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Research paper

Comparative Efficiency Analysis of High-Speed Cross-Belt Sorters Using The SCOR Model: A Case Study from India's Courier Network

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Abstract

The heightened need for rapid and accurate parcel delivery has resulted in the extensive implementation of automated technologies in logistics. This study assesses the operational efficiency and scalability of high-speed cross-belt sorters in comparison to manual sorting methods. This research analyses a case study from Bangalore, India, to evaluate the efficacy of the ZedSORT system compared to manual methods on throughput, labour dependency, cost-effectiveness, and scalability. Quantitative figures indicate a substantial augmentation in daily capacity (from 20,000 to 160,000 parcels), reduced labour needs, and enhanced real-time tracking and interaction with warehouse management systems. This research, based on the SCOR model and Industry 4.0 framework, provides practical insights and proposes a paradigm for the implementation of scalable automation in logistics operations. The findings enhance the discourse on the digital revolution of supply chains, offering lessons for both practitioners and researchers.

Keywords: *Cross-Belt Sorter; Logistics Automation; SCOR Model; Delivery Efficiency; Warehouse Optimization; Industry 4.0.*

1. Introduction

The logistics business is evolving due to an increased volume of shipments requiring expedited and precise delivery. Despite their prevalent usage, conventional manual sorting techniques are unable to meet contemporary demand surges and quality benchmarks. High-speed cross-belt sorters are an automated system capable of scaling according to your requirements. This study examines the application of ZedSORT, an automated cross-belt sorter, and contrasts it with manual sorting methods employed in courier sorting facilities. High-speed cross-belt sorters represent a critical technological advancement in streamlining delivery article sorting processes within complex customer networks, offering substantial improvements in efficiency, speed, and cost-effectiveness (Ran et al., 2021). These sophisticated systems are designed to address the ever-increasing demands of modern logistics and e-commerce, where rapid and accurate sorting is paramount to meeting customer expectations and maintaining a competitive edge (Ahmed, 2019). The integration of automation, particularly through robotic sorting systems, has become indispensable in modern warehouses, enhancing production efficiency and accommodating larger industrial scales (Zhao et al., 2024). The need for efficient sorting solutions stems from the growing volume of parcels and packages handled by distribution centers, driven by the proliferation of online shopping and the demand for faster delivery times (Gao & Liu, 2020). This necessitates a shift from manual processing to automated systems capable of handling a diverse range of items with speed and precision. The development and optimization of these sorting technologies are essential for businesses aiming to enhance their operational capabilities and reduce logistical bottlenecks (Cong, 2015). Cases related the poor delivery services lead for the automation of sorting the articles in the courier sector (Nieoczym et al., 2018).

Optimizing Sorting Processes with Advanced Technologies- Cross-belt sorters utilize a network of independently controlled carriers, or belts, to transport items to their designated destinations with high accuracy and speed (Lu & Chen, 2022). These systems often incorporate advanced scanning and tracking technologies to identify and route items based on their unique characteristics, such as size, weight, and destination. Optical belt sorters, for example, leverage line scan cameras to predict the movement of each particle, enhancing the separation process (Pfaff et al., 2017). Furthermore, the integration of artificial intelligence and machine learning algorithms enables these sorters to adapt to changing conditions, optimize sorting strategies, and identify potential issues before they lead to disruptions. This adaptability is crucial for handling the variability inherent in delivery article sorting, where item characteristics and demand patterns can fluctuate significantly. By employing sophisticated sensors, such as visible spectral range cameras, spectroscopic near-infrared cameras, 3D laser scanners, and metal sensors, these systems can identify and classify a wide variety of materials (Wilts et al., 2021). These sensors can be coupled with machine learning algorithms to improve the accuracy and efficiency of waste sorting processes (Almtireen et al., 2025). The ability to process large volumes of items while maintaining accuracy and minimizing errors is a key advantage of high-speed cross-belt sorters, contributing to improved overall efficiency and reduced operational costs. Moreover, advanced control systems and real-time data analytics provide operators with valuable insights into system performance, enabling them to make informed decisions and optimize sorting parameters for maximum throughput. Sensor-based sorting machinery offers insights into the effect of throughput rate and input composition on sorting performance (Küppers et al., 2020).

The Role of Customer Networks and Space Optimization- The effectiveness of high-speed cross-belt sorters is intrinsically linked to the design and optimization of customer networks (Azadeh et al., 2019). A well-designed network ensures that items are routed efficiently through the sorting process, minimizing transit times and maximizing delivery speed. This involves strategic placement of sorting facilities, optimized transportation routes, and seamless integration with other logistics systems (Varsha et al., 2021). Furthermore, the ability of cross-belt sorters to handle a wide range of item sizes and shapes makes them particularly well-suited for diverse customer networks, where the types of articles being sorted can vary significantly. In addition to efficiency and speed, space optimization is a critical consideration in modern sorting facilities. High-speed cross-belt sorters are often designed to minimize their footprint, allowing for maximum utilization of available space. This is particularly important in urban areas or facilities with limited space, where every square meter must be used effectively. The efficient use of space also contributes to reduced operating costs and improved overall productivity. Minimizing the delay between perception and separation of materials is a significant challenge in sensor-based sorting, largely due to the processing time required by the evaluation system (Maier et al., 2017).

Cost-Effectiveness and Performance Considerations- The implementation of high-speed cross-belt sorters represents a significant investment, but the long-term cost savings and performance improvements can be substantial. These systems reduce the need for manual labor, minimize errors, and increase throughput, leading to lower operating costs and improved customer satisfaction (Seng & Ghani, 2019). Moreover, the ability to quickly adapt to changing demand patterns and handle a wide range of item types makes cross-belt sorters a cost-effective solution for businesses with diverse sorting needs. Furthermore, the data-driven insights provided by these systems enable businesses to optimize their operations, identify areas for improvement, and make informed decisions about resource allocation.

Smart and Efficient Delivery Article Sorting Solutions- To be labelled as 'smart', a delivery article sorting system must incorporate several key features such as real-time data analysis, adaptive learning algorithms, and seamless integration with other logistics systems. These features enable the system to make intelligent decisions about routing, prioritization, and resource allocation, optimizing overall performance and minimizing delays. The integration of sensors and control systems is also important, as it enables the system to monitor its own performance, identify potential issues, and adjust in real-time (Varsha et al., 2021). Smart sorting systems contribute to waste reduction by accurately identifying and removing contaminants, ensuring that valuable materials are not discarded unnecessarily. Such smart systems can also automatically sort date fruits using machine vision and colour sensors controlled by programmable logic controllers, showcasing the application of automation in specific industries (Vandana et al., 2021). Additionally, smart delivery article sorting solutions are designed to be energy-efficient, minimizing their environmental impact and reducing operating costs. They also enhance supply chain operations by speeding up the receipt of incoming materials. The convergence of robotics and automation has revolutionized supply chain management, offering unprecedented efficiency and precision in various processes (Banur et al., 2024). By employing machine learning and image processing techniques, automated systems can accurately grade fresh produce, leading to reduced wastage and customer satisfaction (Junaina et al., 2020).

Optimization and the Future of High-Speed Sorting- The ongoing pursuit of optimization is driving innovation in high-speed cross-belt sorter technology. This includes advancements in areas such as conveyor design, control algorithms, and sensor technology, all aimed at increasing throughput, reducing energy consumption, and improving accuracy. The development of more sophisticated machine learning algorithms is also enabling sorting systems to adapt to changing demand patterns and optimize their performance in real-time. Furthermore, the integration of predictive maintenance capabilities is helping to minimize downtime and extend the lifespan of these systems. By combining edge computing, centralized cloud infrastructure, and distributed communication architecture, it is possible to meet the stringent real-time requirements of industrial automation, ensuring precise and coordinated operation of high-speed sorting systems. Also, the development of automated picking robots plays an important role in alleviating the shortage of agricultural labour, improving production efficiency and product quality (Niu et al., 2025). These advancements promise to further enhance the efficiency, cost-effectiveness, and sustainability of high-speed cross-belt sorters, making them an indispensable tool for businesses seeking to optimize their sorting operations. As automation and robotics become more prevalent in the era of Industry 4.0, smart manufacturing and mechatronics play an increasingly important role (“Industrial Process Improvement by Automation and Robotics,” 2023).

Key Components and Operational Principles- High-speed cross-belt sorters are sophisticated material handling systems designed for the rapid and accurate sorting of items based on various criteria. At their core, these systems utilize a series of interconnected conveyor belts, each equipped with a "cross-belt" that can move laterally to divert items to designated destinations. The operation begins with items being fed onto the main conveyor line, typically after being identified by a barcode scanner, RFID reader, or vision system (Chidinma-Mary-Agbai, 2020). The system then uses sophisticated control algorithms to determine the appropriate destination for each item based on pre-programmed rules or real-time data analysis. As the item approaches its designated destination, the cross-belt activates, gently pushing the item off the main conveyor and onto a take-away line or chute. The speed and precision of this process are critical to the overall performance of the sorting system, requiring tight synchronization between the main conveyor and the cross-belts, and real-time feedback from sensors to ensure accurate item placement. The high-speed capabilities of these sorters make them well-suited for applications in e-commerce fulfilment centers, postal sorting facilities, and distribution centers, where large volumes of items must be sorted quickly and accurately (Kia & Leiding, 2025). Sophisticated software algorithms and control systems manage the routing of items, ensuring precise and timely delivery to their designated locations. The integration of mobile robots can further enhance material handling automation, particularly in tasks such as labelling, feeding production cells, and managing warehouse operations (Melo & Corneal, 2020). Moreover, the development of automated guided vehicles showcases the feasibility of automation, highlighting benefits such as revenue generation and labour cost savings (Tebaldi et al., 2021).

Advantages of High-Speed Cross-Belt Sorters- The implementation of high-speed cross-belt sorters yields a multitude of advantages, significantly impacting the overall efficiency and effectiveness of the sorting process. One of the primary benefits is the increased speed and throughput, enabling the swift processing of a large volume of items in a relatively short period (Johnson, 1998). This capability is crucial for meeting the demands of time-sensitive deliveries and accommodating peak season surges. The enhanced accuracy in sorting ensures that items are routed to their correct destinations, minimizing errors and reducing the risk of mis-shipments, which can lead to customer dissatisfaction and increased operational costs. In addition to speed and accuracy, high-speed cross-belt sorters offer a high degree of flexibility and scalability, allowing them to adapt to changing business needs and accommodate a wide range of item sizes and shapes. This adaptability makes them suitable for various industries and applications, from e-commerce and retail to pharmaceuticals and manufacturing. These systems also offer significant space-saving benefits, as they can be designed to fit into compact layouts and utilize vertical space, maximizing the utilization of available floor space. The automated nature of these sorters reduces the need for manual labour, leading to lower labour costs and improved worker safety. Furthermore, the data-driven insights provided by these systems enable businesses to optimize their sorting processes, identify bottlenecks, and make informed decisions to improve overall operational efficiency.

Integration with Customer Networks- The seamless integration of high-speed cross-belt sorters with customer networks represents a critical aspect of modern supply chain management, enabling real-time visibility and control over the entire order fulfillment process. By connecting these sorting systems with customer order management systems, warehouse management systems, and transportation management systems, businesses can create a cohesive and integrated network that facilitates efficient order processing and delivery. This integration enables real-time order tracking, allowing customers to monitor the status of their orders from placement to delivery, enhancing transparency and improving customer satisfaction. The data generated by the sorting system can be fed back into the customer network, providing valuable insights into order patterns, demand fluctuations, and delivery performance. With the rise in automation within supply chains, the volume of data produced necessitates integrated systems. This information can be used to optimize inventory management, improve forecasting accuracy, and streamline logistics operations (Ada et al., 2021). Moreover, integration with customer networks allows for dynamic rerouting of orders based on real-time conditions, such as traffic congestion, weather delays, or inventory availability. This adaptability ensures that orders are delivered on time and in the most efficient manner possible. Furthermore, the integration of high-speed cross-belt sorters with customer networks can facilitate the implementation of value-added services, such as customized packaging, labelling, and kitting, enhancing the customer experience and creating new revenue streams. The integration of technologies like the Internet of Things, blockchain, big data analytics, artificial intelligence, machine learning, deep learning, and robotics can revolutionize warehouse operations (Geest et al., 2021). Additionally, leveraging big data analytics can help predict future trends, leading to informed decisions in various parts of supply chain management (Tırkolaee et al., 2021).

Optimizing Delivery Article Sorting for Efficiency- To further enhance the efficiency of delivery article sorting, businesses can implement a range of optimization strategies, focusing on process improvements, technology enhancements, and data-driven decision-making. One key area of focus is the optimization of sortation algorithms, which determine the routing of items based on various factors, such as destination, size, weight, and priority. By fine-tuning these algorithms, businesses can minimize travel distances, reduce congestion, and improve the overall throughput of the sorting system. The optimization of warehouse and distribution center operations relies on the effective utilization of resources, inventory management, and process optimization. Another important aspect of optimizing delivery article sorting is the implementation of advanced scanning and identification technologies, such as RFID, barcode scanning, and image recognition. These technologies enable the accurate and rapid identification of items, minimizing manual handling and reducing the risk of errors. Businesses can optimize their sorting processes by implementing real-time data analytics, which provide insights into system performance, identify bottlenecks, and enable proactive adjustments to optimize throughput and minimize downtime. Moreover, businesses can improve the efficiency of delivering article sorting by implementing automated quality control measures, such as weight checks, dimension checks, and visual inspections. These measures help to identify and remove defective or damaged items, ensuring that only high-quality products are delivered to customers. Furthermore, the use of simulation and modelling tools can help businesses to optimize their sorting processes by testing different scenarios and identifying the most efficient configurations.

2. Literature review

The SCOR model, Industry 4.0 frameworks, and smart logistics paradigms exemplify theoretical foundations. Prior studies have demonstrated the significance of automation (Nagpal et al., 2020; Li, 2022) and the inefficacy of manual labour in extensive logistics operations (Burinskienė & Lerher, 2021). However, few studies integrate empirical performance data with theoretical models. The optimization of logistics decisions has become indispensable with the increased movement of goods and services across geographies in globalized trade (Nagpal et al., 2020). Optimization methods can reduce costs related to transportation, storage, and production, while also improving the efficiency of time needed for logistic operations (Pečený et al., 2020). Optimization algorithms can deal with the complex issues of last-mile delivery, such as routing, task allocation, and efficiency (Shuaibu et al., 2025). Intelligent management methods like radio-frequency identification technology and ant colony algorithm are proposed to optimize the logistics distribution path and realize safe and efficient logistics distribution (Li, 2022). A fuzzy DEMATEL-based optimization model improves logistical performance by addressing strategic and tactical changes (Soni & Gupta, 2020). Order fulfillment optimization is crucial to e-commerce operations, impacting inventory management, warehouse operations, and transportation (Quanz et al., 2021). Optimization can involve utilizing transport means, technologies, and human resources more effectively (Pečený et al., 2020). Data analytics and advanced technologies are also crucial in optimizing urban logistics, addressing challenges such as congestion and environmental impact (Ferreira & Esperança, 2025; Mohsen, 2024). The literature review shows the application of order picking strategies, but research related to their selection lacks an integrated approach (Burinskienė & Lerher, 2021). The application of the discrete event simulation method enables various scenario tests in retail warehouses, allowing one to benchmark order picking strategies (Burinskienė & Lerher, 2021). Order picking is also known as order preparation; it is an essential process that directly impacts the efficiency of distribution warehouses and the entire supply chain (Burinskienė & Lerher, 2021; Tajima et al., 2020). Moreover, order picking is the most labor-intensive and costly activity in a warehouse, accounting for approximately 55% of total warehouse operating costs (Burinskienė & Lerher, 2021; Raj et al., 2024). As human workers' activities will be required for a long time to come, investigating the efficiency of the human workforce and warehouse processes is of central importance for e-commerce businesses (Klumpp & Loske, 2021). As such, techniques like augmented reality and gamification can be used to improve the motivation of workers (Ponis et al., 2020). Incorporating smart logistics into the existing logistical models can help optimize complex processes by using computer simulations, which can help detect bottlenecks that have been previously overlooked (Grznár et al., 2020). By analysing the existing warehouse system and determining any present bottlenecks, proposals for optimization can be made (Živičnjak et al., 2022). The implementation of high-speed cross-belt sorters can be a significant investment for businesses, so it is crucial to evaluate the cost-effectiveness of these systems and identify strategies to maximize their return on investment. One way to reduce the cost of high-speed cross-belt sorters is to optimize their design and configuration. This can be achieved by using modular designs, standardized components, and scalable architectures, which allow businesses to tailor the system to their specific needs and avoid unnecessary expenses. Businesses can minimize the energy consumption of high-speed cross-belt sorters by using energy-efficient motors, drives, and control systems, and by optimizing the system's operating parameters. Labor costs associated with order picking represent a substantial portion of total fulfillment center operating costs (Allgor et al., 2023). Furthermore, businesses can reduce the maintenance costs of high-speed cross-belt sorters by implementing preventive maintenance programs, using durable components, and providing adequate training to maintenance personnel. Moreover, businesses can maximize the return on investment of high-speed cross-belt sorters by using them to support value-added services, such as customized packaging, labelling, and kitting. An IoT-enabled cyber-physical system assisted with wearable devices and wireless communication technologies has been developed to cooperate with various stakeholders to achieve higher operational efficiency (Wu et al., 2020). The distribution must mirror the geographical demand split (Sathyanarayana & Patro, 2020). If this does not occur, there will inevitably be an imbalance between supply and demand in each region, which will be rectified through long transportations to satisfy demand (Wu et al., 2020). The implementation of high-speed cross-belt sorters can have a significant impact on warehouse space utilization, so it is crucial to consider the space-saving aspects of these systems and optimize their layout and configuration. Businesses can minimize the footprint of high-speed cross-belt sorters by using compact designs, vertical configurations, and overhead conveyors. Furthermore, businesses can optimize the layout of high-speed cross-belt sorters by integrating them with other warehouse systems, such as automated storage and retrieval systems (AS/RS), conveyor systems, and order picking systems. Moreover, businesses can improve space utilization by using dynamic storage allocation strategies, which allow them to adjust the storage locations of items based on demand and availability. The seamless integration of high-speed cross-belt sorters with the customer network is essential for efficient and timely delivery of goods, so it is crucial to establish robust communication and data exchange protocols between the sorting system and the customer's systems. Also, businesses can establish real-time visibility of the sorting process for customers by providing them with tracking information, order status updates, and delivery notifications (Liu, 2024). Moreover, businesses can integrate high-speed cross-belt sorters with their customer relationship management systems to personalize the customer experience and provide targeted offers and promotions. To ensure that the right items are delivered to the right customers at the right time, it is crucial to implement smart and optimum delivery article sorting strategies. Businesses can implement smart sorting algorithms that use data analytics and machine learning to optimize the sorting process and minimize errors. Also, businesses can use real-time data from the customer network, such as order information, delivery schedules, and customer preferences, to optimize the sorting process and prioritize urgent orders. Furthermore, businesses can implement dynamic sorting strategies that adjust the sorting process based on real-time conditions, such as traffic congestion, weather conditions, and delivery vehicle availability. Same-day deliveries have become common, which places a lot of pressure on logistics providers to deliver with both speed and accuracy (Shuaibu et al., 2025). Maximizing the efficiency with which these systems operate requires understanding and solving a complex problem class that is not currently well defined or understood in the academic literature (Gautam & Geunes, 2023). Ultimately, companies need to know the components needed to develop a data-driven transportation and logistics ecosystem (Kumar, 2021).

3. SCOR model application in high-speed sorting systems

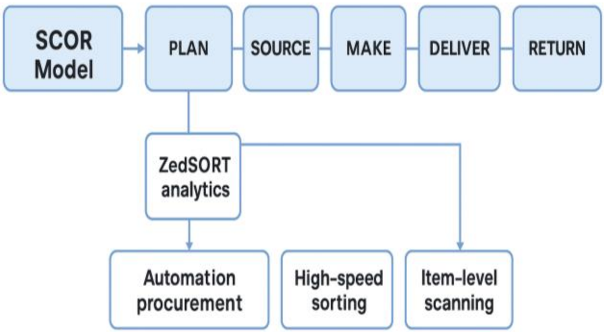

Fig. 1: SCOR Model Application.

From Figure 1, the Supply Chain Operations Reference (SCOR) model, created by the Supply Chain Council (now included in APICS), offers a standardized framework for assessing and enhancing supply chain performance. It classifies supply chain processes into five fundamental management domains: Plan, Source, Make, Deliver, and Return, with "Enable" included as a supplementary step. Within the realm of logistics automation, especially with the implementation of high-speed cross-belt sorters, the SCOR model provides a significant framework for analysis and optimization.

1) Plan: The plan component underscores demand forecasts, capacity planning, and performance evaluation. ZedSORT improves this capability by providing real-time analytics and comprehensive insights into throughput, parcel volume, and operational inefficiencies. These data-driven capabilities empower logistics companies to optimize resource and labour planning, dynamically modify sorting schedules, and synchronize sorter capacity with variable demand.
2) Source: While predominantly associated with procurement, the source process may be expanded to encompass the selection and integration of technology assets. The implementation of ZedSORT corresponds with this phase by procuring sophisticated automation technologies to diminish dependence on manual labour and enhance dependability. This area encompasses vendor partnerships, component standardization, and the sourcing of AI-integrated sortation systems.
3) Make: In manufacturing, make denotes the production process, whereas in logistics, it pertains to the processing and transformation of incoming packages into sorted outputs. The modular architecture and automated control methods of ZedSORT facilitate swift and accurate processing. This guarantees the effective conversion of disordered package intakes into systematic delivery chutes, prepared for transportation, so achieving this SCOR phase with exceptional consistency and quality.
4) Deliver: The delivery process emphasizes order management, transportation, and distribution. ZedSORT significantly influences this sector by facilitating expedited and precise sorting, hence minimizing last-mile delivery delays and improving customer satisfaction.

Integration with Warehouse Management Systems (WMS), Transportation Management Systems (TMS), and real-time order tracking systems for efficient delivery orchestration.

5) Return. The effective management of returns is essential in e-commerce. ZedSORT's data traceability and item-level scanning enhance reverse logistics by enabling precise identification and return of faulty or misrouted products to their source. Automated tracking enhances return cycle analysis, allowing companies to optimize product packing, handling, and routing procedures.

Activate: The Enable component supports all SCOR aspects through infrastructure, information technology, and performance management systems. ZedSORT's interaction with SCADA, WCS, and ERP systems demonstrates advanced technological capability, facilitating transparency, traceability, and real-time decision-making. This functionality enhances operational visibility and conforms with the ideas of Industry 4.0. The Strategic Significance of SCOR in Automation: Aligning sorter deployment with SCOR enables organizations to systematically assess: The most significant impacts of automation on the supply chain. The methods for monitoring and enhancing performance. The trade-offs between investment and return (e.g., throughput versus capital expenditure). ZedSORT demonstrates the operationalization of SCOR via modern automation technologies, enhancing the efficiency, agility, and responsiveness of logistics networks. This congruence substantiates SCOR as an effective diagnostic and prescriptive instrument in digital transformation endeavours.

4. Operational flow and system integration of the zedsort sorting solution

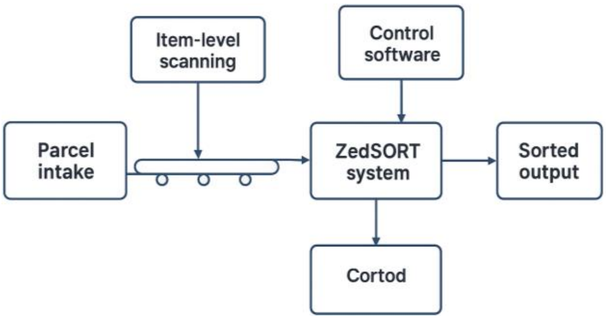

Fig. 2: A Schematic Diagram of ZedSORT Workflow.

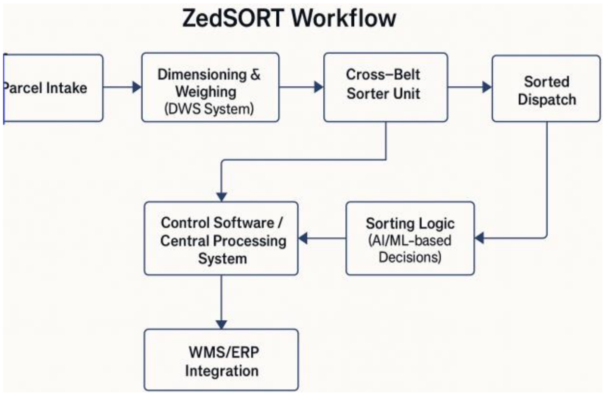

Fig. 3: ZedSORT workflow.

From Figures 2 & 3, the ZedSORT workflow diagrams illustrate the operation and configuration of a high-speed, AI-driven cross-belt sorting machine. This technique is utilized in contemporary logistics and parcel distribution centers. The four visual representations together provide a comprehensive understanding of the package handling process, from input to final delivery. They concentrate on the integration of intelligent technologies such as artificial intelligence, machine vision, control software, and warehouse management systems and enterprise resource planning. Each illustration aids in our understanding of the automation process both conceptually and functionally. They provide both theoretical (such as the use of the SCOR model) and practical logistical insights. The first schematic diagram illustrates the primary sequence of operations within the ZedSORT system. The process starts with "Parcel Intake," during which items are entered into the system. Subsequently, the packages undergo a "dimensioning and weighing" process, wherein DWS (dimensioning, weighing, and scanning) equipment determines their composition and weight. This information is crucial for enhancing sorting logic and downstream processing. The flow thereafter proceeds to the "Cross-Belt Sorter Unit," the mechanical core of the ZedSORT system. The AI-driven software operates the sorter, rapidly directing packages along high-speed conveyors to the appropriate output chutes based on their destination codes. The "Sorted Dispatch" phase displays products that are prepared for shipment, sorted efficiently for final delivery. The "Control Software/Central Processing System" depicted in this picture is the primary locus for decision-making. It executes the entire sorting process. This component is directly linked to the sorter unit and a feedback loop that incorporates "Sorting Logic (AI/ML-based Decisions)." These algorithms analyse historical parcel data, enhance routing precision, and adapt in real-time based on load volume. This software solution integrates with external Warehouse Management Systems (WMS) and Enterprise Resource Planning (ERP) platforms to ensure seamless communication, inventory synchronization, and reporting. This level of digital integration closely resembles the concepts of Industry 4.0 and the Enable component of the SCOR framework. The second design illustrates the identical method in a more straightforward, conveyor-based configuration, emphasizing the mechanical scanning and sorting of things. The ZedSORT system reads barcodes or RFID tags on each item within a package and processes them as they traverse a conveyor line. The "Control Software" is crucial for determining routing decisions, and the result is categorized as "Sorted Output." The term "Cortod" appears to be either a typographical error or a placeholder; nevertheless, it really refers to a downstream component or an intermediate staging area following sorting. This straightforward illustration effectively demonstrates the fundamental functional framework of automated package handling. These illustrations illustrate the interplay between mechanical automation and intelligent decision-making. ZedSORT enhances item delivery efficiency, reduces human reliance within courier networks, and provides real-time visibility of operations. These images effectively illustrate the cohesion of the SCOR model by demonstrating its contributions to planning (forecasting and analytics), making (processing and sorting), delivering (dispatch accuracy), and enabling (data integration). These diagrams serve as both conceptual models and practical blueprints, essential for academic discourse and industrial application.

5. Research objectives

- The objective is to assess the operational effectiveness of manual sorting in comparison to high-speed cross-belt sorting.
- The aim is also to assess the advantages of automation in logistics from an economic, labour, and geographical perspective.
- The aim is to introduce a scalable framework for the implementation of smart sorting systems in developing economies.

6. Methodology

We employed a case study methodology to gather operational data from a courier sorting facility located in Bangalore, India. Data were obtained from the ZedSORT system logs and manual sorting methods conducted concurrently. We analysed metrics such as package volume, processing duration, worker hours, and error rates quantitatively. Cost-efficiency modelling and descriptive analytics were employed. The data was taken from the delivery industry regarding the time taken for sorting 20,000 parcels in a single day with reference to the location of Bangalore, Karnataka, India. The automation sorting process data was gathered Manufacturing company in India i.e, Zed Sorters. The data was analyzed using both methods.

7. Analysis

Metric	Manal Sorting	ZedSORT
Daily Parcel Volume	20,000	1,60,000
Workers Required	4.17 FTEs	0.5 FTE
Sorting Accuracy	94% (approx)	>99.5%
Real-Time Tracking	No	Yes
Integrating with WMS	Limited	Full
Scalability	Low	High

ZedSORT outperformed manual processes on all major operational KPIs. Automation eliminated human error, reduced lead times, and increased throughput by 700%. Modular design facilitated scalability without physical infrastructure overhauls.
Manual Sorting vs. ZedSORT Efficiency.

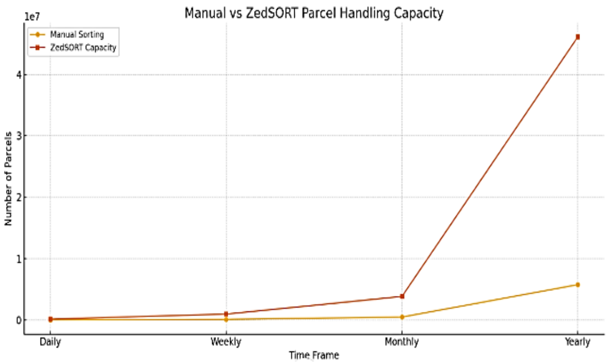

Chart. 1: Manual Sorting vs. ZedSORT Efficiency.

Table 1: Parcel Volume Comparison

Time Frame	Manual Sorting	ZedSORT Capacity
Daily	20,000	160,000
Weekly	120,000	960,000
Monthly	480,000	3,840,000
Yearly	5,760,000	46,080,000

From Table 1, every day, about 4.17 full-time workers sort 20,000 items by hand at a rate of 600 packages per hour per person throughout an 8-hour shift. This level of efficiency may appear possible, but as operational demands grow, manual sorting methods quickly illustrate how limited they are. One of the worst things is that the throughput is poor. The speed and amount of labour that people can perform each day are quite limited. With only four or five employees, we can't manage more than 20,000 parcels a day. These constraints slow down processing a lot during busy times like the holidays or flash sales. ZedSORT, on the other hand, can handle up to 160,000 shipments a day, which is eight times more than the old system. This feature ensures that operations will be ready for any future surges in demand. Another huge difficulty with sorting by hand is that it takes many people. It costs a lot of money and time to hire, train, and maintain staff, especially in logistical settings where individuals depart and perform the same tasks repeatedly, which may be tedious. Also, manual procedures are more likely to make mistakes and are less reliable. When individuals make mistakes, items typically go to the incorrect spot, things get broken, and deliveries take longer than they should. Automated barcode scanning, clever chute mechanisms, and carefully controlled discharge systems help ZedSORT reduce these risks. The system makes all sorting tasks more precise and consistent. People realize that it's challenging to scale up manual installations. To obtain bigger buildings up and running, need more people, equipment, and time. ZedSORT, on the other hand, has a modular and extremely scalable architecture. Companies may quickly add more loops, discharge chutes, or twin-deck sorting carts to increase capacity without having to make big changes to existing infrastructure or recruit more staff. One of the worst things about doing it by hand is that you can't see the data in real time. With traditional methods, you can't get real-time updates on the shipment's location, duration, or handling. ZedSORT fills this gap by interfacing with both Warehouse Management Systems (WMS) and Enterprise Resource Planning (ERP) systems. SCADA and Warehouse Control Systems (WCS) also provide information in real time. This interface allows operators to monitor system performance, track packages, and address issues before they arise. By making cycle counts more precise, ZedSORT affords inventory management better operational control. This is because every package is scanned and stored in a digital format. It also reduces inventory turnover by making it quicker to refill and finish orders, and it helps cut down on lead time by getting shipments to their destinations faster. Overall, it is getting harder for a logistics or delivery business that handles more than 20,000 items a day to maintain sorting them by hand. ZedSORT speeds up sorting and reduces the amount of personnel needed.

8. Discussion and conclusion

The use of ZedSORT, an advanced high-speed cross-belt sorting technology, represents a significant advancement in enhancing logistics in alignment with the broader objectives of intelligent supply chain management. Logistics businesses face pressure to enhance both speed and precision while maintaining low costs, as delivery volumes continue to increase due to the growth of e-commerce and urbanization. ZedSORT effectively addresses these issues by integrating robotic automation, artificial intelligence (AI), machine vision, and real-time decision-making systems. These constitute the essential attributes of intelligent logistics. ZedSORT significantly reduces human error and enhances accuracy. The system uses machine vision to identify, categorize, and dispatch packages based on their dimensions, configuration, barcode, or RFID data. This ensures a superior level of accuracy (>99.5%), surpassing typical manual sorting rates. AI algorithms continuously enhance sorting logic, enabling the system to learn from operational data and adapt to evolving parcel characteristics and volumes in real time. Utilizing ZedSORT in conjunction with Warehouse Management Systems (WMS), Enterprise Resource Planning (ERP) platforms, and Supervisory Control and Data Acquisition (SCADA) systems enables real-time monitoring of parcel movement, sorter performance, and workflow efficiency. This link facilitates proactive decision-making, reduces downtime, and enables the reallocation of resources according to system demand and supply schedules. Each item is digitally scanned, recorded, and tracked from its arrival until its departure, therefore facilitating inventory management. Although robotic sorters such as ZedSORT offer certain advantages, they also present significant challenges. It is essential to have substantial capital initially to purchase, implement, and integrate the system. Moreover, individuals require time to acquire the skills necessary to operate, repair, and manage automated devices. These challenges can be particularly arduous for small and medium-sized enterprises (SMEs). Industry case studies indicate that a return on investment (ROI) is often observed within 12 to 18 months due to increased throughput, reduced labor expenses, and diminished operational errors. ZedSORT exemplifies the increasing sophistication and data-driven nature of logistical operations. Its implementation transforms package handling and demonstrates the integration of intelligent technologies into conventional supply chain processes. As supply chains become increasingly complex and consumers want same-day delivery, technologies such as ZedSORT will be essential for ensuring the logistics sector remains adaptable, scalable, and competitive.

9. Theoretical implications

The findings of this study robustly endorse and expand upon the concepts presented in the Supply Chain Operations Reference (SCOR) model. They demonstrate how automation and digital technology may enhance logistics operations across all six primary domains: plan, source, make, deliver, return, and enable. ZedSORT is a rapid cross-belt sorting system that enhances operational visibility, reactivity, and scalability—three critical performance metrics emphasized by the SCOR architecture. ZedSORT's capability to provide real-time data enhances the Plan component by allowing more accurate predictions and adaptable scheduling. The system's ability to capture high-resolution data on parcel movement and sorter operations facilitates dynamic planning. The sorter transforms incoming raw packages into structured bundles throughout the Make and Deliver phases. This aligns with SCOR's concepts of value creation and order fulfilment. The traceability characteristics of ZedSORT enhance the return phase by refining reverse logistics and mistake recovery. This study contributes to the growing corpus of knowledge about Industry 4.0 enablers by demonstrating the impact of technologies such as AI, machine vision, IoT sensors, and ERP/WMS integration on business operations. These solutions transform conventional logistics into an intelligent, adaptable system capable of managing fluctuations in demand and significant unpredictability. Much of the prior research discusses the theoretical advantages of these technologies; however, this paper provides empirical data from India that illustrates both the performance enhancements and the challenges encountered in system automation. The study addresses a significant gap in the academic literature, as few empirical investigations have compared manual and automated sorting in high-volume delivery networks. It incorporates a practical example from a developing economy, which is typically excluded from global supply chain analyses. The research corroborates and enhances supply chain management theory by juxtaposing performance outcomes with established theoretical models.

10. Practical implications

This research gives logistics professionals and decision-makers a scalable methodology for assessing and putting into place automated sortation systems. ZedSORT's success shows that automation should not just be considered a way to cut down on labour costs but also to improve long-term competitiveness, accuracy, and service quality. Automation may help logistics companies that handle a lot of packages, especially during busy times like peak seasons or flash sales. It can help with problems like human error, throughput limits, and managing workers. Systems like ZedSORT are modular and scalable, which means that organizations can gradually increase their sorting capacity without having to make major changes to the structure. This makes them perfect for markets that are changing and developing. Also, combining ZedSORT with WMS and ERP systems makes it possible to manage inventory in real time, do predictive maintenance, and fix problems before they happen. This makes customers happier and makes the supply chain more resilient. To achieve last-mile delivery optimization and keep service-level agreements (SLAs), these features are highly important. The results also point up essential things to think about while making financial plans. The study reveals that a return on investment (ROI) is usually possible within 12 to 18 months, even if the initial capital expenses are high. This is because there is less human labour, faster processing speeds, and fewer operational disturbances. This means that even mid-sized logistics companies can afford to use automation. Finally, the methodology and KPIs in this research may assist decision-makers in comparing their existing operations, figuring out if they're ready for automation, and preparing for the future. This evidence-based methodology may help logistics businesses in emerging nations move from old ways of doing things to smart logistics ecosystems. This will help them stay competitive in a global market that is changing quickly.

11. Limitations and future work

This study's results offer helpful information about the advantages of employing high-speed cross-belt sorters such as ZedSORT; nevertheless, many limitations must be acknowledged. The research is founded on a singular case study conducted at a courier sorting facility in Bangalore, India. This scenario exemplifies the potential application of automation in a novel market; nevertheless, the results may not be transferable to other locations, industries, or logistical contexts. Various forms of infrastructure, workforce readiness, finance availability, and regulatory frameworks may all influence the outcomes of equivalent initiatives in different locations. The performance metrics under consideration are insufficient in number. This study primarily focuses on operational KPIs such as parcel volume, throughput, labour dependency, and system integration. However, it fails to include the automated system's long-term financial sustainability, maintenance challenges, or energy consumption—factors that are increasingly critical for assessing the comprehensive impacts of smart logistics technology. Furthermore, environmental considerations such as reducing carbon footprints and minimizing energy use are excluded from the current scope. Given the global emphasis on green logistics and sustainable practices, future research should investigate the environmental impacts of high-speed sorting systems, including their power consumption, management of electronic waste, and emission reduction capabilities. The study lacks a detailed discussion on the potential applications of real-time optimization, predictive analytics, or autonomous decision-making algorithms, despite ZedSORT's utilization of AI and machine vision. These are emerging domains that might significantly enhance system resilience and performance. Future research should investigate how AI may alter sorting parameters in real time based on live data streams, fluctuations in demand, and predictive models. Ultimately, enabling the model to function across several regions or distinct business sectors would enhance its use and offer more details about the impact of automation on global supply chains.

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