of IoT is lower than that of Cloud Computing and Edge Computing, which is shown in Fig. 8.

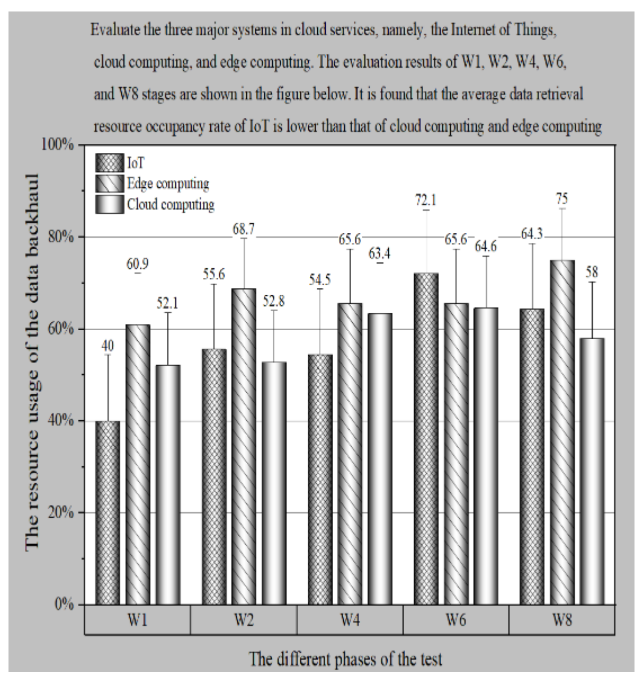

Fig. 8. Evaluation of data backhaul resource usage for IoT, cloud computing, and edge computing.

In the constructed IoT database, the logistic capacity data is retrieved from SQL, and the information table used, which restricts the data fields, only uses two types of data, int, and Varchar, as shown in Table IV.

TABLE IV. SQL CAPACITY INFORMATION RETRIEVAL TABLE

Field Name	Field type	Can it be left blank	explain
ID	Int	NO	Self-increment primary key
Warehouse_ID	Int	NO	Warehouse number
Vehicle status	Int	NO	Vehicle status
Vehicle_id	Int	NO	Vehicle number
Vehicle position	Varchar	NO	Vehicle position
Description	Varchar	YES	Order details

To accurately replicate real-life IoT scenarios, the dimensions and construction of the simulation model need to follow the exact scale of the actual device. The process starts with the precise dimensioning and construction of the model according to the device manufacturer's detailed specifications, followed by an in-depth analysis of the entire simulation framework. The component modules are carefully constructed and finally brought together into a unified model system through a series of integration steps using uplink technology. To facilitate the seamless integration of the model across different software, the model templates are exported to STL format files, which greatly facilitates their importation into 3ds Max, thus allowing the user to adjust the mapping and optimize the surface details. To further enhance the realism of the simulation, the powerful rendering engine of 3ds Max is fully utilized, and its on-screen rendering function effectively enhances the realistic texture of the model. In terms of material and color selection, users can carefully choose from a rich library of materials and color samples to ensure that the surfaces of the model's components accurately reflect the texture and hue of the actual materials. In addition, to bring the design closer to real-world application scenarios, users can also subtly incorporate labeling elements, such as unique texture pattern files and brand logos, which undoubtedly add a sense of realism and professionalism to the overall design.

The logistics of IoT are finally warehoused, and the goods in the warehouse are still accessed using SQL's database, and the specific access and querying are done using three numeric types: int, varchar, and date, as shown in Table V.

TABLE V. SQL INBOUND ORDER FIELD QUERIES

Field Name	Field type	Can it be left blank	explain
ID	Int	NO	Self increment primary key
Creator_id	Int	NO	Creator ID
Bill_type	Int	NO	Order type
Start_time	Date	NO	Process start time
Real_time	Date	NO	Actual process time
State	Varchar	NO	State
Description	Varchar	YES	Order details

C. AHP and Entropy Weight Method for Logistics Supply Chain Evaluation

AHP and entropy weight method of logistics supply chain evaluation system is divided into four steps, firstly, to determine the indicator system of the evaluation object, secondly, to determine the AHP weights, again to determine the weights of entropy weight method, and finally to utilize the comprehensive weights for comprehensive analysis. The calculation of the evaluation object index system determination and objective assignment method-entropy weight method is shown in Table VI.

TABLE VI. EVALUATION OF INTERNET OF THINGS INDICATOR SYSTEM AND ENTROPY WEIGHT METHOD

Name	Weight	Difference Coe	Information entropy
Mobile electronic equipment	0.1198	0.043	0.953
Sensor market size	0.1231	0.001	0.864
Internet Popular rate	0.2981	0.089	0.943
Fixed broadband terminal	0.0471	0.012	0.896
IPv6 size	0.1871	0.074	0.798
R and D	0.2001	0.051	0.453
Technological personnel	0.1143	0.011	0.976
IoT personnel	0.0178	0.053	0.768
Number of patents	0.1841	0.095	0.989
GDP	0.0231	0.043	0.742

In the evaluation, the normal distribution function of the efficiency loss of the IoT is to be considered, and there are three peaks of the specific normal distribution, which are shown centrally in this paper, it turns out that the loss point is between [-1, 1] and [500, 600], and therefore, does not affect the results of this paper, and the specific normal function, as shown in Fig. 9.

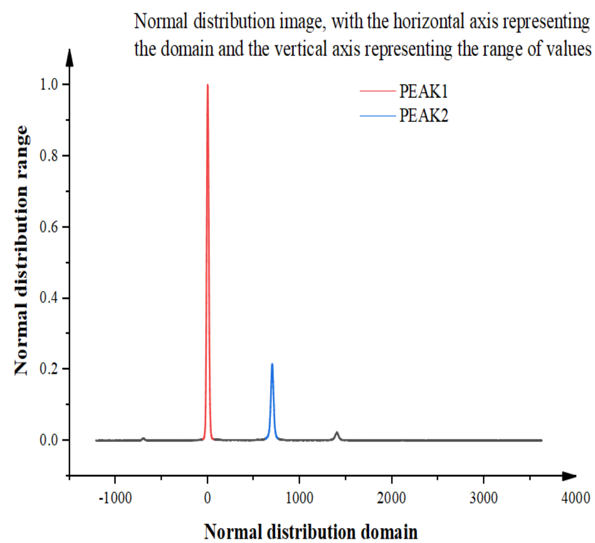

Fig. 9. Normal distribution of IoT efficiency loss.

After using the objective assignment method entropy weight method to determine the weights, but also to use the AHP method of IoT evaluation of subjective weight determination, the difference between it and entropy weight method is that one belongs to the objective assignment method, one belongs to the subjective assignment method, the combination of the two to eliminate the defects of subjective and objective assignment of IoT, using the advantages of both, the following B1 ~ B10 represent 1 ~ 10 in Table VII respectively. Specific methods are as follows:

TABLE VII. ASSIGNMENT OF AHP FOR IOT EVALUATION

B|A	A1 0.322	A2 0.3331	A3 0.4331	Weight
B1	0.0423			0.0294
B2	0.3513			0.1321
B3	0.4091			0.0431
B4	0.0121			0.0213
B5	0.0311			0.0741
B6		0.1812		0,2913
B7		0.4121		0.0123
B8		0,3941		0.0478
B9			0.6412	0,1239
B10			0.3586	0.2312

This evaluation study is divided into three parts: comprehensive weights (i.e., a subjective and objective combination of weights), consistency test results, and IoT development index, The consistency test is a test of the AHP method, placed here the more intuitive expression of the accuracy of the empirical results, the IoT development index also shows an upward trend, as shown in Table VIII.

TABLE VIII. COMPOSITE WEIGHTS, CONSISTENCY TEST, AND IOT INDUSTRY DEVELOPMENT INDEX FOR IOT

Secondary indicators	Weight	Consistency	Level
B1	0.071	0.0784	0.6131
B2	0.124	0.0423	0.741
B3	0.232	0.0741	0.764
B4	0.041	0.0913	0.898
B5	0.021	0.0871	0.912
B6	0.251	0.0214	1.009
B7	0.031	0.0871	1.031
B8	0.071	0.0912	1.423
B9	0.012	0.0172	1.632
B10	0.129	0.0842	1.762

V. CONCLUSION AND FUTURE WORKS

This study deeply explores the core role and significant effect of IoT technology in the coordinated response mechanism of logistics supply chain management, which provides strong theoretical support and practical guidance for the intelligent transformation of the logistics industry. Through systematic analysis and practical verification, we have clarified that IoT, as a representative of the new generation of information technology, lays a solid foundation for the transparency, intelligence, and efficiency of the logistics supply chain with its powerful data sensing, transmission, and processing capabilities. The coordination and response mechanism of the logistics supply chain has realized a qualitative leap. IoT technology not only realizes real-time and accurate information sharing among nodes of the supply chain and eliminates the barrier of information asymmetry, but also improves the sensitivity and response speed of the supply chain to market changes through intelligent analysis and prediction. This data-based decision-making support makes the supply chain more accurate and efficient in resource allocation, inventory management, logistics scheduling, etc., effectively reducing operating costs and risks. More importantly, the application of IoT technology promotes the in-depth integration and synergy of all links in the supply chain, forming a closer and more flexible supply chain network. In the face of unexpected events or market demand fluctuations, the IoT-driven coordination and response mechanism can quickly adjust strategies and optimize resource allocation to ensure the stability and resilience of the supply chain. This ability is of great significance for enhancing the overall competitiveness of the logistics industry and coping with the complex and volatile market environment.

The study has several limitations that warrant further exploration. Firstly, the proposed IoT-driven logistics supply chain coordination mechanism may lack generalizability across industries with diverse operational needs. Secondly, challenges such as network latency, data inconsistency, and device interoperability affecting real-time data accuracy remain inadequately addressed. Thirdly, the scalability of the framework for larger, more complex supply chains is not thoroughly evaluated. Lastly, the economic feasibility of implementing the proposed technologies, especially for small- and medium-sized enterprises, is insufficiently analyzed. Future research could focus on adapting the framework to different industries, integrating advanced technologies like blockchain, AI, and edge computing to enhance system reliability, exploring sustainable IoT practices to reduce environmental impact, and conducting detailed cost-benefit analyses to assess the economic viability of such systems.

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REFERENCES

[1] R. Huo et al., "A comprehensive survey on blockchain in industrial internet of things: Motivations, research progresses, and future challenges," IEEE Communications Surveys & Tutorials, vol. 24, no. 1, pp. 88–122, 2022, doi: 10.1109/COMST.2022.3141490.

[2] S. Yadav, S. Luthra, and D. Garg, "Internet of things (IoT) based coordination system in Agri-food supply chain: development of an efficient framework using DEMATEL-ISM," Operations management research, vol. 15, no. 1, pp. 1–27, 2022, doi: 10.1007/s12063-020-00164-x.

[3] K. Sallam, M. Mohamed, and A. W. Mohamed, "Internet of Things (IoT) in supply chain management: challenges, opportunities, and best practices," Sustainable Machine Intelligence Journal, vol. 2, pp. 3–1, 2023, doi: 10.61185/SMIJ.2023.22103.

[4] M. Ben-Daya, E. Hassini, and Z. Bahroun, "A conceptual framework for understanding the impact of the Internet of things on supply chain management," Operations and Supply Chain Management: An International Journal, vol. 15, no. 2, pp. 251–268, 2022, doi: 10.31387/oscm0490345.

[5] K. L. Keung, C. K. Lee, and P. Ji, "Industrial Internet of things-driven storage location assignment and order picking in a resource synchronization and sharing-based robotic mobile fulfillment system," Advanced Engineering Informatics, vol. 52, p. 101540, 2022, doi: 10.1016/j.aei.2022.101540.

[6] X. Chen, C. He, Y. Chen, and Z. Xie, "Internet of Things (IoT)—blockchain-enabled pharmaceutical supply chain resilience in the post-pandemic era," Frontiers of Engineering Management, vol. 10, no. 1, pp. 82–95, 2023, doi: 10.1007/s42524-022-0233-1.

[7] R. Mishra, R. K. Singh, T. U. Daim, S. F. Wamba, and M. Song, "Integrated usage of artificial intelligence, blockchain and the internet of things in logistics for decarbonization through paradox lens," Transportation Research Part E: Logistics and Transportation Review, vol. 189, p. 103684, 2024, doi: 10.1016/j.tre.2024.103684.

[8] L. Liu, W. Song, and Y. Liu, "Leveraging digital capabilities toward a circular economy: Reinforcing sustainable supply chain management with Industry 4.0 technologies," Computers & Industrial Engineering, vol. 178, p. 109113, 2023, doi: 10.1016/j.cie.2023.109113.

[9] P. Kumar and S. Aziz, "Managing Supply Chain Risk with the Integration of Internet of Things in the Manufacturing Sector of Pakistan," Dutch Journal of Finance and Management, vol. 5, no. 2, p. 22405, 2023, doi: 10.55267/djfm/13676.

[10] Y. Mashayekhy, A. Babaei, X.-M. Yuan, and A. Xue, "Impact of Internet of Things (IoT) on inventory management: A literature survey," Logistics, vol. 6, no. 2, p. 33, 2022, doi: 10.3390/logistics6020033.

[11] M. Song, X. Ma, X. Zhao, and L. Zhang, "How to enhance supply chain resilience: a logistics approach," The International Journal of Logistics Management, vol. 33, no. 4, pp. 1408–1436, 2022, doi: 10.1108/IJLM-04-2021-0211.

[12] M. Rajabzadeh and H. Fatorachian, "Modelling factors influencing IoT adoption: With a focus on agricultural logistics operations," Smart Cities, vol. 6, no. 6, pp. 3266–3296, 2023, doi: 10.3390/smartcities6060145.

[13] M. M. Billah, S. S. Alam, M. Masukujjaman, M. H. Ali, Z. K. M. Makhbul, and M. F. M. Salleh, "Effects of Internet of Things, supply chain collaboration and ethical sensitivity on sustainable performance: moderating effect of supply chain dynamism," Journal of Enterprise Information Management, vol. 36, no. 5, pp. 1270–1295, 2023, doi: 10.1108/JEIM-06-2022-0213.

[14] W. Liu, S. Wei, S. Wang, M. K. Lim, and Y. Wang, "Problem identification model of agricultural precision management based on smart supply chains: An exploratory study from China," Journal of Cleaner Production, vol. 352, p. 131622, 2022, doi: 10.1016/j.jclepro.2022.131622.

[15] W. C. Tan and M. S. Sidhu, "Review of RFID and IoT integration in supply chain management," Operations Research Perspectives, vol. 9, p. 100229, 2022, doi: 10.1016/j.orp.2022.100229.

[16] D. Kumar, R. K. Singh, R. Mishra, and T. U. Daim, "Roadmap for integrating blockchain with Internet of Things (IoT) for sustainable and secured operations in logistics and supply chains: Decision-making framework with case illustration," Technological Forecasting and Social Change, vol. 196, p. 122837, 2023, doi: 10.1016/j.techfore.2023.122837.

[17] R. Kumar, S. Rani, and M. A. Awadh, "Exploring the application sphere of the Internet of things in industry 4.0: a review, bibliometric and content analysis," Sensors, vol. 22, no. 11, p. 4276, 2022, doi: 10.3390/s22114276.

[18] Y. Liu, C. Yang, K. Huang, W. Gui, and S. Hu, "A systematic procurement supply chain optimization technique based on industrial Internet of things and application," IEEE Internet of Things Journal, vol. 10, no. 8, pp. 7272–7292, 2022, doi: 10.1109/JIOT.2022.3228736.

[19] F. Ye, K. Liu, L. Li, K.-H. Lai, Y. Zhan, and A. Kumar, "Digital supply chain management in the COVID-19 crisis: An asset orchestration perspective," International Journal of Production Economics, vol. 245, p. 108396, 2022, doi: 10.1016/j.ijpe.2021.108396.

[20] P. Kumar and R. K. Singh, "Application of Industry 4.0 technologies for effective coordination in humanitarian supply chains: a strategic approach," Annals of Operations Research, vol. 319, no. 1, pp. 379–411, 2022, doi: 10.1007/s10479-020-03898-w.

[21] I. Vlachos, R. M. Pascazzi, M. Ntotis, K. Spanaki, S. Despoudi, and P. Repoussis, "Smart and flexible manufacturing systems using autonomous guided vehicles (AGVs) and the Internet of things (IoT)," International Journal of Production Research, vol. 62, no. 15, pp. 5574–5595, 2024, doi: 10.1080/00207543.2022.2136282.

[22] D. Kumar, R. K. Singh, R. Mishra, and S. F. Wamba, "Applications of the Internet of things for optimizing warehousing and logistics operations: A systematic literature review and future research directions," Computers & Industrial Engineering, vol. 171, p. 108455, 2022, doi: 10.1016/j.cie.2022.108455.

[23] G. Zhang, Y. Yang, and G. Yang, "Smart supply chain management in Industry 4.0: the review, research agenda and strategies in North America," Annals of Operations Research, vol. 322, no. 2, pp. 1075–1117, 2023, doi: 10.1007/s10479-022-04689-1.

[24] W. Liu, S. Long, and S. Wei, "Correlation mechanism between smart technology and smart supply chain innovation performance: A multi-case study from China's companies with Physical Internet," International Journal of Production Economics, vol. 245, p. 108394, 2022, doi: 10.1016/j.ijpe.2021.108394.

[25] X. Mu and M. F. Antwi-Afari, "The applications of Internet of Things (IoT) in industrial management: a science mapping review," International Journal of Production Research, vol. 62, no. 5, pp. 1928–1952, 2024, doi: 10.1080/00207543.2023.2290229.

[26] P. Kumar, D. Sharma, and P. Pandey, "Coordination mechanisms for digital and sustainable textile supply chain," International Journal of Productivity and Performance Management, vol. 72, no. 6, pp. 1533–1559, 2023, doi: 10.1108/IJPPM-11-2020-0615.

[27] S. Al-Ayed and A. Al-Tit, "The effect of supply chain risk management on supply chain resilience: The intervening part of Internet-of-Things," Uncertain Supply Chain Management, vol. 11, no. 1, pp. 179–186, 2023, doi: 10.5267/j.uscm.2022.10.009.

[28] Z. Dong, W. Liang, Y. Liang, W. Gao, and Y. Lu, "Blockchained supply chain management based on IoT tracking and machine learning," EURASIP Journal on Wireless Communications and Networking, vol. 2022, no. 1, p. 127, 2022, doi: 10.1186/s13638-022-02209-0.

[29] L. Li, Y. Gong, Z. Wang, and S. Liu, "Big data and big disaster: a mechanism of supply chain risk management in the global logistics industry," International Journal of Operations & Production Management, vol. 43, no. 2, pp. 274–307, 2023, doi: 10.1108/IJOPM-04-2022-0266.

[30] A. Egwuonwu, C. Mordi, A. Egwuonwu, and O. Uadiale, “The influence of blockchains and internet of things on the global value chain,” Strategic Change, vol. 31, no. 1, pp. 45–55, 2022, doi: 10.1002/jsc.2484.

[31] S. Yadav, T.-M. Choi, S. Luthra, A. Kumar, and D. Garg, “Using Internet of Things (IoT) in agri-food supply chains: A research framework for social good with network clustering analysis,” IEEE Transactions on Engineering Management, vol. 70, no. 3, pp. 1215–1224, 2022, doi: 10.1109/TEM.2022.3177188.

[32] A. Rejeb et al., “Unleashing the power of the Internet of things and blockchain: A comprehensive analysis and future directions,” Internet of Things and Cyber-Physical Systems, vol. 4, pp. 1–18, 2024, doi: 10.1016/j.iotcps.2023.06.003.

[33] S. Khan, R. Singh, S. Khan, and A. H. Ngah, “Unearthing the barriers of Internet of Things adoption in the food supply chain: A developing country perspective,” Green Technologies and Sustainability, vol. 1, no. 2, p. 100023, 2023, doi: 10.1016/j.grets.2023.100023.

[34] R. M. L. Rebelo, S. C. F. Pereira, and M. M. Queiroz, “The interplay between the Internet of things and supply chain management: Challenges and opportunities based on a systematic literature review,” Benchmarking: An International Journal, vol. 29, no. 2, pp. 683–711, 2022, doi: 10.1108/BIJ-02-2021-0085.

[35] H. Tran-Dang, N. Krommenacker, P. Charpentier, and D.-S. Kim, “The Internet of Things for Logistics: Perspectives, application review, and challenges,” IETE Technical Review, vol. 39, no. 1, pp. 93–121, 2022, doi: 10.1080/02564602.2020.1827308.