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Systemic Barriers and Technological Opportunities in Transforming Urban Logistics

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ABSTRACT : Urban logistics systems, particularly in the area of last-mile delivery, are undergoing rapid transformation driven by technological advancements such as automation, artificial intelligence, and big data analytics. This study employs a narrative review methodology to examine the interplay between technological innovations and systemic factors influencing logistics performance across urban environments. Literature was systematically gathered from major academic databases using strategic keyword combinations, focusing on social, economic, technological, and institutional dimensions. The results indicate that while emerging technologies significantly enhance delivery efficiency and operational reliability, their impact is often constrained by structural barriers including outdated regulations, limited infrastructure, and socio-economic disparities. Social acceptance, economic readiness, and institutional support emerge as crucial enablers of successful technology adoption. The discussion highlights the necessity for integrated frameworks that address these systemic issues, proposing policy-driven interventions such as collaborative governance models, digital infrastructure investment, and capacity-building initiatives. However, significant gaps remain in the literature, particularly regarding the experiences of low-income urban regions and the role of user behavior in shaping adoption outcomes. This study emphasizes the urgent need for policy alignment and infrastructural equity to ensure that the benefits of innovation are accessible and sustainable across diverse urban contexts. It concludes by advocating for context-sensitive, interdisciplinary research that bridges technological potential with systemic inclusiveness.

Keywords: urban logistics; last-mile delivery; technological adoption; smart city infrastructure; policy and governance; digital transformation; inclusive innovation

INTRODUCTION

In recent years, urban logistics has emerged as a critical component of global supply chain systems, especially in light of the growing challenges associated with last-mile delivery. The increasing demand for faster, more flexible, and consumer-centric delivery options has placed unprecedented

pressure on urban infrastructure and transportation networks. The COVID-19 pandemic further exacerbated these challenges, leading to an exponential rise in urban deliveries, which in turn triggered a surge in greenhouse gas emissions and urban congestion (Golińska-Dawson & Sethanan, 2023). Simultaneously, consumer expectations for rapid delivery have risen dramatically, intensifying the need for operational resilience and adaptive logistics planning (Engesser et al., 2023). Case-based research, such as that of Ouadi et al. (2022), underscores the empirical reality of logistical and transportation strain in urban areas, thereby reinforcing the necessity for strategic innovation and reform in the sector.

Parallel to these operational challenges is a broader technological transformation within the field of logistics. Scholars have emphasized a global shift towards digitalization and automation as essential to overcoming rising complexity in urban logistics (Dong et al., 2021). Disruptive innovations such as autonomous vehicles and big data analytics are increasingly integrated into the urban logistics landscape, promising enhanced efficiency, adaptability, and environmental sustainability. Patella et al. (2020) provided a systematic review of green vehicle adoption in short-distance deliveries, highlighting an industry-wide transition not only toward economic efficiency but also environmental responsibility. Mehmood et al. (2017) have further articulated the urgency of developing analytical frameworks that support strategic decision-making within these evolving technological contexts.

Empirical data highlights the relevance of these transformations. For instance, Golińska-Dawson and Sethanan (2023) documented a significant rise in urban freight movement post-COVID-19, correlating with an increase in CO2 emissions and vehicular density in metropolitan corridors. Engesser et al. (2023) corroborated these findings, showing that consumer demand for express delivery services has surged, leading to logistical bottlenecks and overstretched infrastructure systems. Ouadi et al. (2022) extended these insights by detailing how public transportation networks have become entangled with freight needs, especially in mixed-use urban spaces, thus necessitating reevaluation of shared infrastructure.

Further, Dong et al. (2021) illustrated how advanced technologies such as big data analytics and machine learning are being leveraged to dynamically optimize freight flows and predict logistical disruptions. Patella et al. (2020) quantified the ecological advantages of green delivery solutions, showing measurable reductions in fuel consumption and emission levels. These findings converge on the necessity for holistic, forward-thinking approaches to urban logistics management that accommodate not only operational efficiency but also broader environmental and societal considerations.

Nevertheless, significant challenges persist in implementing these innovations effectively. As Rathore et al. (2022) noted, organizational inertia and lack of executive support often hinder the adoption of disruptive logistics technologies. Regulatory gaps also persist, leaving many innovations in a state of policy ambiguity. Mehmood et al. (2017) stressed the need for integrated data analytics systems capable of processing and interpreting dynamic, real-time data to inform operational decisions in urban contexts. In addition, Zhou et al. (2024) and Taniguchi et al. (2024) highlighted the complexities involved in developing optimized routing algorithms. These require

multidisciplinary strategies that consider infrastructure limitations, demand variability, and network interactions.

Environmental concerns further compound these difficulties. As Golińska-Dawson and Sethanan (2023) emphasized, the urgent need to mitigate the environmental impact of last-mile delivery necessitates the widespread implementation of green technologies and practices. Patella et al. (2020) echoed this concern, advocating for a systemic transition toward environmentally sustainable logistics frameworks that balance economic imperatives with ecological stewardship.

Despite the growing body of literature addressing urban logistics innovation, several critical gaps remain. From a methodological standpoint, most studies rely heavily on quantitative approaches utilizing aggregated datasets. These studies often fail to capture the complex, real-time dynamics and interactions within urban transport ecosystems. Mehmood et al. (2017) pointed to the underutilization of big data-integrated operational models in decision-making processes. Likewise, Rathore et al. (2022) identified shortcomings in existing analytical frameworks for assessing the organizational and regulatory dimensions of technology adoption, noting that conventional tools like the Delphi method inadequately represent the multi-layered nature of disruptive technology implementation.

Substantively, much of the existing research focuses narrowly on enhancing operational performance, reducing emissions, and improving delivery reliability through technological interventions such as autonomous vehicles and robotic delivery systems (Masood et al., 2021; Engesser et al., 2023). While these efforts have yielded valuable insights, they often overlook systemic integration across logistical components and ignore the broader socio-economic implications of these technological shifts. This narrow focus limits the discourse, excluding cross-sector collaboration between technology, policy, and market dynamics in urban environments.

This review aims to bridge these methodological and substantive gaps by adopting an integrative framework that combines quantitative big data analytics with qualitative methods to explore technology adoption barriers and strategic decision-making in urban logistics. This dual approach will yield a more holistic understanding of how technological systems interact with regulatory frameworks and socio-economic factors. Furthermore, this study addresses the geographic bias in the current literature, which predominantly examines developed urban centers with sophisticated infrastructure. By focusing on underrepresented regions—specifically urban centers in developing nations struggling with logistical modernization—this review seeks to contribute to the development of adaptive, sustainable, and inclusive urban logistics strategies (Mehmood et al., 2017; Rathore et al., 2022; Masood et al., 2021; Engesser et al., 2023).

The scope of this review includes a comparative analysis of technological, regulatory, and organizational factors influencing last-mile delivery in urban settings. Special attention will be given to evaluating green logistics technologies, integration of digital platforms, and policy frameworks that facilitate or hinder innovation. The geographic focus encompasses both Global North and Global South contexts, with an emphasis on cities where infrastructure limitations present unique challenges and opportunities for innovation. By incorporating diverse case studies and cross-

sectional analyses, this review will offer a nuanced perspective that is both globally informed and locally grounded.

This review aims to critically examine how systemic barriers intersect with technological innovations in transforming urban logistics, particularly in last-mile delivery.

The paper is structured as follows: Section 2 outlines the methodological approach, Section 3 presents the thematic results and discussion, and Section 4 concludes with strategic recommendations and future research directions.

METHOD

This study adopts a narrative review methodology to explore contemporary developments and challenges in urban logistics and delivery innovation. A narrative review allows for a comprehensive and interpretive synthesis of existing knowledge, integrating findings from diverse studies to generate new insights and identify research gaps. This approach is particularly suited for complex, interdisciplinary topics such as urban logistics, where a variety of empirical, theoretical, and methodological contributions converge across different contexts.

To ensure the reliability and depth of the literature reviewed, a structured search strategy was employed across multiple high-impact academic databases, including Scopus, Web of Science, IEEE Xplore, and ScienceDirect. These databases were selected due to their wide coverage and ability to index peer-reviewed publications from diverse fields, including transportation, logistics, urban planning, and data science (Engesser et al., 2023; Patella et al., 2020). These platforms also support advanced search functionalities, enabling the precise identification of literature relevant to the themes of this review.

The search process was guided by the use of carefully selected keywords and Boolean operators to ensure thematic coherence and methodological transparency. Core search terms included "urban logistics", "last-mile delivery", "city logistics", "autonomous delivery", "smart urban freight", and "big data". These were combined using operators such as AND, OR, and NOT to construct nuanced queries. For instance, a typical query used was ("urban logistics" OR "city logistics") AND ("last mile" OR "autonomous delivery") AND ("big data" OR "sustainability"). This formulation ensured that only thematically relevant literature was retrieved, increasing both the sensitivity and specificity of the search results (Engesser et al., 2023).

In addition to thematic refinement, geographic focus was introduced through keywords such as "developing countries", "emerging economies", and "urbanizing regions". This adjustment addressed the prevalent geographical imbalance in existing research and ensured the inclusion of studies from underrepresented regions. The expanded geographic lens allowed for a more global understanding of urban logistics, capturing insights from both advanced and developing infrastructure environments (Patella et al., 2020).

For inclusion in this narrative review, studies had to meet specific criteria: they must be peer-reviewed journal articles published between 2010 and 2024, written in English, and directly relevant to one or more of the review's focal areas, including the application of autonomous technologies, big data in logistics, sustainable last-mile delivery solutions, or regulatory and strategic frameworks for urban freight systems. Conference proceedings were included only when they contributed unique empirical findings or theoretical advancements not present in journal literature.

Studies were excluded if they focused on rural logistics, non-technological urban planning, or personal mobility unless directly linked to freight systems. Editorials, opinion articles, and reports lacking methodological rigor or empirical foundation were also excluded. Duplicate articles retrieved from multiple databases were identified and removed using reference management software to ensure clarity and precision in the dataset.

The literature selection followed a three-stage process: title screening, abstract evaluation, and full-text review. Titles were first reviewed for obvious relevance, after which abstracts were analyzed to determine thematic fit with the review objectives. Full texts of potentially eligible studies were then read thoroughly to confirm methodological robustness, empirical value, and alignment with the inclusion criteria.

Although narrative reviews do not typically employ formal quality scoring, an internal appraisal was conducted to assess each study's contribution to the overall synthesis. This involved evaluating the clarity of research questions, appropriateness of methods, validity of findings, and significance of conclusions. Lower-quality studies were not excluded outright but were interpreted with caution during synthesis.

The narrative review integrated a wide variety of research designs, including case studies, modeling-based analyses, conceptual papers, and literature reviews. Empirical works offered insights into the real-world application of technologies such as autonomous delivery vehicles, vehicle platooning, and data-enabled routing systems. Theoretical and conceptual studies contributed broader perspectives on policy development, sustainability frameworks, and the socio-economic implications of logistics innovations.

The synthesis of literature was conducted thematically, guided by emergent patterns across the reviewed works. Core themes included operational efficiency, digital integration, environmental sustainability, policy and regulatory challenges, and social equity considerations in logistics innovation. This thematic structuring allowed for an in-depth and coherent presentation of findings that aligns with the interdisciplinary nature of the topic.

In summary, this narrative review draws upon a robust body of scholarly work to provide a multifaceted understanding of urban logistics systems and technological innovation. The methodological approach ensures both breadth and depth of analysis, supporting a critical interpretation of trends, barriers, and future directions in the field.

RESULT AND DISCUSSION

The narrative review revealed four primary thematic dimensions that significantly shape urban logistics systems and the innovation landscape: social, economic, technological, and institutional factors. Each of these dimensions exhibits varying levels of influence across different urban contexts, contributing uniquely to the evolution and effectiveness of last-mile delivery and broader urban freight operations. This section presents a thematic synthesis of findings from peer-reviewed literature, with empirical and comparative insights drawn from both developed and developing country contexts.

Social factors emerged as critical determinants of the success or failure of innovative logistics systems. Alam et al. (2024) emphasized the strong correlation between societal acceptance and the implementation success of new delivery technologies. In societies with progressive attitudes toward technological advancement, the integration of autonomous delivery vehicles and smart freight platforms was notably smoother. Cultural norms and community attitudes were found to play a pivotal role, particularly in influencing user trust and behavioral adaptation. In urban areas where sustainability values are socially reinforced, communities tend to demonstrate higher receptivity to eco-logistics solutions such as electric vehicles and shared delivery platforms. This dynamic was further elaborated by Melo (2021), who identified environmental norms as either enablers or inhibitors of distribution efficiency, depending on their alignment with policy initiatives and infrastructural readiness.

Empirical evidence from Vallino et al. (2018) supported these qualitative insights with quantitative data showing that environmentally driven social behavior correlates positively with logistical performance. For example, in Northern European cities where pro-ecological norms are widely adopted, delivery networks have become more compact, resulting in shorter delivery routes and fewer emissions per delivery unit. This convergence of social values and operational efficiency highlights the strategic value of incorporating community engagement and cultural sensitivity into urban logistics planning.

Economic considerations continue to exert a profound impact on logistics systems, particularly in shaping the degree and quality of technological adoption. Turienzo et al. (2023) outlined how robust financial environments catalyze the modernization of logistics infrastructure and enable investments in digital platforms and smart mobility systems. Cities in high-income countries tend to exhibit greater adoption of advanced logistics solutions, driven by both public and private sector investments. These include deployment of automated warehousing, intelligent transport systems, and real-time data analytics to improve freight movement.

Contrastingly, Bhattacharjya et al. (2022) identified significant disparities in logistics performance between developed and developing nations. In low-income countries, logistical inefficiencies are often rooted in inadequate infrastructure and restricted access to enabling technologies. Their comparative analysis highlighted that while developed countries are progressing toward integrated multimodal logistics systems, developing economies are still grappling with fundamental issues such as traffic congestion, lack of distribution centers, and insufficient digital integration. These findings underscore a structural imbalance in the global logistics ecosystem, reinforcing the need for international collaboration and targeted policy interventions to bridge the technological divide.

The technological dimension is perhaps the most frequently discussed factor in the contemporary literature on urban logistics transformation. Dong et al. (2021) highlighted the rise of disruptive technologies, including autonomous vehicles, drones, and advanced data systems, as foundational to the reconfiguration of last-mile delivery. Their study emphasized how such technologies are redefining logistical efficiency by minimizing human error, increasing delivery speed, and enhancing system responsiveness.

Taniguchi et al. (2024) expanded on these findings by demonstrating how digital platforms and advanced analytics optimize route planning and resource allocation. Large-scale simulations revealed that the implementation of algorithm-based delivery routing can reduce operational costs by up to 23% while simultaneously lowering emissions. Moreover, real-time data processing enables dynamic re-routing in response to traffic patterns and delivery constraints, thereby increasing delivery reliability and customer satisfaction. These insights demonstrate not only the operational benefits of technological adoption but also its environmental and economic implications.

Despite these advantages, the literature also acknowledges the challenges of technological integration, particularly in urban areas with limited digital infrastructure. Some cities lack the basic ICT infrastructure to support such technologies, limiting their benefits to technologically mature urban centers. This highlights the importance of contextualized planning and investment strategies that are tailored to local technological readiness and demographic profiles.

Institutional and regulatory frameworks form the backbone of sustainable innovation in urban logistics. Rathore et al. (2022) identified regulatory inertia and fragmented governance as primary barriers to technology adoption. The absence of coherent policy frameworks often results in ambiguity around legal responsibilities, data governance, and liability in the event of system failures. These gaps hinder the scaling and standardization of autonomous delivery systems across jurisdictions.

A comparative analysis by Li et al. (2020) illustrated how different national policy environments impact the implementation of unmanned delivery vehicles. In countries such as Singapore and the Netherlands, where regulatory systems are adaptive and technology-forward, autonomous delivery pilots have transitioned into commercial applications. Conversely, in countries with rigid and outdated regulatory structures, the deployment of such innovations remains in experimental or stalled phases. This disparity emphasizes that technological innovation alone is insufficient; it must be coupled with proactive governance and institutional adaptability to generate meaningful impact.

Moreover, the effectiveness of institutional arrangements also reflects in urban governance models. Cities with centralized transport authorities and strong inter-agency collaboration have demonstrated greater success in integrating logistics innovations. These models facilitate coordinated infrastructure planning, policy alignment, and joint investment strategies that reduce operational fragmentation. The institutional flexibility to support public-private partnerships has also emerged as a recurring theme in successful case studies, particularly in regions undertaking smart city transformations.

In sum, the findings of this narrative review affirm that urban logistics innovation is not a unidimensional phenomenon. Instead, it is the result of complex interactions among social

acceptance, economic capacity, technological capability, and institutional governance. The literature consistently demonstrates that progress in urban logistics requires holistic strategies that address each of these domains in concert. Additionally, comparative insights underscore the importance of context-sensitive approaches, where lessons from high-income, digitally advanced cities must be adapted thoughtfully to address the realities of urban environments in developing economies.

As urbanization intensifies and consumer demand for timely deliveries continues to rise, the stakes for building adaptive, efficient, and equitable logistics systems grow higher. The interplay of socio-cultural dynamics, economic resources, technological tools, and regulatory institutions must be considered in tandem to ensure that innovations in last-mile delivery are both sustainable and inclusive. The next sections of this review will delve deeper into these interactions and discuss strategic pathways to overcome the systemic challenges identified in the literature.

The findings of this narrative review substantiate and expand upon existing literature, affirming the transformative impact of technological innovation on urban logistics systems, particularly in the context of last-mile delivery. Research by Mehmood et al. (2017) and Masood et al. (2021) emphasizes the pivotal role of artificial intelligence, automation, and big data analytics in reconfiguring urban freight operations. These technological advances are driving a paradigm shift that encompasses not only operational optimization but also the development of strategic decision-making frameworks that integrate real-time data and predictive analytics. These insights are aligned with broader discourses in the literature that document the growing convergence between technological innovation and logistical performance in urban environments.

Yet, despite the transformative potential of such innovations, this review also reveals a persistent tension between technological capabilities and structural constraints. As Rathore et al. (2022) argue, adoption barriers remain prevalent due to limited executive support and outdated regulatory systems. These structural impediments compromise the scalability of logistics innovation, particularly in regions where institutional rigidity or market hesitancy inhibits the integration of disruptive technologies. The work of Sindi and Woodman (2021) corroborates this perspective by highlighting discrepancies between technological readiness and commercial adoption. While autonomous haulage vehicles and delivery robots show considerable promise in simulation and controlled trials, real-world application is often hindered by industrial inertia and an uneven technology adoption curve. These contradictions reveal a fundamental disconnect between innovation and implementation, suggesting that technological solutions alone are insufficient without comprehensive institutional reform and adaptive governance.

Systemic inequality, particularly in access to infrastructure and services, further complicates the technological landscape in urban logistics. Evidence from Rathore et al. (2022) and Bhattacharjya et al. (2022) illustrates how socioeconomic disparities between and within countries result in divergent logistics outcomes. High-income urban centers with advanced infrastructure and access to skilled labor are better positioned to adopt and benefit from advanced delivery technologies. In contrast, cities in low-income regions often lack the foundational infrastructure required for digital integration and smart logistics deployment. These disparities underscore the role of systemic inequality as a critical barrier to equitable innovation diffusion, reinforcing the necessity of

integrative approaches that combine technology development with infrastructure investment and policy alignment.

In analyzing these constraints, the literature suggests that systemic barriers such as infrastructure underdevelopment, regulatory fragmentation, and economic inequality must be addressed in tandem with technological innovation. Urban logistics does not operate in a vacuum; rather, it is embedded in broader institutional, social, and economic contexts that significantly influence its performance and adaptability. As such, technological innovation must be situated within a systemic reform agenda that promotes inclusivity and resilience across diverse urban settings.

To navigate these complex challenges, scholars have proposed a range of policy frameworks and intervention strategies. Engesser et al. (2023) advocate for the development of collaborative roadmaps that bridge the public-private divide, aligning regulatory frameworks with emerging technologies. This collaborative model emphasizes fiscal incentives, regulatory adaptation, and digital infrastructure investment as foundational pillars for fostering innovation. Complementing this approach, Rathore et al. (2022) emphasize the need for targeted capacity-building initiatives, including executive training programs and workforce upskilling, to support the transition toward automated logistics systems.

Sindi and Woodman (2021) and Masood et al. (2021) offer further elaboration on potential interventions through the use of large-scale simulation models and multi-agent frameworks. These tools enable stakeholders to map logistical networks, identify systemic bottlenecks, and simulate the effects of different policy and operational strategies. By incorporating data-driven models into decision-making, these frameworks facilitate more informed resource allocation and infrastructure planning, contributing to the resilience and scalability of logistics systems. Such approaches are particularly valuable in addressing the multifaceted nature of urban logistics, where social behavior, policy constraints, and technological readiness intersect.

However, despite these promising directions, the literature reviewed also reveals several limitations that merit further investigation. First, the predominance of case studies and quantitative models in technologically advanced urban centers limits the generalizability of current findings. There remains a dearth of research focusing on the unique challenges faced by developing urban areas, where data availability is limited and logistical systems are highly fragmented. Additionally, many existing studies tend to isolate technological variables without adequately accounting for the socio-political and economic ecosystems within which these technologies are deployed. This analytical gap underscores the need for more holistic, interdisciplinary research methodologies that integrate qualitative perspectives, local contexts, and participatory stakeholder engagement.

Second, while the reviewed literature frequently discusses barriers to technology adoption, there is relatively limited exploration of user-centered factors, such as public trust, community engagement, and behavioral economics. As Alam et al. (2024) and Melo (2021) point out, social norms and cultural attitudes can significantly shape the trajectory of technological implementation. Future studies would benefit from deeper exploration of these socio-cultural dimensions to ensure that logistics innovations are not only technologically sound but also socially accepted and behaviorally viable.

Third, the rapid evolution of logistics technology itself introduces a degree of uncertainty regarding long-term sustainability and scalability. Technologies such as autonomous vehicles, drones, and AI-driven platforms are advancing rapidly, often outpacing the regulatory and ethical frameworks designed to govern them. This misalignment raises critical questions about data privacy, operational accountability, and the environmental footprint of new delivery systems. These concerns highlight the importance of proactive policy development that anticipates future challenges rather than reacting to them retroactively.

In addition, the global nature of supply chains necessitates an international perspective on urban logistics reform. Comparative insights, such as those presented by Li et al. (2020), demonstrate that countries with agile, innovation-oriented regulatory systems are better equipped to integrate emerging logistics technologies. In contrast, jurisdictions characterized by regulatory rigidity often experience delayed implementation and fragmented market development. Drawing from these comparisons, it becomes evident that cross-national learning and international collaboration are essential for establishing best practices and harmonizing policy standards.

Overall, this discussion reveals that while the potential for transformative change in urban logistics is substantial, it is contingent upon a constellation of interdependent factors. Technological advancement must be matched with institutional agility, infrastructure readiness, socio-cultural adaptability, and inclusive policy design. Without such alignment, the promise of efficient, sustainable, and equitable urban freight systems will remain unrealized. Future research must therefore move beyond technological determinism and engage with the systemic realities that shape urban logistics in diverse settings.

CONCLUSION

This study has underscored the multifaceted dynamics that shape the transformation of urban logistics, particularly in the domain of last-mile delivery. Through a narrative review, the findings confirm the increasing significance of technological innovation—including automation, artificial intelligence, and big data analytics—in improving delivery efficiency and system responsiveness. However, this transformation remains uneven due to systemic barriers such as regulatory rigidity, infrastructural disparities, and socio-economic inequalities. The discussion further highlighted the contradiction between the promise of advanced technologies and the structural limitations that hinder their full implementation, particularly in developing urban contexts.

Addressing these challenges requires an integrated policy framework that aligns technological adoption with infrastructure development and institutional reform. Collaborative public-private partnerships, regulatory adaptability, fiscal incentives for digital infrastructure, and capacity-building initiatives for logistics stakeholders are crucial interventions. Furthermore, inclusive strategies must consider local socio-cultural conditions to ensure broader acceptance and equitable distribution of technological benefits.

Future research should focus on underrepresented urban regions and adopt interdisciplinary approaches that integrate social, economic, and behavioral perspectives. Expanding the empirical

base beyond technologically mature environments will enrich understanding and provide more context-sensitive solutions. Enhancing accessibility, strengthening institutional coordination, and investing in digital readiness remain pivotal strategies in realizing inclusive and sustainable urban logistics systems.

Policymakers should prioritize the development of adaptive regulatory frameworks, investment in digital infrastructure, and incentives for green logistics technologies.

Logistics transformation must be seen not only as a matter of efficiency but also as a pathway toward broader urban sustainability, equity, and technological inclusivity.

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