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LAST-MILE DELIVERY AND FULFILMENT EFFICIENCY IN E-COMMERCE

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Abstract—*The rapid growth of e-commerce has transformed the retail landscape, with businesses increasingly relying on dark stores to meet the demands of online consumers. A dark store is a retail facility dedicated solely to fulfilling online orders, without direct customer interaction. These stores are strategically positioned to facilitate quicker order processing and delivery, especially for groceries and essentials. However, the management of dark stores presents a unique set of operational challenges that need to be addressed for the success of e-commerce platforms.*

This review paper focuses on understanding the operational hurdles that e-commerce platforms encounter in managing dark stores. These challenges encompass logistical inefficiencies, inventory inaccuracies, last-mile delivery issues, and the integration of advanced technology to streamline operations.

Another significant consideration is the role of location and infrastructure. Additionally, workforce management in dark stores poses its own challenges. As dark stores rely heavily on labor for picking, packing, and other tasks, managing a motivated and efficient workforce is critical for maintaining smooth operations.

This review paper attempts to dwell into various factors and issues involved in the last mile delivery, of e-commerce platforms by reviewing various research papers.

Keywords: *Last mile delivery, operational challenges, dark stores, supply chain management, logistics*.

INTRODUCTION:

The evolution of e-commerce has given rise to innovative fulfilment solutions, with dark stores emerging as a crucial component in modern retail operations. Dark stores have experienced dramatic growth, particularly accelerated by the COVID-19 pandemic, representing a fundamental shift in how retailers approach urban logistics and fulfilment.

In this rapidly evolving landscape of e-commerce, the emergence of dark stores—facilities dedicated solely to online order fulfilment—has introduced a unique set of operational challenges that requires close examination. While dark stores promise to enhance delivery efficiency and optimize inventory management, they also present significant hurdles in terms of logistics, workforce management, and customer service. The integration of dark stores into existing supply chain frameworks necessitates innovative strategies to ensure seamless operations, mitigating issues such as stock discrepancies and employee training inefficiencies. Furthermore, as consumer expectations for faster delivery times escalate, the pressure on dark store management systems intensifies, prompting a re-evaluation of current practices. This research review paper explores the intricacies of managing dark stores, focusing on the operational hurdles that hinder their efficiency and proposing potential solutions to address these challenges effectively.

SCOPE OF THE STUDY:

The study focuses on developing a comprehensive understanding of dark stores as an emerging fulfilment model in e-commerce logistics and their growing relevance in modern retail operations. It examines key operational areas including logistics management, inventory control, workforce management, technological integration, and last-mile delivery systems.

The paper also explores the role of advanced technologies such as Artificial Intelligence (AI), automation, RFID, robotics, and real-time tracking systems in improving dark store efficiency. The scope includes location planning, infrastructure requirements, zoning regulations, and supply chain coordination affecting dark store performance. It considers how operational efficiency in dark stores influences delivery speed, order accuracy, and overall customer experience. The research situates dark store growth within the accelerated adoption of online retail following the COVID-19 pandemic. The study synthesizes findings from existing academic literature, industry reports, and prior empirical studies to identify key operational themes.

LIMITATION OF THE STUDY:

1. The study is based on secondary data only, with data collected and analyzed at different times at different geographical areas and hence its application may be limited.
2. Dark stores being a relatively new concept, there is limited scholarly literature available compared to traditional warehousing or retail fulfilment models.
3. Findings are derived from studies conducted across different countries and markets; operational realities may vary by region, especially in developing economies.
4. Technology in e-commerce logistics evolves quickly; tools, systems, and automation practices discussed may become outdated over time.
5. The review does not include statistical testing, modeling, or performance measurement metrics due to its qualitative literature-based nature.
6. Differences in operational practices among various e-commerce companies are not analyzed in depth.
7. While operational issues are discussed, detailed financial analysis such as ROI of automation, cost–benefit of RFID, etc., is beyond the study's scope.
8. Psychological, cultural, and behavioral aspects affecting dark store employees are not empirically examined.

STATEMENT OF THE PROBLEM:

The rapid expansion of e-commerce has significantly transformed retail fulfilment systems, leading to the emergence of dark stores as a strategic solution for faster order processing and last-mile delivery. While dark stores enhance delivery speed and inventory proximity to customers, their management introduces a complex set of operational challenges that e-commerce platforms are still striving to address effectively.

Dark store operations require seamless coordination between inventory systems, logistics networks, workforce processes, and technological infrastructure. However, many organizations face persistent issues such as stock inaccuracies, order fulfilment delays, inefficient warehouse layouts, and supply chain disruptions. In addition, last-mile delivery complexities, urban infrastructure constraints, and zoning regulations further complicate operational efficiency.

Workforce management presents another critical challenge, as dark stores depend heavily on manual labour for picking, packing, and dispatching orders. High attrition rates, inadequate training, productivity pressures, and peak-season staffing shortages adversely affect service quality and operational continuity.

Moreover, although advanced technologies such as artificial intelligence, automation, robotics, and RFID systems promise operational optimization, their integration remains uneven due to high costs, skill gaps, system compatibility issues, and cybersecurity risks. This creates a gap between technological potential and actual operational performance.

Despite the growing adoption of dark stores, existing literature remains fragmented, with limited consolidated understanding of the multidimensional operational issues involved in their management. As consumer expectations for rapid and error-free delivery continue to rise, it becomes imperative to systematically examine these operational hurdles.

Therefore, the core problem addressed in this review paper is to identify, analyse, and synthesize the key operational challenges faced by e-commerce platforms in managing dark stores, and to understand the technological, logistical, infrastructural, and workforce factors influencing their efficiency and sustainability.

REVIEW OF LITERATURE:

In recent years there has been a drastic transformation in consumer behaviour and retail operations, giving rise to innovative models such as dark stores. Dark stores are essentially retail spaces optimized for online order fulfilment rather

than in-person shopping, facilitating faster delivery and increased efficiency in supply chain management. This concept not only reflects the growing reliance on digital e commerce platforms but also emphasizes the operational hurdles inherent in managing such facilities.

The e-fulfilment process, a critical component of e-commerce, has been the subject of extensive research. (Jain et al., 2017) Studies have identified several key dimensions of e-fulfilment, including e-business quality, product quality, pricing, availability, timeliness, condition, and ease of return, all of which influence customer satisfaction and repurchase intent. As e-commerce has grown, retailers have had to adapt their fulfilment strategies to meet the evolving demands of online shoppers.

One such adaptation has been the rise of the "dark store" – a retail outlet that has been repurposed as a fulfilment centre to handle the surge in online orders. (Jain et al., 2017) By leveraging these strategically located facilities, retailers can optimize their supply chain and logistics operations, placing products closer to customers and enabling faster delivery times, ultimately enhancing the overall e-fulfilment experience for consumers.

E-Commerce platforms leverage vast amounts of data and hence machine learning techniques become crucial for enhancing the capabilities of dark stores by predicting inventory needs and optimizing logistics (Rutvij H Jhaveri et al., 2022). Moreover, as the lines between digital and physical retail continue to blur, dark stores offer a glimpse into the future of shopping, where virtual experiences begin to converge with real-world interactions, further complicating operational strategies (Yogesh K Dwivedi et al., 2022). Therefore, addressing the management issues surrounding dark stores is imperative for sustainable e-commerce growth.

The emergence of dark stores has revolutionized the landscape of e-commerce by facilitating rapid fulfilment of online orders, yet they pose distinct operational challenges. One significant hurdle is the need for sophisticated logistics to ensure service quality, as fulfilment costs can severely impact profitability. As noted, costs of fulfilment and service quality currently represent major barriers, highlighting the tension between operational efficiency and consumer expectations (Fernie et al., 2014). Furthermore, the integration of automation technologies in dark stores is complicated by a shortage of skilled labour, which can stymie attempts to enhance productivity and scalability. In this competitive environment, the rush to adopt new technologies, such as robotics for inventory management, underscores the urgency of addressing these operational inefficiencies. The logistics sector finds itself in a state of flux, where effective strategies are essential to navigate the dynamic demands of e-commerce while maintaining a sustainable edge (Companik et al., 2018).

Effective inventory management and stock accuracy are critical components in overcoming the operational hurdles faced by e-commerce platforms, especially in the context of dark store management. As competition intensifies, the efficient use of technology such as Radio Frequency Identification (RFID) can significantly enhance visibility across the supply chain. The implementation of RFID not only improves stock accuracy but also addresses the common challenges associated with inventory discrepancies, enabling businesses to meet the increasing customer service demands. This technological investment is further supported by research indicating that modern warehousing represents a substantial portion of logistics costs in the U.S., underscoring the imperative for enhanced operational efficiency and accuracy in inventory practices (Companik et al., 2018). However, it is essential to recognize that despite its potential benefits, the adoption of RFID is often hindered by understanding gaps and implementation challenges, necessitating a comprehensive strategy to facilitate effective integration into e-commerce operations (Li et al., 2006).

In the evolving landscape of e-commerce, the integration of technology within dark store management is crucial to overcoming operational challenges. As consumer expectations for swift and efficient service rise, retailers must leverage advanced technologies to optimize their inventory and sales processes. For instance, a mobile-based information system can enhance operational efficiency by automating sales recording and improving digital accessibility for customers, as evidenced in the study of Cahaya Store, which utilized the Ward and Peppard method to identify strategic technological enhancements in its operations (Ariati N et al., 2024). Moreover, leading players like Amazon demonstrate the efficacy of sophisticated systems that facilitate smooth customer interactions and robust inventory management, ultimately enriching user experience and driving sales growth (Alan D Smith et al., 2017). By addressing these operational hurdles through effective technology integration, dark stores can not only streamline their processes but also adapt to rapidly changing market dynamics, ensuring sustained competitiveness.

The integration of automation and artificial intelligence (AI) into e-commerce operations plays a crucial role in addressing the multifaceted challenges associated with dark store management. By leveraging AI algorithms, companies can optimize inventory management, predict demand trends, and enhance order fulfilment processes, thereby reducing operational inefficiencies. Additionally, automation technologies, such as robotic picking systems and automated inventory tracking, streamline workflows and minimize human error, which is vital in environments where precision is

paramount. This is particularly pertinent as organizations increasingly rely on real-time data analysis to inform strategic decisions about inventory allocation and customer service enhancement. Moreover, advancements in Cyber Threat Intelligence (CTI) mining highlight the necessity for sophisticated security measures to protect sensitive data amidst these automated systems (Sun N et al., 2023). As the e-commerce landscape evolves, the interplay between automation and AI will not only augment operational capabilities but will also facilitate a resilient framework for managing the pressing challenges of dark store logistics (Yogesh K Dwivedi et al., 2022).

The integration of sophisticated technologies, such as RFID, is poised to enhance inventory visibility and streamline supply chain processes, yet the implementation of such systems is fraught with challenges. Issues such as tag costs, standardization, and data management require careful consideration and innovative strategies to overcome, as highlighted in existing literature (Khumawala et al., 2006). Furthermore, while RFID offers the potential for improved efficiency and accuracy within dark store operations, its widespread adoption remains limited due to understanding and practical challenges (Li et al., 2006). Thus, a multifaceted approach that encompasses both technological solutions and organizational commitment is essential for e-commerce businesses aiming to mitigate these operational barriers. By prioritizing these initiatives, companies can better leverage dark store configurations to meet the evolving demands of the market.

RESEARCH METHODOLOGY:

The research is conducted purely on secondary data available. Various researches have been conducted with a lot of literature available to e-commerce platforms. However, with the rise of dark stores especially in the post Covid-19 period a lot of research is required in this regard.

Numerous research papers were consulted with topics related to dark stores and E-commerce platforms (references have been provided at the end). The main criteria for selection of the secondary data were – relevance, credibility, recency and accessibility. Based on the literature a few critical areas were arrived upon.

FINDINGS:

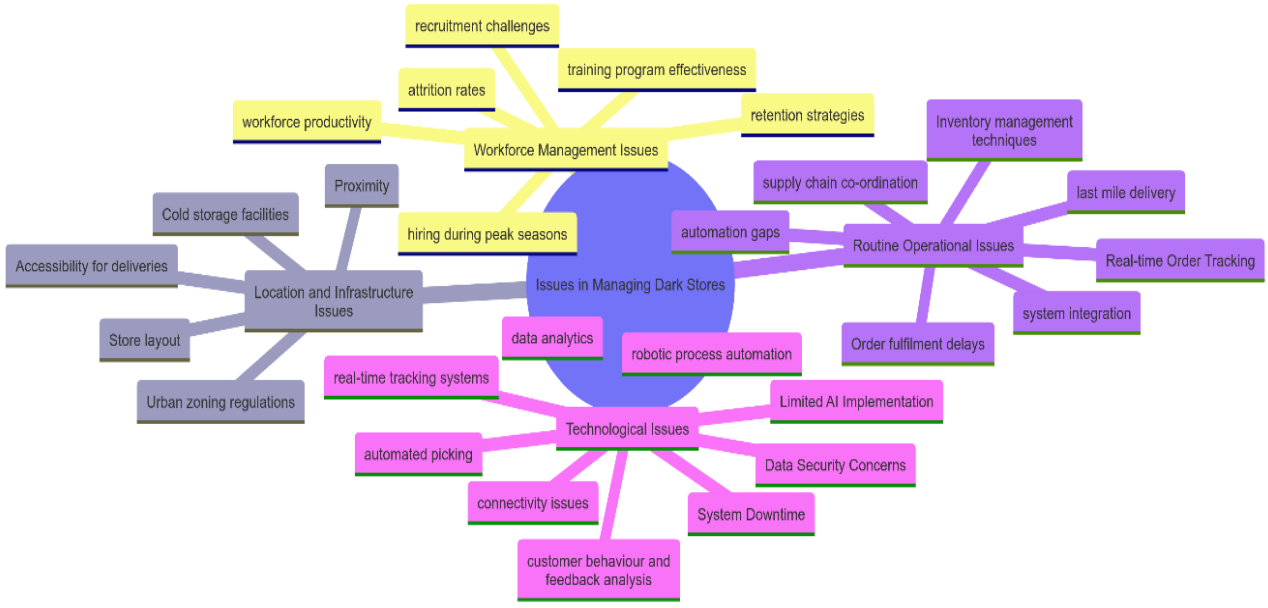

Figure showing mind map of key issues in managing dark stores

Dark stores are a relatively new concept and an evolving one. It has many multifaceted dynamic challenges. Some major issues can be broadly classified as:

a) Location and Infrastructure Issues - The major aspects that affect the operations include – Proximity of the dark store to markets, Urban zoning regulations, Accessibility for deliveries, Store layout, Cold storage facilities

b) Workforce Management Issues – Includes recruitment challenges, attrition rates, hiring during peak seasons, training program effectiveness, retention strategies to be employed and workforce productivity.

c) Routine Operational Issues – Includes Inventory management techniques and Inventory tracking systems to reduce stock outs and overstocking, Order fulfilment delays, last mile delivery, supply chain co-ordination, system integration and automation gaps.

d) Technological Issues – These include automated picking, robotic process automation, artificial intelligence for demand forecasting, real-time tracking systems, artificial intelligence driven inventory management, system downtime and server issues, connectivity issues, cyber security risks, data analytics and customer behaviour and feedback analysis.

CONCLUSION:

The management of dark stores in e-commerce presents complex operational challenges that require innovative solutions. As indicated by recent research, success in this space demands a careful balance of technological implementation, operational efficiency, and urban integration. The future of dark store operations will likely depend on the industry's ability to address these challenges while maintaining service quality and cost-effectiveness.

The evolution of dark store operations continues to shape the future of retail logistics, with emerging solutions and best practices developing rapidly. Ongoing research and practical implementation will be crucial in addressing the operational hurdles faced by this innovative fulfilment model.

In addressing the operational hurdles associated with dark store management within the e-commerce sector, organizations must adopt a multifaceted strategy that emphasizes efficiency and adaptability. One effective approach involves investing in advanced inventory management systems, which utilize real-time data analytics to optimize stock levels and enhance order fulfilment processes. Furthermore, training employees on best practices for inventory handling and utilizing automated picking systems can significantly improve operational efficiency. Implementing streamlined communication channels between warehouses and fulfilment centres is also critical, as it reduces delays and promotes a cohesive workflow that can adapt to fluctuations in demand. Finally, fostering a culture of continuous improvement encourages regular assessment of operational processes, allowing companies to identify bottlenecks proactively and implement innovative solutions. By integrating these strategies, e-commerce businesses can effectively navigate the complexities of dark store management, ultimately enhancing customer satisfaction and operational performance.

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