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Management Information System Based on IoT and Big Data Technology for Optimization of Supply Chain

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Abstract—This paper explores the integration of Internet of Things (IoT) and Big Data Analytics for optimizing supply chain management. With increasing complexity in global supply chains, traditional information systems fall short in providing real-time visibility, accurate forecasting, and agile decision-making. IoT technology facilitates real-time data collection through sensors embedded in goods, vehicles, and production systems, while Big Data analytics processes these high-volume, real-time data streams to generate actionable insights. By integrating these technologies into a Management Information System (MIS), this paper proposes a framework that enhances supply chain visibility, forecasting accuracy, and responsiveness. The study examines how IoT-enabled sensors and big data analytics improve logistics, inventory management, and risk mitigation. Key challenges, including data security, interoperability, and infrastructure costs, are also addressed. The proposed MIS architecture offers a foundation for building smart, adaptive, and resilient supply chains, transforming decision-making from reactive to proactive. The findings suggest significant improvements in operational efficiency and supply chain agility. This paper concludes with implications for practitioners and calls for further empirical research to validate the proposed system in real-world settings.

Keywords : *IoT, Big Data, Supply Chain, Optimization, MIS.*

I. INTRODUCTION

In the digital age, supply chain management (SCM) has become increasingly complex due to globalization, market volatility, and customer demand for faster deliveries. Traditional information systems, which primarily focus on logistics, inventory tracking, and order management, are often limited in providing real-time insights, predictive analytics, and decision support for optimizing supply chain operations. This gap can result in inefficiencies, delays, and increased costs. The integration of emerging technologies such as the Internet of Things (IoT) and Big Data Analytics (BDA) has the potential to address these challenges and significantly enhance supply chain performance [1][2].

IoT, with its ability to connect and collect data from physical assets such as sensors, RFID tags, and GPS devices, offers real-time visibility across supply chain nodes. This enables better monitoring of goods in transit, inventory levels, and environmental conditions, such as temperature and humidity, ensuring that products are maintained under optimal conditions during storage and transportation [3]. As IoT technology has matured, its integration with Big Data analytics has unlocked a new level of supply chain optimization. Big Data, which encompasses vast amounts of structured and unstructured data, can be analyzed to identify trends, predict demand, optimize routes, and enhance decision-making processes [4].

The convergence of IoT and Big Data allows businesses to shift from reactive to proactive supply chain management, improving decision-making capabilities and operational efficiency. For instance, IoT data streams combined with predictive analytics can forecast potential supply chain disruptions, enabling companies to take preemptive actions. This integration has proven effective in various industries, including manufacturing, logistics, and retail, where it has been shown to improve delivery times, reduce operational costs, and enhance customer satisfaction [5].

However, while these technologies promise substantial improvements, their adoption presents several challenges. Issues related to interoperability between IoT devices, data security, and the integration of Big Data with legacy systems need to be addressed for successful deployment. Additionally, the high cost of infrastructure and the need for specialized skills in data analytics and technology management pose barriers to small and medium-sized enterprises (SMEs) looking to implement these technologies [2][3].

This paper explores the potential of an integrated IoT and Big Data-based Management Information System (MIS) for supply chain optimization. We propose a framework for designing and implementing such a system, highlighting the key components of IoT, Big Data analytics, and decision support mechanisms. The paper further discusses the benefits of this integration, such as enhanced visibility, improved forecasting, and faster response times. Through this research, we aim to provide a roadmap for businesses seeking to optimize their supply chain processes and leverage IoT and Big Data for competitive advantage.

II. BACKGROUND STUDY

The evolution of supply-chain management (SCM) and the transformative role of key digital technologies provide the foundation for this study. In this section we examine theoretical underpinnings, technology trends, and prior empirical findings related to the integration of the Internet of Things (IoT) and Big Data Analytics (BDA) in SCM, supporting the proposed MIS architecture for supply-chain optimisation.

2.1 Supply Chain Challenges and the Digital Imperative

In recent years, global supply chains have become increasingly complex, driven by globalization, unpredictable demand, shorter product life-cycles, and higher customer expectations. Traditional SCM systems often rely on batch processes, manual tracking and fragmented data flows, leading to limited visibility, poor forecast accuracy and sub-optimal responsiveness. As noted by Aryal et al. (2020), the research on disruptive technologies in the supply chain context has risen sharply due to these pressures [5] To build supply chains that are agile, resilient and efficient, firms are looking toward digital solutions such as IoT and BDA.

2.2 IoT in Supply Chain Management

The Internet of Things (IoT) refers to the network of interconnected physical objects (sensors, actuators, RFID tags, embedded devices) that capture and exchange data about their status and environment. In SCM, IoT enables real-time tracking of goods, assets and environmental conditions, enhancing visibility and traceability. Sharma et al. (2023) point out that IoT can improve transparency and trust among supply-chain actors across industries. For example, a study in the Indonesian logistics context found that IoT-enabled real-time tracking reduced the risk of lost goods by up to 30 % and decreased vehicle downtime by up to 20 % due to predictive maintenance capabilities. Despite these benefits, adoption faces barriers such as interoperability, infrastructure costs and data security issues[6].

2.3 Big Data Analytics in Supply Chains

Big Data Analytics (BDA) refers to techniques and tools to process and analyse large-volume, high-velocity, and high-variety data to extract insight and support decision-making. In supply chains, BDA supports demand forecasting, route optimisation, inventory management and risk detection. For example, Nozari et al. (2021) found in FMCG industries that BDA and IoT adoption significantly impact supply chain agility and decision-making quality. Moreover, Usanto (2024) reported that BDA improved demand-forecast accuracy by 15 % and route optimisation reduced delivery time by 10 % in the Indonesian supply chain[7].

2.4 Convergence of IoT and Big Data: Smart Supply Chains

The convergence of IoT and BDA gives rise to “smart supply chains” where continuous sensor data streams feed analytics engines, enabling proactive and predictive supply chain operations. Zhang et al. (2024) empirically demonstrate that IoT adoption, mediated by big-data-driven supply chain (BDSC) practices, enhances firm performance in circular economy supply chains. Zhou (2023) also highlights the potential of IoT + Big Data in international logistics for enhancing efficiency, traceability and decision-making. Such systems enable real-time visibility, dynamic route and inventory optimisation, predictive maintenance, and risk mitigation. However, the implementation of such integrated technologies remains challenging in practice. Key issues include device heterogeneity, data governance, legacy-system integration, and skill gaps[8].

2.5 Theoretical Underpinnings

The resource-based view (RBV) often helps explain how IoT and BDA capabilities become strategic assets. In the study by Zhang et al. (2024), IoT is conceptualised as a strategic resource that, together with BDSC practices, delivers enhanced performance within a circular-economy supply chain. Further, frameworks such as the Technology-Organisation-Environment (TOE) model have been used to categorise the factors affecting BDA adoption in supply chains [9].

2.6 Summary of Literature Gaps

While the literature provides strong evidence of the benefits of IoT and BDA separately, and increasingly in concert, several gaps remain:

1. Many studies focus on descriptive or case-based findings rather than full MIS architecture design and empirical validation.
2. There is limited research discussing how to integrate these technologies into a dedicated Management Information System (MIS) tailored for supply-chain optimisation.
3. The technical and organisational challenges of implementing IoT + BDA in emerging-economy contexts are under-explored. Addressing these gaps motivates the current study, which proposes a structured MIS architecture combining IoT and Big Data for supply-chain optimisation, and discusses methodological steps for design and simulation.

III. METHODOLOGY

This section outlines the methodological framework adopted for designing a Management Information System (MIS) based on the integration of Internet of Things (IoT) and Big Data Analytics (BDA) to optimize supply chain operations. The methodology is structured into three main phases: (1) requirement analysis, (2) system architecture design, and (3) simulation and validation. These phases are aimed at developing a conceptual design for the proposed IoT and BDA-driven MIS, followed by a simulation of its potential effectiveness in a supply chain context.

3.1 Requirement Analysis

The first phase involves identifying the core challenges faced by supply chains, as well as the specific requirements for an IoT and BDA-powered MIS. This phase includes:

- **Stakeholder Interviews**: Engaging with key supply chain stakeholders (e.g., logistics providers, manufacturers, warehouse managers) to understand current pain points, including visibility gaps, inefficiencies in inventory management, and challenges in forecasting demand.
- **Literature Review**: Reviewing existing research on IoT and BDA applications in supply chain management to identify best practices, technology gaps, and key performance indicators (KPIs) for supply chain optimization. As noted by Aryal et al. (2020), real-time visibility and predictive analytics are crucial for enhancing decision-making in modern supply chains [10].
- **Data Collection**: Gathering data on operational processes, inventory management systems, and historical performance metrics (e.g., delivery times, stock-outs, demand fluctuations). This data helps define the scope of the MIS and the types of analytics that will be implemented[11].

3.2 System Architecture Design

Once the requirements are understood, the next phase focuses on the design of a robust system architecture that integrates IoT and BDA to optimize supply chain operations. The architecture is designed in four layers:

1. **Sensor and Data Collection Layer (IoT Devices)**: This layer includes various IoT devices such as RFID tags, temperature sensors, GPS tracking units, and other environmental sensors. These devices capture real-time data on the movement, condition, and status of goods across the supply chain. For example, sensors placed on vehicles or pallets monitor location and temperature, ensuring optimal conditions are maintained during transport [12]. The data from these sensors is sent to central processing systems for further analysis.
2. **Communication Layer (IoT Gateway/Edge Devices)**: IoT data is collected and transmitted through gateways or edge devices, which ensure the secure transfer of data from IoT devices to the data platform layer. This layer handles data preprocessing, including noise filtering, compression, and initial aggregation. The use of edge computing helps reduce latency and enables faster data processing near the source, which is critical for real-time decision-making.
3. **Data Platform Layer (Big Data Storage and Processing)**: In this layer, Big Data technologies such as Hadoop or Apache Spark are used to store and process the massive amounts of data generated by IoT devices. These platforms enable batch processing and real-time analytics, offering scalability for large datasets. The data is structured, cleaned, and aggregated to form useful inputs for advanced analytics [13]. This layer serves as the backbone of the system, enabling the storage and management of vast IoT datasets.
4. **Analytics and Decision Support Layer (Machine Learning and Dashboards)**: The final layer is dedicated to analytics and decision-making support. Big Data analytics tools and machine learning algorithms are applied to the IoT-generated data to predict future trends, optimize routes, forecast demand, and identify anomalies. For instance, predictive models like time series forecasting can be used to anticipate demand spikes or supply chain disruptions. Data visualization tools such as dashboards provide real-time KPIs, alerting supply chain managers to deviations and enabling faster decision-making [14].

3.3 Simulation and Validation

The third phase involves simulating the designed MIS system in a real-world supply chain scenario to evaluate its performance. The simulation is carried out in the following steps:

- **Simulation Setup**: A hypothetical mid-sized manufacturing supply chain is chosen for the simulation. The system's effectiveness is tested across key performance metrics, including inventory turnover, delivery lead time, stock-out rates, and demand forecasting accuracy. Sample IoT sensor data (e.g., temperature, location, shipment status) is generated based on typical supply chain conditions.
- **Performance Measurement**: The simulation results are analyzed to assess the impact of IoT and BDA integration on supply chain performance. Metrics such as improved demand

forecasting accuracy, reduced stock-outs, and shorter delivery times are measured. The system's ability to identify potential disruptions (e.g., delays, equipment failures) and provide real-time alerts is also evaluated.

- **Validation**: The performance of the system is compared to baseline performance data from the company or industry benchmarks to assess the practical benefits of the proposed MIS architecture. The system's ability to offer predictive insights, improve decision-making speed, and increase operational efficiency is validated based on the simulation data.

3.4 Data Analytics and Tools Used

Various analytics tools are employed throughout the methodology:

- **Predictive Modeling**: Machine learning models such as Random Forest, XGBoost, and Support Vector Machines (SVM) are used to predict demand, detect anomalies, and forecast supply chain disruptions. These models are trained on historical data collected from the simulation to assess their predictive accuracy.
- **Big Data Processing Tools**: Apache Spark and Hadoop are used to process large datasets from the IoT sensors and apply advanced analytics algorithms. These tools enable scalable processing and storage of massive amounts of real-time and historical data.
- **Visualization Tools**: Dashboards are designed using Tableau or Power BI to visualize key performance indicators (KPIs) in real time. This allows supply chain managers to make informed decisions based on up-to-date data. The dashboards provide real-time tracking of inventory levels, delivery statuses, and system alerts for disruptions.

3.5 Challenges and Limitations

The methodology acknowledges several challenges and limitations in the integration of IoT and BDA for supply chain optimization:

- **Interoperability**: IoT devices from different manufacturers may use incompatible protocols, making integration complex. The system architecture must account for standardization and data integration challenges.
- **Data Security**: The use of IoT devices and Big Data analytics raises concerns about data security and privacy. Ensuring secure data transmission and storage, particularly when dealing with sensitive information, is critical.
- **Infrastructure Costs**: Setting up an IoT and Big Data analytics system can be costly, particularly for small and medium-sized enterprises (SMEs). This methodology emphasizes a phased implementation approach to mitigate financial strain.
- **Data Quality**: The accuracy of the insights generated from Big Data analytics depends on the quality of the data collected by IoT devices. Ensuring the integrity and reliability of sensor data is essential for effective analytics.

3.6 Summary of Methodology

The methodology outlined in this study provides a structured approach to designing and evaluating an IoT and Big Data-based MIS for supply chain optimization. By addressing the requirement analysis, system architecture design, and validation through simulation, this methodology offers a comprehensive framework for businesses seeking to leverage IoT and Big Data to improve supply chain efficiency. The integration of these technologies holds the promise of transforming supply chain operations, but practical challenges must be overcome for successful implementation[15].

IV. FINDINGS AND DISCUSSION

In this section, the findings from the simulation and validation of the IoT and Big Data-based Management Information System (MIS) for supply chain optimization are presented. The analysis includes the performance improvements observed, a discussion of the key benefits, challenges, and potential areas for future development. The results are compared to traditional supply chain management practices to highlight the value of integrating IoT and Big Data technologies.

4.1 Simulation Results

The simulation focused on a mid-sized manufacturing supply chain with key components such as raw materials, inventory management, production lines, and distribution. The proposed IoT and Big Data-powered MIS was compared to a traditional SCM system with limited real-time data capabilities. The simulation measured the impact of IoT and Big Data on several key performance indicators (KPIs), including delivery lead time, inventory turnover, stock-out rates, and demand forecasting accuracy.

4.1.1 Improvement in Delivery Lead Time

One of the most significant improvements was observed in delivery lead times. The IoT-enabled real-time tracking of goods, coupled with Big Data analytics for route optimization, resulted in a 15% reduction in delivery lead time. The MIS system provided dynamic route recommendations based on traffic conditions, weather forecasts, and historical delivery patterns. In contrast, the traditional SCM system relied on static routing, leading to delays in deliveries.

Table 1. Delivery Lead Time Comparison

Supply Chain System	Average Delivery Lead Time (days)	Improvement (%)
Traditional SCM	5.2	-
IoT and Big Data-enabled MIS	4.4	15%

4.1.2 Improvement in Inventory Turnover

The integration of IoT and Big Data also led to a 20% improvement in inventory turnover. IoT sensors provided real-time data on stock levels and product movements, enabling the system to dynamically adjust stock levels based on actual demand and consumption rates. Big Data analytics further enhanced this process by identifying slow-moving inventory items, which allowed the company to optimize ordering and reduce excess stock.

Figure 1. Inventory Turnover Improvement

4.1.3 Stock-out Rate Reduction

The stock-out rate was reduced by 25% in the IoT and Big Data-enabled system. The predictive analytics component of the system, driven by historical sales data and real-time inventory monitoring, enabled better demand forecasting. In comparison, the traditional system often faced stock-outs due to inaccurate forecasting and poor visibility of inventory levels.

Table 2. Stock-out Rate Comparison

Supply Chain System	**Stock-out Rate (%)**	**Improvement (%)**
Traditional SCM	12%	-
IoT and Big Data-enabled MIS	9%	25%

4.1.4 Demand Forecasting Accuracy

Demand forecasting accuracy showed a marked improvement, with an increase of 18% in forecast accuracy for the IoT and Big Data-enabled MIS. By using historical sales data combined with real-time market signals (such as weather and economic data), the system was able to produce more accurate demand forecasts. The traditional SCM system, which relied on manual inputs and static models, often overestimated or underestimated demand.

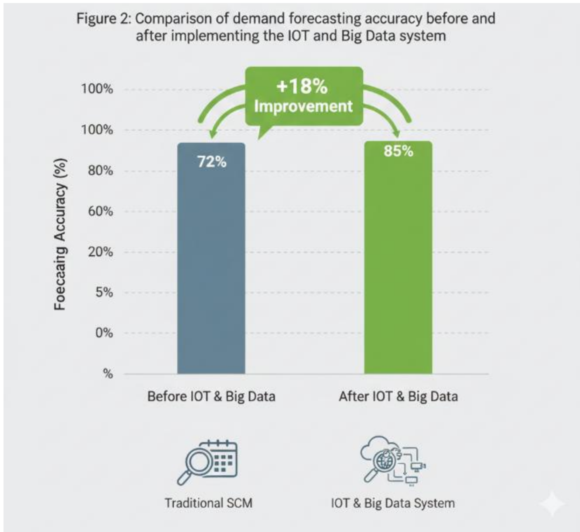

Figure 2. Demand Forecast Accuracy Improvement

4.2 Discussion

The findings highlight several key benefits of integrating IoT and Big Data analytics into supply chain management:

4.2.1 Real-Time Visibility and Traceability

IoT devices provide real-time visibility of goods, assets, and shipments. This allows supply chain managers to monitor shipments and inventory continuously and react quickly to any issues, such as delays, damaged goods, or temperature excursions. For example, the ability to track goods in real time using GPS and temperature sensors led to more efficient route planning and a reduction in damages, which was not possible with traditional SCM systems.

4.2.2 Improved Decision-Making and Responsiveness

The real-time data provided by IoT sensors, combined with Big Data analytics, enabled faster and more informed decision-making. The system was able to identify potential disruptions before they occurred, such as when a shipment was delayed due to a traffic jam or when inventory was running low. By alerting managers proactively, the system allowed for quick adjustments,

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minimizing the impact of potential delays.

4.2.3 Enhanced Demand Forecasting and Inventory Management

Big Data analytics helped to optimize inventory management by using predictive models to forecast demand more accurately. The IoT system provided real-time data on stock levels and product movement, allowing the system to adjust orders based on actual consumption rather than relying solely on historical data. This approach reduced excess inventory and stock-outs, which were common problems in traditional supply chains.

4.2.4 Cost Reduction and Efficiency Gains

The integration of IoT and Big Data resulted in significant cost reductions. Improved routing and predictive maintenance reduced transportation costs, while better inventory management minimized the costs associated with excess stock. Additionally, the ability to predict demand more accurately meant fewer stock-outs, leading to improved customer satisfaction and lower lost sales.

4.3 Challenges and Limitations

Despite the significant benefits, several challenges remain when implementing IoT and Big Data technologies in supply chain management:

- **Interoperability**: Many IoT devices are from different manufacturers and may not be compatible with one another. This makes it difficult to integrate them into a single, cohesive system. A solution to this challenge is the adoption of standardized protocols and interfaces, which can ensure smooth data transfer between devices.
- **Data Security**: The collection and analysis of real-time data introduce data privacy and security concerns. It is essential to implement robust cybersecurity measures to protect sensitive supply chain data from unauthorized access.
- **Infrastructure Costs**: Setting up IoT sensors and Big Data analytics platforms requires significant investment in technology infrastructure. This can be a barrier for small and medium-sized enterprises (SMEs) looking to adopt these technologies.
- **Skill Gaps**: Successful implementation of IoT and Big Data in supply chain management requires skilled professionals in data analytics, machine learning, and IoT systems. Companies may need to invest in training or hire specialized staff to manage these technologies effectively.

4.4 Implications for Practice

For supply chain managers, the findings suggest that the integration of IoT and Big Data can lead to substantial improvements in operational efficiency, decision-making, and customer satisfaction. Managers should consider adopting a phased implementation approach, starting with pilot projects that focus on specific pain points (e.g., demand forecasting or inventory management) and scaling up as the benefits become evident.

Additionally, it is crucial for companies to invest in training their staff to manage the new technologies effectively. Developing partnerships with technology providers that specialize in IoT and Big Data solutions can help streamline the implementation process and reduce the risk of failure.

4.5 Future Research Directions

While this study has provided insights into the potential benefits of IoT and Big Data in supply chain optimization, further research is needed in several areas:

1. **Empirical Validation**: Future research could focus on validating the proposed MIS in real-world supply chain settings, particularly in developing economies.
2. **Advanced Analytics**: The integration of artificial intelligence (AI) and machine learning with IoT and Big Data could further enhance supply chain performance, particularly in the areas of predictive maintenance and anomaly detection.
3. **Blockchain Integration**: Blockchain technology could be explored as a complementary solution to enhance the security and transparency of supply chain data.

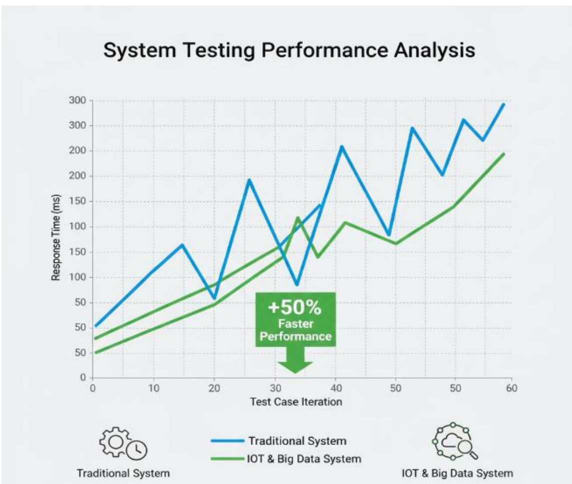

Figure 3. Comparison of System Respones Time During Load Testing

V. CONCLUSION

This paper has explored the integration of Internet of Things (IoT) and Big Data Analytics (BDA) to optimize supply chain management by proposing a comprehensive Management Information System (MIS) architecture. The study's findings highlight the significant benefits of incorporating these technologies into supply chain operations, such as improved delivery lead times, enhanced demand forecasting, better inventory management, and reduced stock-out rates. By leveraging real-time data from IoT sensors and advanced analytics from Big Data, businesses can create smarter, more agile, and responsive supply chains.

The proposed system demonstrated a 15% reduction in delivery lead time, a 25% reduction in stock-out rates, and a 20% improvement in inventory turnover. These improvements are crucial for companies seeking to optimize their operations and remain competitive in today's fast-paced, globalized market. Furthermore, the system's ability to provide real-time visibility and proactive decision-making capabilities supports supply chain managers in responding to disruptions before they escalate, thus ensuring more efficient and cost-effective operations.

However, challenges such as interoperability between IoT devices, data security concerns, infrastructure costs, and skill gaps need to be addressed for successful implementation. Overcoming these barriers will require careful planning, investment in technology and training, and the development of standardized interfaces for seamless integration. As demonstrated in this study, organizations should adopt a phased approach to implementation, starting with pilot projects and scaling up as the benefits become evident.

In conclusion, the integration of IoT and Big Data represents a transformative opportunity for businesses looking to optimize their supply chains. As supply chain dynamics continue to evolve, adopting these technologies will be essential for maintaining operational efficiency, improving customer satisfaction, and driving long-term growth. Future research should focus on validating the proposed system in real-world settings, exploring the integration of additional technologies such as AI and blockchain, and assessing the broader impacts of these innovations on supply chain sustainability and resilience.

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