Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/BA08.20250316
Published: December 20, 2025

Advanced Supply Chain Monitoring in Fashion Retail: An Industry 4.0 Approach Integrating IoT, Data Analytics, and Real-Time Tracking

Mohammad Fazle Rabbe
Department of Textile Engineering Management
Bangladesh University of Textiles (BUTEX)
92, Shaheed Tajuddin Ahmed Avenue, Tejgaon Industrial Area
Dhaka – 1208, Bangladesh
fazlerabbebutex@gmail.com

Abhisheke Chakrabortty
Budapest University of Technology and Economics
Budapest, Hungary
abhi.butex43@gmail.com

Aditya Bhattacharjee
Lecturer
Department of Textile Engineering
Port City International University
Nikunja Housing Society, South Khulshi,
Chattogram-4225, Bangladesh
adityabhattacharjee327@gmail.com

Bebe Fatema Bristy
Lecturer
Department of Textile Engineering
BGMEA University of Fashion and Technology (BUFT)
Nishatnagar (West part of Uttara), Turag
Dhaka-1230, Bangladesh
bebefatemabristy@gmail.com

Abstract

As a multi-trillion-dollar global market with one of the world's most extensive supply chains, the fashion industry confronts unique challenges daily, driven by rapidly shifting trends, globalized sourcing networks, and evolving consumer expectations. To remain competitive, fashion retailers must consistently deliver high-quality products on time while maintaining cost efficiency. Within this landscape, the Ready-Made Garments (RMG) sector, characterized by its vast, intricate, and highly dynamic supply chain, depends increasingly on advanced tracking systems to address these logistical complexities. Through a comprehensive review of peer-reviewed literature, industry reports, and

emerging technological trends, this study examines the prevailing supply chain tracking methods currently deployed in the fashion industry, including RFID, Data Matrix, GPS, and data analytics. Moreover, it explores the potential of real-time tracking technologies such as the Internet of Things (IoT) and blockchain, with a critical comparative cost analysis of these technologies to evaluate their practicality and scalability. The study concludes by outlining future strategic directions for the retail sector to integrate these advanced systems into existing supply chain infrastructures, aiming to enhance transparency, efficiency, and resilience across the global fashion ecosystem.

Keywords
Supply Chain, RFID, Data Analytics, Internet of Things, Blockchain

1. Introduction
In a market worth $1.77 trillion and powered by 430 million workers, textile and fashion stand as one of the world's most vast, dynamic, and intricately connected industries (Asim, 2025). As Industry 4.0 reshapes global manufacturing, the textile and fashion industry is confronting major supply chain vulnerabilities. Fast-changing trends and global sourcing reveal serious information gaps and poor visibility, making it difficult for customers to confirm ethical practices or product authenticity (Agrawal et al., 2021).

One of the most significant advancements in this area could be the introduction of real-time. Tracking technologies. Real-time supply chain tracking systems are technological innovations that offer a constant, current view of products at every stage of the chain. These technologies include the Internet of Things (IoT), Radio Frequency Identification (RFID), blockchain, and cloud-based platforms (Helo & Shamsuzzoha, 2020). These technologies provide real-time visibility, enabling businesses to track the movement of items, reduce inefficiencies, and ensure transparency throughout the supply chain. On top of this, the real-time tracking data is not only helpful for the day-to-day operations, but it can also create insights through key performance indicators, allowing the companies to improve their supply chains (Helo & Shamsuzzoha, 2020). DHL clearly identifies three key benefits of real-time package tracking. First, it empowers businesses to make proactive decisions through immediate access to shipment data. Second, it significantly enhances customer service by providing precise delivery predictions and timely updates on delays. Finally, it strengthens risk management by effectively identifying potential issues before they escalate (DHL, 2024). Now the question arises for the criteria for a tracking system to achieve visibility. The two major criteria for supply chain visibility are the connectivity of the supply chain and the sharing of information (Figure 1). The information must be of quality, having characterizations such as timelines, accuracy, and completeness. This necessitates the integration of data from telematics systems, enterprise resource planning, transport management systems, and warehouse management systems. On the other hand, supply chain visibility depends on the technological infrastructure via which information is passed (Wycislak, 2021).

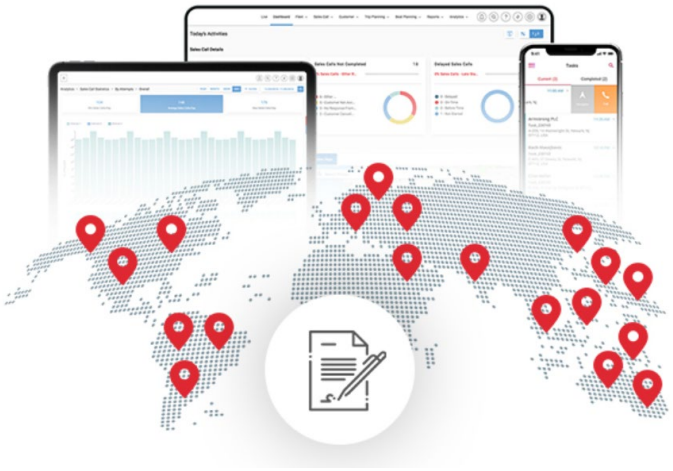

Figure 1. Real Time Tracking (Loginext)

This article examines a range of real-time tracking technologies used within the fashion supply chain, with particular emphasis on RFID for inventory management, data matrix codes, QR codes, and consumer-driven real-time data

tracking. It also presents a critical cost analysis of these technologies to evaluate their practicality and scalability. The study concludes by proposing strategic pathways for integrating these advanced systems into existing supply chain infrastructures, with the goal of strengthening transparency, efficiency, and resilience across the global fashion ecosystem.

2. Literature Review

For real-time tracking, it's important to create a structure that supports real-time data collection. For instance, Decathlon has built a system that fosters data collection from raw material, product, product life, and customer data. They collect data from events and attributes unique to each product from factories, warehouses, stores, and customers. These data are used to improve their supply chain continuously (Decathlon, 2024). Also, it has been noted that the advantages of real-time information technologies rely on the quality of reporting and the analytical capabilities of management for obtaining benefits from the supply chain (Oliveira & Handfield, 2019a). This is why it is crucial to choose the technologies that are most suitable for the organization. Global clothing brands like H&M Group, Zara, and Alexander McQueen are adopting RFID, blockchain, and IoT to improve supply chain management, transparency, and sustainability (Pal & Yasar, 2020). Several major global apparel companies, including LVMH, Gucci, Nike, and Burberry, also leverage RFID, blockchain, and IoT technologies to manage their operations efficiently. These firms use these advanced systems for diverse purposes, ranging from enhancing supply chain traceability, combating counterfeit luxury goods, and optimizing massive-scale inventory logistics, to improving customer loyalty programs (Unhelkar et al., 2022). This widespread adoption across both fast fashion and luxury sectors highlights an industry-wide shift toward transparent, digitally integrated supply chains (Figure 2).

Figure 2. Types of Real-Time Supply Chain Tracking System

There are many types of technologies that are being used in supply chain management for real-time tracking. The Table 1 below provides an overview of the systems.

Table 1. Types of Available Real-Time Tracking Technology

Technology	Details	Citation
RFID (Radio Frequency Identification)	This is the most renowned radiofrequency-based system. It uses radio waves to identify and track inventories and assets in real time, reducing human error. This increases the asset's visibility in the supply chain. It can also be used as a formidable building block for the Internet of Things, allowing companies to efficiently keep track of their goods.	(DHL, 2024; Monsreal et al., 2011)
IoT (Internet of Things)	The Internet of Things (IoT) interlinks numerous devices and sensors essential for the shipping process. By the collection and evaluation of data from these interconnected devices, businesses acquire critical insights into the status and quality of their shipments, facilitating proactive decision-making and the resolution of problems. In addition, by integrating IoT with technologies like QR codes and RFID, real-time monitoring of goods in the supply chain is possible.	(Li et al., 2017) (DHL, 2024)
Blockchain	Blockchain offers immutable records and secure transaction tracking. Blockchain-based tradability can provide flexibility and traceability of the supply chain in order to create a sustainable supply chain that is transparent to all the partners.	(Agrawal et al., 2021)
GPS	GPS is widely used for tracking the real-time location of goods, particularly in outdoor environments. GPS provides data points by using elements of real-time as well as location. GPS can be combined with other technologies for both the maximization of efficiency and the lessening of the costs of the application.	(Wycislak, 2021)
QR Codes	QR codes serve as an economical method for monitoring products, facilitating the tracing of objects across different phases of the supply chain. They may be integrated with RFID to offer real-time visibility and monitor data about products.	(Li et al., 2017)
AI-based Predictive Analytics and Data Analytics	Artificial intelligence utilizes real-time data from IoT devices and tracking systems to forecast supply chain interruptions, optimize routing, and predict delays. This can also include analyzing sales data to predict demand in order to manage inventories in time.	(Brintrup et al., 2020; Loureiro et al., 2018; Rajagopal et al., 2023)

3. Automatic Tracking Systems Using RFID and Data Matrix (QR Code)

3.1. Using RFID for tracking goods in warehouses as well as stores:

Radio Frequency Identification (RFID) is a sophisticated automatic identification technology that integrates several critical components, including RFID tags, readers, edge servers, middleware, and application software (Chao et al., 2007; Rao et al., 2005). Among these, the core components are the RFID tag (often referred to as a transponder), the RFID reader (also known as a transceiver or interrogator), and the associated data processing software. An RFID tag is a compact device that can be affixed to or embedded within products, animals, or individuals. It typically comprises a microchip for data storage and an antenna that facilitates the reception and transmission of radio-frequency signals from an RFID reader. The data stored on the tag includes the Electronic Product Code (EPC) as well as pertinent product information, such as the manufacturer's name, batch number, year of production, and pricing (Myny et al., 2010; Sarma et al., 2001). This technology enables seamless tracking and management of items in various applications, enhancing workflow efficiency and inventory accuracy.

Decathlon, a global sports retailer, uses RFID technology to automate checkout, improve inventory management, and boost security. RFID tags on products enable real-time tracking, reducing costs and theft while enhancing the online shopping experience. Customers can view stock availability for larger items like bicycles across stores. (Decathlon). Since 2019, all Decathlon products have included RFID tags for easy tracking and theft prevention. Their RFID project, initiated in 2008, is one of retail's largest, featuring nearly 50,000 in-house designed readers that cover the entire supply chain, from manufacturing to store checkout.(DECATHLON, 2024)

Marks & Spencer, a leading UK retailer, adopted RFID technology to improve inventory accuracy as part of its omnichannel strategy, initially focusing on retail stores with plans to expand across the supply chain (Figure 3).(Angeles, 2016a) Before RFID, M&S used optical scanners with barcodes to track 400-600 items per hour. RFID enables accurate scanning of up to 15,000 items per hour. (Angeles, 2016b)

Figure 3. (a) Supply Chain in Decathlon (b) RFID being used in M&S stores (Swedberg, 2015)

The Table 2 below summarizes different fashion brands using RFID for real-time tracking.

Table 2. Fashion Brands and their use of RFID for real-time tracking

Brand Name	**Use**	**Citations**
Burberry	RFID tags are present in products in their 500 stores spread across 50 countries, which can communicate with shoppers' mobiles, giving information about how items were produced or recommendations on how they can be worn or used."	(Marr, 2017)
Ralph Lauren	In Ralph Lauren's Manhattan flagship store, RFID technology in the fitting rooms identifies the items customers bring in. This system displays available colors and sizes on a screen, streamlining the shopping experience.	(Launchmetrics, 2022)
Rebecca Minkoff	Rebecca Minkoff's implementation of RFID technology aims to eliminate long checkout lines, offering a more convenient shopping experience. Customers can place items on RFID-enabled tables, where the system identifies the products, allowing payment through an iPad.	(Alvarez, 2016)
H&M	H&M uses RFID to track its items in store, look for product issues, and increase productivity.	(RFID, 2024)

3.2. Using Data Matrix and QR codes for Production and In-Store Tracking

Data Matrix codes, standardized by GS1, are gaining traction in the apparel industry for real-time tracking of products throughout production and retail. These two-dimensional barcodes utilize a compact grid of black and white modules to achieve high data density. Each module encodes binary data, which is read by imaging scanners that relay the information to enterprise systems, including ERP and inventory management (Figure 4). Typically, the encoded data features identifiers like the Global Trade Item Number (GTIN), serial numbers, and lot numbers, aiding precise identification and supply chain traceability. Integrated error correction algorithms in Data Matrix and QR codes allow for reliable data recovery, even from partially damaged codes. Practically, these codes are used on labels or packaging and can be scanned with specialized devices or smartphone cameras. GS1's standardization fosters interoperability within global supply chains, enhancing both transparency and efficiency in tracking products and materials across manufacturing and retail operations. (GS1, 2018)

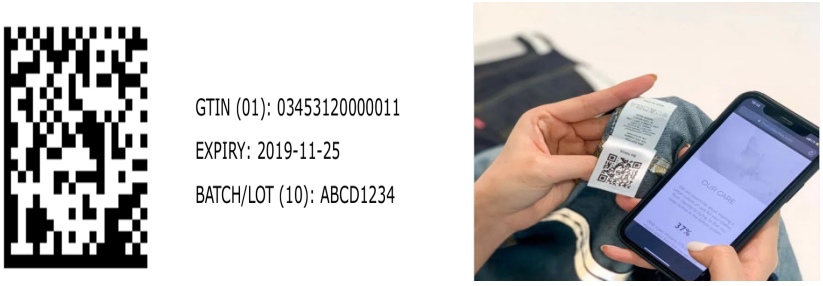

Figure 4. (a) An Example of a Data Matrix and the Data it represents. ("GS1 DataMatrix Guideline ", 2018) (b) QR codes can be used to track the information of items in Retail ("Fashion's new tech essential: QR codes," 2020)

The Data Matrixes and QR Codes can provide enhanced traceability by efficient tracking from manufacturing to retail, improving inventory management, and reducing losses. They can store a lot of data in a compact format, making them suitable for small items like clothing tags ("Types of Barcodes in the Apparel Industry: A Comprehensive Guidez,"). On top of that, they can seamlessly integrate with Supply Chain Systems. They can easily connect to ERP (Enterprise Resource Planning) systems, ensuring that product information is updated in real-time across all stakeholders ("GS1 DataMatrix Guideline,"). Additionally, Data Matrix codes are recognized for their cost-effectiveness in various industrial applications. They offer high data capacity and small size, providing a variety of cost-effective labeling options ("The Advantages of Using 2-Dimensional Datamatrix Barcodes,"). Data Matrix and QR codes are often more cost-effective than RFID technology in industrial applications. These two-dimensional codes require minimal investment, as they can be printed directly on packaging or labels without expensive materials or complex processes. They can be scanned with standard imaging devices or smartphone cameras, eliminating the need for costly specialized equipment. In contrast, RFID systems require electronic tags and dedicated readers, increasing costs and making Data Matrix and QR codes a more economical choice for many businesses. (Ladislav KARRACH, 2020). In a business like fashion retail, where real-time data can provide insights that can make or break the business, Data Matrix serves as a very powerful tool. For instance, DHL is a popular shipping service for fashion brands, utilizing QR codes to improve operational efficiency and optimize logistics. By integrating Warehouse Management Systems with QR codes, DHL enables real-time inventory tracking, reducing errors and speeding up processes like picking and packing. Each shipment is assigned a unique QR code for tracking updates, aiding in product authentication and quality control by encoding information like batch numbers. QR codes also enhance customer interaction by providing easy access to shipping information and services. scans(DHL).

An example of real-time advertising using a QR code can be found in live television. Lacoste featured a QR code campaign that ran on television while Novak Djokovic was playing tennis in a match (Figure 5). This QR code was routed to the online store where athletic consumers could shop the products they liked from the professional athlete, from their own homes ("QR Codes for Fashion,").

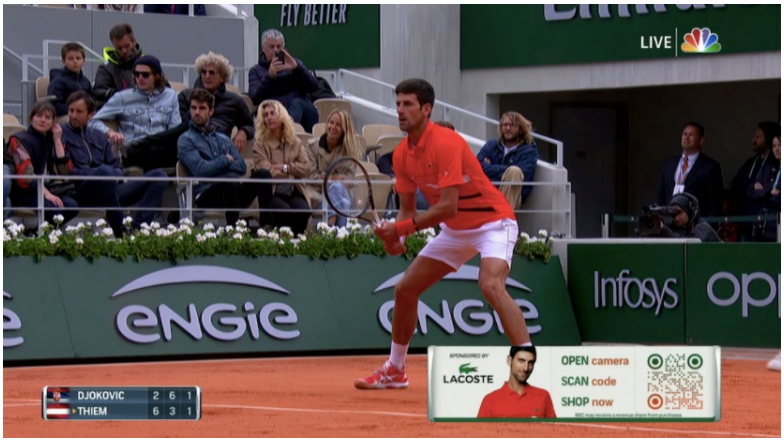

Figure 5. Real Time Advertising and Product Availability Tracing by QR codes ("QR Codes for Fashion")

Despite having advantages over technologies like RFID in cost, QR Codes and Data Matrixes have their own disadvantages in some sections due to their reliance on line-of-sight for scanning, meaning the code must be visible to the scanner (Table 3). RFID also supports batch scanning, enabling the simultaneous reading of multiple tags, while QR and Data Matrix codes require individual scanning. The data storage capacity is also significantly less than RFID.

Table 3. Fashion Brands and their use of Data Matrix/ QR Codes for real-time tracking

Brand Name	Use	Citation
Burrberry	It was the first brand in the world to make use of Snapchat's Snapcode feature. Allowing customers to unlock information by scanning barcodes attached to their products.	(Marr, 2017)
Nike	Nike is using QR codes in their NYC flagship stores for the "shop the look" feature. Nike also connected its QR Code to its store's dressing room, allowing customers to select their size and send the clothing to a fitting room to try on.	(*How to Use QR Codes on Clothing for Your Marketing Strategies*, n.d.)
H&M	Used Data Matrix codes to replace barcodes for better inventory tracking and a seamless in-store experience.	(GS1 UK | How H&M Has Transformed Customer Experience Using Global Retail Standards, n.d.)

3.3. Using Real-Time Consumer Data to Manage Inventories in factories and stores

Dynamic inventory management is becoming vital for fashion retailers to maintain competitiveness. Retailers can use real-time consumer data to make informed decisions that can help optimize inventory management and promptly address the preferences of customers. (Caro & Gallien, 2010). Zara's inventory management system uses real-time data to adjust stock based on consumer behavior, allowing for quick turnover and reduced excess inventory. By leveraging consumer insights, Zara optimizes restocking to ensure popular items are available while minimizing the risk of overstocking underperforming products.(DFREIGHT, 2024).

British fashion brand Burberry leverages Big Data and Artificial Intelligence (AI) to enhance sales and customer satisfaction through loyalty programs that encourage data sharing. Sales assistants use tablets to provide personalized recommendations based on customers' purchase history and social media activity. For instance, if a customer buys a coat, assistants may suggest a popular handbag that pairs well with it. In 2015, Burberry reported a 50% increase in repeat customers due to this personalized approach. Additionally, by updating product images based on sales data, they achieved a 100% sales increase for a particular bag that struggled online.(Marr, 2017).

Consumer data typically leads to trend analysis, which is crucial for understanding preferences and evolving fashion trends. Fashion is increasingly influenced by media, influencers, and celebrities rather than just runways. Real-time analysis of online search data and social media trends is essential, using tools like heat maps to track search patterns. Geolocation offers insights into customer behavior, allowing retailers to tailor catalog recommendations and promotions. With real-time data, retailers can update their catalogs promptly.(Gave, 2022)

4. Cost Analysis of Real-Time Tracking System

From the section above, the conclusion can be drawn that Bar Codes, RFID, and Real Time Data are real-time tracking technologies that are continuously being used in the fashion retail supply chain, with a greater focus on Bar Codes and RFID, with the former being used the most. The other technologies are yet to come to this specific sector, the main reason being the cost of implementation and the return on investment. In order to get a clear understanding of the feasibility of using these real-time tracking technologies in the fashion retail supply chain, it is crucial to have an overview of the cost of implementing these. Because, if the cost of the technology is way too high than the profit margin, then it would be unwise to pursue that in this particular business. The table below aims to provide a brief overview of the financial aspects of these technologies. The costs of Blockchain and IoT were not included here as there is not sufficient data on the web, and they are way too costly to implement in Retail Business as of now (Table 4).

Table 4. The Cost Breakdown of Real-Time Tracking Technologies

Technology Name	Estimated Cost	Challenges	References
RFID	- Tag Price: $0.10 to $0.50 per tag - Reader Cost: $1,000–$3,000 per reader - Requires additional devices: RFID antennas, handheld antennas, middleware/software, RFID printers, RFID encoders, security/authentication systems (RFID access control), and custom software applications.	- High implementation costs - Data management complexity - Adoption barriers in various industries	(Halstead, 2020; Modrák & Moskvich, 2012)
GPS	- GPS tracker price ranges from $100 to $500 - Best suited for tracking vehicles and containers during transit	- Limited to en-route tracking only	(Macealois, 2024)
QR Codes / Data Matrix	- Code reader cost: $40–$80 per piece - Code cost: $0.10–$0.30 per piece - No additional infrastructure required	- Dependency on visibility and physical condition - Vulnerability to security risks - Slow scanning process	(Amazon.Com:
AI-based Predictive Analytics / Data Management	- Development cost varies by industry: • Manufacturing: $30,000–$500,000 • Retail & E-Commerce: $40,000–$200,000 • Logistics & Supply Chain: $50,000–$300,000 - Requires proper data collection devices and collaboration with high-tech gadgets	- High establishment cost - Complex data collection and integration requirements	(Patel, 2025)

Now, since QR Codes/ Data Matrix and RFID are the two most used real-time tracking technologies in the apparel sector, these two have been compared more thoroughly in the section below in Table 5

Table 5. QR Codes/Data Matrix VS RFID

Feature	QR Code/ Data Matrices	RFID	Citations
Cost	Lower cost, making it economical for wide-scale deployment.	Higher initial costs due to expensive infrastructure and tags, potentially limiting use in smaller businesses.	(Roberti, 2012)
Data Capacity	Limited data capacity per QR code; often requires frequent updates for comprehensive tracking.	Greater data storage capacity with unique IDs, supporting complex tracking needs across the supply chain.	(Coltman et al., 2008)
Line of Sight	Requires line-of-sight scanning, slowing down processes in larger warehouses.	Does not require line-of-sight, improving efficiency in large-scale warehousing and logistics.	(Coltman et al., 2008)
Security	QR codes are more vulnerable to counterfeiting and cloning, which may reduce supply chain security.	RFID tags are more secure, but there are privacy concerns with tracking if not carefully managed.	(Schapranow et al., 2011)
Implementation	Quick and easy to implement with minimal infrastructure.	Requires significant infrastructure and integration with enterprise systems, which can add complexity.	(Schapranow et al., 2011)(Roberti, 2012)
Read Speed and Efficiency	Slower and manual scanning is required for each item.	Rapid scanning of multiple items simultaneously enhances inventory and logistics efficiency.	(Michael & McCathie, n.d.)
Environmental Limitations	Less durable in harsh environments and can be damaged by exposure to dirt or water.	More robust; can function effectively in dirty, metallic, or wet environments.	(Schapranow et al., 2011)
Scalability for Item-Level Tagging	Effective for basic item-level tagging but limited for large-scale, automated tracking due to manual scanning needs.	Highly scalable for automated, item-level tracking across the entire supply chain, suitable for high-volume environments.	(Garrido Azevedo & Carvalho, 2012)
Real-Time Data Updates	Limited real-time tracking capability; requires re-scanning for updates.	Enables real-time tracking without additional scanning, facilitating continuous updates as items move through the supply chain.	(Moon & Ngai, 2008)
Technical Barriers	None, except for being manual and time-consuming.	While scanning, there can be unintentional reads. RFID reads everything nearby, even the RFID on the user wearing it.	(RFID, 2024)

5. Benefits of Real-Time Supply Chain

Real-time data empowers managers with up-to-the-minute insights, enabling swift and informed decision-making. By continuously monitoring key performance indicators—such as inventory levels, shipment statuses, and stock movements- organizations can maintain operational efficiency and respond proactively to emerging issues. (Intralogistics, 2023). When managers can compare current data with historical trends, their ability to make strategic decisions improves significantly. This dynamic data environment lays the foundation for Decision Support Systems (DSS), which centralize information to detect patterns, forecast disruptions, and recommend timely interventions. DSS platforms also foster collaboration among supply chain professionals, allowing them to share insights and streamline decision-making processes (Mirbagheri, 2023)

The integration of real-time tracking technologies further enhances supply chain visibility, offering stakeholders a continuous, end-to-end view of material flows and order statuses. Leveraging cloud computing, mobile devices, distributed systems, and data integration tools, managers can now detect bottlenecks and disruptions across their

networks with unprecedented clarity. (Oliveira & Handfield, 2019b). This visibility translates into tangible cost savings by improving resource utilization and logistics efficiency. Companies can swiftly identify and resolve inefficiencies—such as transportation delays or inventory mismanagement—thereby minimizing waste. (Agarwal, 2018).Vendor Managed Inventory (VMI) systems complement these efforts by allowing suppliers to autonomously monitor and replenish stock levels. This reduces the need for excessive safety stock and lowers storage costs (Duchessi & Chengalur-Smith, 2008). Additionally, real-time tracking enhances security protocols, deters theft, and minimizes asset loss—delivering further cost benefits to retailers (DECATHLON, 2024).

Beyond operational gains, real-time inventory systems foster stronger collaboration across departments. By providing a unified view of inventory data, they enhance coordination among sales, marketing, production, and logistics teams, leading to faster, more cohesive decision-making (SUCCHI, 2023). Moreover, the ability to collect data throughout the product lifecycle offers valuable insights for sustainable design and manufacturing. This supports waste reduction and promotes circularity within the supply chain. (DECATHLON, 2024)

6. Challenges for the Real-Time Supply Chain Tracking Implementation

The implementation of real-time tracking technologies such as RFID, IoT, and blockchain presents substantial financial, technical, and organizational challenges. High initial costs—including hardware acquisition (RFID tags, IoT sensors) and cloud infrastructure—can be prohibitive for many businesses. (Makhija & Chugan, 2015; Ramadan et al., 2017). Integrating these technologies with existing ERP systems is often complex and resource-intensive, while ongoing maintenance demands regular updates and oversight. Although phased implementation and scalable solutions may help, the upfront investment remains a major hurdle.

A major technical barrier is the integration of data from diverse platforms across the supply chain, such as logistics, warehouse, and ERP systems, which often lack interoperability (Bose et al., 2008). Data integrity issues—like inaccuracies, delays, and missing information—can undermine system effectiveness. Managing the vast volume of real-time data requires robust infrastructure and advanced analytics; without these, managers may be overwhelmed rather than empowered (Adenekan et al., 2024).Even with skilled personnel and integration platforms, achieving a unified system is a long and demanding process. Privacy and security concerns further complicated adoption. IoT devices connected via wireless networks are vulnerable to cyberattacks, risking exposure of sensitive data such as inventory levels and shipment locations (Aliahmadi & Nozari, 2023; Dangi et al., 2023; Ruzbahani, 2024). While blockchain offers enhanced security, poorly implemented systems may fall short of expected standards. Organizations must enforce strong cybersecurity protocols and train staff accordingly, yet balancing accessibility with security remains a persistent challenge. (Gedam et al., 2022) Resistance from employees and stakeholders is another obstacle. Transitioning from manual or barcode-based systems to advanced technologies like RFID and IoT requires a cultural shift. Employees may fear job displacement or struggle to acquire new skills. (Nakitende, 2024; Pippenger, 2014)

Finally, deploying these systems across global supply chains introduces further complexity. Companies operate in regions with varying levels of technological readiness, infrastructure, and regulatory environments. (Helo & Shamsuzzoha, 2020; Wu et al., 2019). In rural areas, poor connectivity can delay data transmission, and integrating new systems may require costly customization. Ensuring device and software compatibility across diverse settings is both expensive and labor-intensive. While phased rollouts and scalable planning are essential, achieving seamless implementation across all locations remains a formidable challenge. (Wagner et al., 2022)

7. Conclusion

This investigation demonstrates the transformative potential of real-time tracking technologies in reshaping the fashion retail supply chain. The analysis reveals that the integration of RFID, QR codes, and data analytics align effectively with current supply chain infrastructures, enabling dynamic inventory management, heightened visibility, and reduced inefficiencies. While advanced technologies such as blockchain and IoT show strong long-term promise, their present cost structures limit widespread deployment within fashion retail environments. By identifying a balanced approach that prioritizes affordability without compromising functionality, this study provides a novel and actionable framework for future technology adoption in fashion supply chains. This strategic comparison not only addresses immediate operational challenges but also positions the industry to seamlessly integrate more advanced systems as technological maturity increases and implementation costs decline. Ultimately, this article contributes

meaningful guidance for practitioners and researchers by outlining a practical innovation pathway capable of strengthening the transparency, efficiency, and resilience of the global fashion ecosystem.

8. Future Work

The future of fashion retail real-time tracking technologies depends on creating solutions that strike a compromise between scalability, cost, and smooth connection with current infrastructure. Cost-effectiveness is crucial since the business has very small profit margins when compared to industries like the automobile sector. In addition to guaranteeing the endurance of tags and labels under a variety of handling and environmental circumstances, systems must be able to handle huge volumes of objects across different locations without incurring significant reconfiguration costs. The capacity to offer real-time sight of items during manufacturing, transportation, and in-store operations is equally crucial for improving supply chain responsiveness and transparency.

The immediate future offers more obvious avenues for innovation, even though long-term trends over the next ten years are still unpredictable. Systems that combine RFID or Data Matrix technology with GPS monitoring and sophisticated data analytics should be given top priority by fashion labels, manufacturers, and retailers. By enabling effective monitoring, predictive insights, and adaptive decision-making, this integration will put the sector in a position to handle changing customer expectations and operational difficulties. The fashion retail industry can create robust, scalable, and future-ready monitoring systems that boost competitiveness in a market that is changing quickly by adopting these technologies.

References

Adenekan, O. A., Solomon, N. O., Simpa, P., & Obasi, S. C., Enhancing manufacturing productivity: A review of AI-driven supply chain management optimization and ERP systems integration, *International Journal of Management & Entrepreneurship Research*, vol. 6, no. 5, pp. 1607–1624, 2024.

Agarwal, P., The impact of technology on supply chain management and logistics: An analytical study, *Information Technology in Industry*, vol. 6, no. 1, 2018.

Agrawal, T. K., Kumar, V., Pal, R., Wang, L., & Chen, Y., Blockchain-based framework for supply chain traceability: A case example of the textile and clothing industry, *Computers & Industrial Engineering*, vol. 154, p. 107130, 2021.

Aliahmadi, A., & Nozari, H., Evaluation of security metrics in AIoT- and blockchain-based supply chains using a neutrosophic decision-making method, *Supply Chain Forum: An International Journal*, vol. 24, no. 1, pp. 31–42, 2023.

Alvarez, E., How Rebecca Minkoff uses technology to make fashion stores stand out, *Engadget*, Dec. 2016.

Angeles, R., Marks & Spencer's RFID initiative: Laying the foundation for omnichannel retailing, in *RFID Technology Applications*, Springer, pp. 193–206, 2016.

Asim, M., Global apparel industry statistics for 2025, *Customcy Blog*, 2025.

Bose, I., Pal, R., & Ye, A., ERP and SCM systems integration: The case of a valve manufacturer in China, *Information & Management*, vol. 45, no. 4, pp. 233–241, 2008.

Brintrup, A., Pak, J., Ratiney, D., Pearce, T., Wichmann, P., Woodall, P., & McFarlane, D., Supply chain data analytics for predicting supplier disruptions: A case study in complex asset manufacturing, *International Journal of Production Research*, vol. 58, no. 11, pp. 3330–3341, 2020.

Caro, F., & Gallien, J., Inventory management of a fast-fashion retail network, *Operations Research*, vol. 58, no. 2, pp. 257–273, 2010.

Chao, C.-C., Yang, J.-M., & Jen, W.-Y., Determining technology trends and forecasts of RFID through bibliometric analysis, *Technovation*, vol. 27, no. 5, pp. 268–279, 2007.

Coltman, T., Gadh, R., & Michael, K., RFID and supply chain management: Introduction to the special issue, *Journal of Theoretical and Applied Electronic Commerce Research*, vol. 3, no. 1, pp. 3–6, 2008.

Dangi, A. K., Pandurang, G. A., Bachhav, G. V., Chakravarthi, M. K., Gehlot, A., & Shukla, S. K., Blockchain applications for security challenges in IoT, in *Proc. IEEE AISC*, pp. 582–585, 2023.

DECATHLON, *Decathlon RAIN RFID Project*, 2024.

DHL, Real-time tracking for business insight and control, DHL Logistics Whitepaper, 2024.

Gedam, M. G., Karmore, S., & Deogade, W. K., Challenges and solutions for secure data access through blockchain-based IoT, *International Journal of Innovations in Engineering and Science*, vol. 7, no. 8, pp. 110–116, 2022.

GS1, *GS1 DataMatrix Guideline: Technical Overview*, GS1, 2018.

Halstead, J., RFID cost factors: Tags to implementation, *Link Labs Blog*, 2020.

Helo, P., & Shamsuzzoha, A. H. M., Real-time supply chain: A blockchain architecture for project deliveries, *Robotics and Computer-Integrated Manufacturing*, vol. 63, p. 101909, 2020.

Li, Z., Liu, G., Liu, L., Lai, X., & Xu, G., IoT-based tracking and tracing platform for prepackaged food supply chains, *Industrial Management & Data Systems*, vol. 117, no. 9, pp. 1906–1916, 2017.

Loureiro, A. L. D., Miguéis, V. L., & da Silva, L. F. M., Deep neural networks for sales forecasting in fashion retail, *Decision Support Systems*, vol. 114, pp. 81–93, 2018.

Makhija, D., & Chugan, P. K., Drivers for adoption of RFID technology in manufacturing organizations, *International Journal of Information Technology & Computer Sciences Perspectives*, vol. 4, no. 3, pp. 1635–1642, 2015.

Marr, B., How Burberry uses artificial intelligence and big data, *Forbes*, 2017.

Michael, K., & McCathie, L., The pros and cons of RFID in supply chain management, in *Proc. International Conference on Mobile Business*, pp. 623–629, 2005.

Mirbagheri, S., Leveraging data warehousing and decision support systems for supply chain management, in *Proc. IEEE SmartCloud*, pp. 111–115, 2023.

Modrák, V., & Moskvich, V., Impacts of RFID implementation on cost structure in networked manufacturing, *International Journal of Production Research*, vol. 50, no. 14, pp. 3847–3859, 2012.

Moon, K. L., & Ngai, E. W. T., Adoption of RFID in fashion retailing: A value-added framework, *Industrial Management & Data Systems*, vol. 108, no. 5, pp. 596–612, 2008.

Oliveira, M. P. V. de, & Handfield, R., Analytical foundations for real-time supply chain capabilities, *International Journal of Production Research*, vol. 57, no. 5, pp. 1571–1589, 2019.

Pal, K., & Yasar, A. U. H., IoT and blockchain technology in apparel manufacturing supply chain data management, *Procedia Computer Science*, vol. 170, pp. 450–457, 2020.

Ramadan, M., Al-Maimani, H., & Noche, B., RFID-enabled real-time manufacturing cost tracking system, *International Journal of Advanced Manufacturing Technology*, vol. 89, no. 1–4, pp. 969–985, 2017.

Rao, K. V. S., Nikitin, P. V., & Lam, S. F., Antenna design for UHF RFID tags: A review, *IEEE Transactions on Antennas and Propagation*, vol. 53, no. 12, pp. 3870–3876, 2005.

Sarma, S., Brock, D., & Engels, D., Radio frequency identification and the electronic product code, *IEEE Micro*, vol. 21, no. 6, pp. 50–54, 2001.

Unhelkar, B., Joshi, S., Sharma, M., Prakash, S., Mani, A. K., & Prasad, M., Enhancing supply chain performance using RFID and decision support systems: A systematic review, *International Journal of Information Management Data Insights*, vol. 2, no. 2, p. 100084, 2022.

Wu, H., Cao, J., Yang, Y., et al., Data management in supply chains using blockchain: Challenges and a case study, in *Proc. IEEE ICCCN*, pp. 1–8, 2019.

Wycislak, S., Real-time visibility in transportation networks of complex supply chains, *International Journal of Supply Chain Management*, vol. 10, 2021.

Biographies

Mohammad Fazle Rabbe is a dynamic textile professional with a strong background in product development and merchandising within the fashion and apparel industry. He currently serves as Executive, Merchandising (Product Development) at The Source Expert (Medici Fashion DMCC BD Liaison Office) since 2024, where he specializes in developing knit, woven, and flat-knit products. With over four years of hands-on experience in product development, Fazle Rabbe Mahfuz has consistently delivered innovative and practical solutions, leading material and component development while ensuring strict adherence to fabric quality, lab-dips, wash effects, print processes, and cost optimization. He collaborates closely with global teams across design, sourcing, sustainability, and quality to meet buyer requirements, while maintaining updated material pricing and analyzing sourcing risks. Prior to his current role, he served as Junior Executive (2022–2024) and Management Trainee Officer (2021–2022) at Aman Knittings Ltd., where he oversaw supplier quality requirements, executed new orders, managed deliveries, supported quality issue resolution, and contributed to product development for kids' and men's wear, including child safety compliance. He holds a B.Sc. in Textile Engineering from Bangladesh University of Textiles (BUTEX) and combines technical expertise with strong skills in communication, leadership, critical thinking, and adaptability, making him a versatile professional in textile product innovation.

Abhisheke Chakrabortty is currently pursuing his Master's in Logistics Engineering at Budapest University of Technology and Economics as a Stipendium Hungaricum awardee after finishing his Bachelor's in Textile Engineering

from Bangladesh University of Textiles, and about a year of working in the industry. His passion in research revolves around topics such as: Technologies and data analysis techniques for supply chain, Industry 4.0, Reverse Logistics, Green Logistics as well as Sustainability in Product Development and Sourcing.

Aditya Bhattacharjee has completed his B.Sc. in Textile Engineering from Bangladesh University of Textiles, majoring in Apparel Engineering, under the Faculty of Textile Fashion Design and Apparel Engineering. After completing his graduation, he began his professional journey as an academician, serving as a Lecturer in Textile Engineering at the Department of Textile Engineering at "Port City International University", one of the leading institutions for textile engineering in Chattogram and Bangladesh. Beyond teaching, he is actively engaged in engaged in research and academic development, aiming to bridge the gap between traditional textile practices and modern technological advancements. His research interests include improving fabric properties and characteristics through the application of nanomaterials, eco-friendly plasma finishing, integration of wearable sensors to the fabric, and development of smart textiles.

Bebe Fatema Bristy has completed her B.Sc. in Textile Engineering from the Bangladesh University of Textiles in the Department of Apparel Engineering, under the Faculty of Textile Fashion Design and Apparel Engineering. She secured the 1st merit position with the highest grade till now in her department. This academic excellence earned her the *Dean's Award*, the *UGC Medha Britti Award*, and a nomination for the prestigious *Prime Minister Gold Medal*, the nation's highest honor for a student. Following graduation, she embarked on her professional journey as an academician, beginning as a Lecturer in the Department of Textile Engineering at "University of Scholars" and currently serving at "BGMEA University of Fashion & Technology", one of Bangladesh's leading private universities specializing in textiles and apparel education. Her research work spans diverse areas of textile materials, with a consistent focus on innovation, sustainability, and advancing the field through both academic inquiry and practical application. Her published research projects include the development of self-cleaning defense textile material surfaces for military personnel, nanotechnology, graphene-based wearable sensors, smart textiles, LCA of textile materials, and apparel production systems. Her current works under review include studies on superhydrophobic surface functionalization of textiles, graphene-based multifunctional protective clothing, and using textile wastewater as a feedstock for renewable hydrogen production. Looking to the future, she has ambitious plans to continue her academic journey while contributing to the materials industry in meaningful ways with her unwavering commitment to research and impressive track record.