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Assessing the Role of Logistics Vehicles in Traffic Congestion and Air Pollution: Policy Implications from Surabaya's CBD

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ABSTRACT: Urban freight transport is essential for sustaining city economies, yet its unmanaged growth poses serious risks to mobility and environmental health. This study aims to evaluate the contribution of logistics vehicle operations to traffic congestion and air pollution in Surabaya's central business district (CBD). Using a qualitative case study approach, data were collected through interviews, field observations, and secondary documentation. Results show that logistics vehicles account for 18–23% of peak-hour traffic, leading to 20–30% longer travel times, while air quality measurements recorded $PM_{2.5}$ levels exceeding WHO thresholds, especially during logistics peak periods. These impacts are largely driven by the absence of delivery time restrictions, outdated vehicle standards, and insufficient infrastructure. Unlike global cities that implement structured freight policies, Surabaya lacks urban consolidation centers, low-emission zones, and delivery scheduling mechanisms, resulting in overlapping freight–commuter flows and heightened emissions. Findings provide evidence-based insights for implementing time-window regulations, low-emission zones, and consolidation hubs in rapidly urbanizing cities. This study contributes to urban freight literature by highlighting the compounded effects of fragmented delivery practices and outdated fleets in a Southeast Asian secondary city, offering a framework for data-driven policy reforms toward sustainable logistics.

Keywords: Urban Freight Transport, Traffic Congestion, Air Pollution, Sustainable Logistics, Surabaya CBD.

INTRODUCTION

consolidating deliveries, thereby reducing trip frequency and improving traffic flow. Similarly, the implementation of off-peak delivery schedules, particularly in Tokyo and London, has helped prevent freight-related traffic during critical commuter windows (Bektaş et al., 2017).

Despite advances in global urban freight strategies such as urban consolidation centers (UCCs), off-peak delivery, and low-emission fleets. ittle is known about how logistics vehicles specifically contribute to congestion and pollution in Indonesia's secondary cities like Surabaya. This gap is critical because developing cities face fragmented regulations, outdated vehicle standards, and insufficient infrastructure (He & Haasis (2020);Oliveira et al. (2019)).

Surabaya's situation illustrates the broader gap between urban logistics demands and regulatory capacity. As freight volumes grow, the absence of time window restrictions, loading zones, and low-emission incentives contributes to systemic inefficiencies. Recent data shows a lack of route consolidation among retailers, with individual deliveries made multiple times to the same commercial destinations. This pattern results in increased vehicle mileage, elevated emissions, and road congestion—an unsustainable trajectory for any modernizing city.

The implications of unmanaged urban freight extend beyond traffic dynamics. Gómez-Marín et al. (2020) and Pandya (2023) demonstrate that idling delivery trucks exacerbate air pollution and reduce road space efficiency. Public health is also at stake, as $PM_{2.5}$ concentrations during peak logistics activity have exceeded WHO thresholds in Surabaya's CBD (DLH Surabaya, 2023). These particles penetrate deep into the lungs and bloodstream, posing serious health risks for pedestrians and vulnerable populations.

International comparisons highlight the transformative potential of sustainable freight initiatives. In Paris and London, the creation of low-emission zones (LEZs) has significantly curtailed the presence of diesel-powered freight vehicles in urban centers, fostering a shift toward electric logistics fleets (Dablanc & Montenon, 2021). In contrast, Surabaya has yet to adopt emission-based access controls, remaining reliant on conventional diesel logistics operations. The absence of UCCs or micro-distribution hubs further undermines the potential for systemic freight efficiency.

In light of these issues, this study seeks to answer: How do logistics vehicle operations contribute to traffic congestion and air pollution in Surabaya's CBD? By addressing this question, the research generates empirical insights to inform policy measures such as delivery scheduling, UCCs, and low-emission zones that can enhance urban sustainability in rapidly urbanizing cities.

METHOD

This study employed a qualitative case study design to explore the dynamics of freight vehicle operations and their impacts on congestion and air quality in Surabaya's central business district (CBD). A qualitative approach was chosen because it allows for in-depth exploration of contextual, operational, and policy-related factors influencing urban freight (Paddeu, (2017);Browne et al., (2022)).

The research focused on Surabaya's CBD, particularly Jalan Tunjungan, Jalan Embong Malang, and Jalan Basuki Rahmat, areas with dense commercial activity and high freight traffic. Fieldwork was conducted in August–September 2024, coinciding with peak logistics operations prior to year-end demand.

Respondents were selected through purposive sampling, ensuring that individuals with relevant expertise or direct experience in logistics operations or urban environmental monitoring were included. A total of 10 informants participated, comprising:

- Three officials from the Surabaya Department of Transportation (Dishub) and Environmental Agency (DLH), who contributed technical data and regulatory perspectives;
- Two managers from local logistics firms and retail distribution services;
- Three active freight drivers operating in the CBD;
- Two local office workers and residents directly affected by urban freight activities. This stakeholder diversity ensured a comprehensive view of the logistics-traffic-environment interface and enriched the qualitative data collected.

Three primary methods were utilized for data collection:

In-depth Interviews: Semi-structured interviews were conducted to extract informants' views on logistics vehicle patterns, bottlenecks, air quality concerns, and the efficacy of existing policies. These interviews lasted 45-60 minutes and followed flexible thematic guides to capture spontaneous and reflective responses.

Field Observation: Systematic observations were carried out during peak traffic periods (07:00–10:00 and 16:00–18:30) across identified hotspots in the CBD. Observations focused on traffic flow disruptions, roadside unloading behavior, and the spatial distribution of freight vehicles. Visual records and field notes were maintained.

Document Analysis and Secondary Data: Supplementary data were collected from governmental reports, particularly from Dishub and DLH Surabaya, as well as local news articles, city traffic maps, and air quality index (AQI) reports.

This triangulated method ensured that the study captured both the subjective and objective aspects of urban freight operations, increasing the reliability and contextual depth of the analysis (Olsson et al., 2019).

Data were analyzed thematically following Miles, Huberman, & Saldaña (2014). The process included:

- Data reduction through coding interview transcripts and field notes,
- Data display using narrative matrices and thematic clustering,
- Conclusion drawing supported by respondent validation and peer discussion.

Validity was ensured through triangulation of sources, member checking, and audit trails, consistent with best practices in qualitative logistics research (Letnik et al., 2022; Yakeen, 2024).

RESULT AND DISCUSSION

The research engaged ten purposively selected informants from diverse backgrounds relevant to urban logistics in Surabaya. These included three technical staff from the Department of Transportation (Dishub) and the Environmental Agency (DLH), two logistics and retail managers, three active freight drivers, and two local office workers based in the CBD area. This stratification ensured a comprehensive capture of both operational and experiential dimensions of urban freight challenges. Their input formed the basis of a thematically organized dataset that reflects multifaceted understandings of logistics congestion and air quality implications. The varied perspectives gathered helped validate the findings by reflecting differentiated experiences based on role and exposure within the logistics ecosystem (Karakikes & Nathanail, 2022; Oliveira et al., 2019).

Operational Patterns of Freight Vehicles in Surabaya CBD

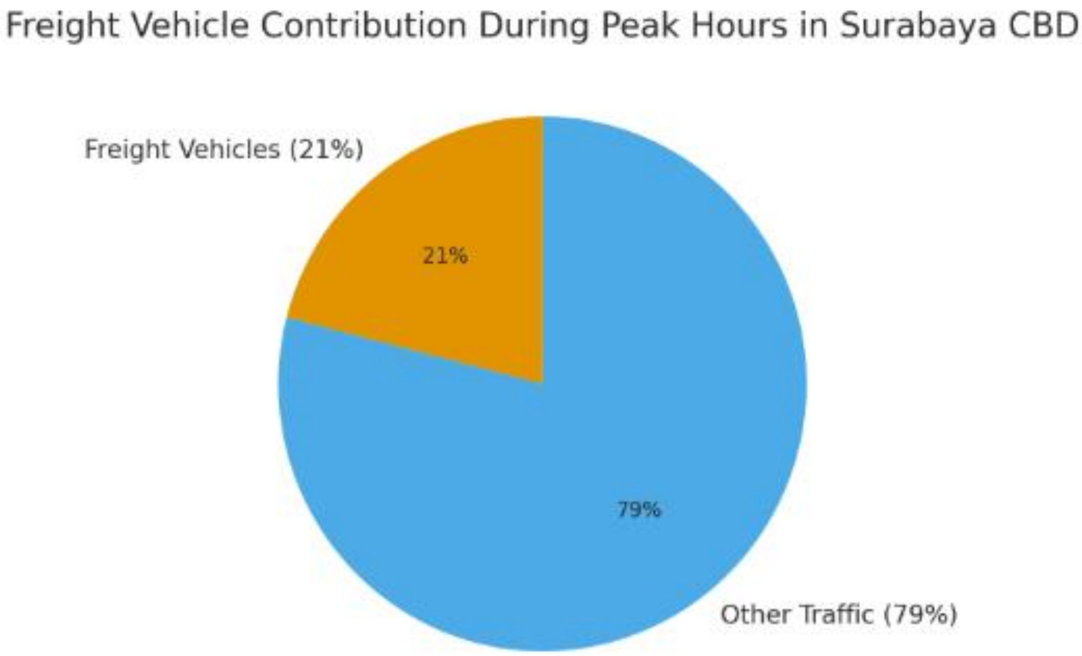
Field observations confirmed that logistics vehicle activity peaked during 07:00–10:00 and 16:00–18:30, periods corresponding with citywide commuter congestion. Informants reported a lack of regulated delivery windows, allowing unrestricted freight movement that competes with private and public transit flows. Drivers noted routine deliveries scheduled twice daily to the same urban destinations, driven by immediate merchant demands rather than coordinated distribution planning.

Stakeholders identified key congestion points along Jalan Embong Malang, Jalan Basuki Rahmat, and Jalan Tunjungan. Frequent on-street parking by delivery vehicles for loading/unloading exacerbated delays, often blocking traffic lanes and impeding visibility. These patterns mirror findings from comparable urban logistics studies, underscoring how unscheduled freight movement compounds peak-hour congestion (Gallo et al., 2024).

Contribution to Traffic Congestion

Traffic counts showed that freight vehicles represented 18–23% of peak-hour volume. Travel times on freight-heavy routes increased by 20–30%, e.g., a 7-minute trip on Jalan Basuki Rahmat extended to 11–12 minutes. These inefficiencies reflected the absence of route consolidation and centralized scheduling among logistics firms.

Figure 1. Freight Vehicle Contribution During Peak Hours



Impact on Air Pollution and Urban Environment

AQI data from the DLH in August 2024 revealed significant spikes in $PM_{2.5}$ concentrations during peak logistics operations, with levels reaching up to 40 µg/m³—well above WHO-recommended thresholds. This was attributed primarily to older diesel-powered freight vehicles lacking EURO 4 emission controls.

Community members, particularly those working near delivery hotspots, reported respiratory discomfort, frequent coughing, and increased perception of air pollution. Informants cited prolonged idling and outdated engine standards as contributing factors to localized emissions. These findings resonate with broader literature highlighting the linkage between freight transport and elevated urban pollution levels (Jones et al., 2020; Oskarbski & Kaszubowski, 2018).

The absence of dedicated unloading zones further magnified micro-environmental degradation, as logistics vehicles frequently occupied traffic lanes and sidewalk perimeters. This disrupted pedestrian flows and compounded environmental stressors in already constrained urban corridors.

In summary, the research evidences clear causal links between urban logistics inefficiencies and both traffic congestion and environmental decline in Surabaya's CBD. The lack of delivery scheduling, outdated vehicle standards, and infrastructural constraints collectively form a landscape that undermines urban mobility and livability. These outcomes reinforce the urgency for integrated freight management policies and investments in low-emission logistics systems.

The findings demonstrate that Surabaya's freight transport system operates in a chaotic and unsynchronized manner, with unrestricted deliveries during peak hours and fragmented scheduling among firms. Unlike structured systems in cities such as Tokyo or Barcelona that enforce delivery time windows (Taniguchi et al., 2020). Surabaya allows freight vehicles to overlap with commuter flows, intensifying congestion. This results in overlapping flows of commuter and freight traffic, contributing to urban gridlock. Giuliano & Dablanc (2019) identify this regulatory gap as a central cause of congestion in dense metropolitan areas. Without structured scheduling or centralized coordination, freight activity exacerbates traffic volumes at critical junctions such as Jalan Embong Malang and Jalan Basuki Rahmat.

Moreover, local demand-side practices compound the inefficiencies. Retailers and hotels often request multiple deliveries throughout the day, lacking a consolidated route system or city distribution centers. This aligns with the global critique of fragmented last-mile logistics in developing cities, where economic actors pursue efficiency at the firm level while imposing systemic inefficiencies on the urban transport network (Allen et al., 2017; Mepparambath et al., 2022). The absence of urban consolidation centers (UCCs) or micro-hubs further illustrates Surabaya's infrastructural shortfall in managing freight inflow into the CBD.

The traffic congestion resulting from freight vehicle operations not only delays private commutes but also imposes broader socio-economic costs. Observational data shows that logistics vehicles account for up to 23% of traffic during peak periods, causing 20–30% delays on affected routes. This mirrors findings from Zhang (2021) and Holguín-Veras et al. (2020), who show that freight traffic contributes significantly to micro-congestion in strategic business districts. Beyond lost time, such congestion raises logistical delivery costs, reduces retail predictability, and degrades public transport performance. Russo & Comi (2016) note that these externalities disproportionately affect urban residents, especially low-income workers relying on timely mobility.

From an environmental perspective, the study reveals that freight transport is a major contributor to urban air pollution. Diesel-fueled vehicles, many lacking EURO 4 emission standards, release high levels of PM2.5 and NO2 during peak hours. Air Quality Index (AQI) readings in Surabaya's CBD often exceed WHO thresholds during peak logistics periods. Similar patterns are noted in World Bank (2022) assessments of urban freight in developing nations. Brauer et al. (2019) emphasize that short-term exposure to PM2.5 can lead to acute respiratory infections and cardiovascular risks, especially for vulnerable populations such as pedestrians and motorcyclists.

The lack of low-emission zones (LEZs) or green logistics incentives in Surabaya further hampers environmental management. In contrast, cities like London and Paris have pioneered LEZs that restrict fossil-fuel freight vehicles and incentivize electric alternatives (Dablanc & Montenon, 2021). These measures have reduced transport-related carbon emissions by over 70%, showcasing the potential of targeted regulatory reform. Surabaya's delay in adopting similar measures reflects institutional inertia and limited stakeholder coordination, echoing findings from Sahu et al. (2022) regarding freight governance gaps in emerging economies.

International comparisons highlight potential pathways for reform. Gómez-Marín et al. (2020) and Aksoy & Gürsoy (2023) demonstrate how adaptive policies combining emissions control, delivery scheduling, and infrastructure redesign can mitigate congestion and pollution in congested cities.

These case studies provide valuable templates for Surabaya, which must balance economic growth with sustainable transport systems.

Furthermore, the socio-political context of Surabaya suggests the importance of participatory policy development. As shown in Duin et al. (2018), stakeholder engagement, including retailers, logistics firms, regulators, and residents, is essential in crafting logistics regulations that are enforceable and equitable. The present study's qualitative approach reveals a broad consensus among stakeholders regarding the need for structured delivery systems, yet no mechanisms currently exist to translate these views into formal policy.

Institutional and infrastructural innovation is thus pivotal. Investment in UCCs, smart delivery platforms, and electric logistics fleets would not only enhance efficiency but also position Surabaya as a regional model of urban freight modernization. Strategic alignment between transportation planning and environmental regulation is necessary to avoid policy fragmentation. As Sahu et al. (2022) and Karakikes & Nathanail (2022) suggest, cities must adopt integrative governance models that anticipate future freight demand and leverage digital technologies for dynamic logistics management.

CONCLUSION

This study demonstrates that logistics vehicles significantly exacerbate urban challenges in Surabaya's CBD, constituting up to 23% of peak-hour traffic**,** prolonging travel times by 20–30%**,** and elevating $PM_{2.5}$ levels beyond WHO thresholds due to reliance on aging diesel fleets. These findings highlight the inefficiencies of an unregulated freight system where the absence of delivery scheduling, outdated vehicle standards, and inadequate infrastructure undermine urban mobility and public health. By documenting these gaps in a secondary city context, the study contributes to urban freight literature and provides evidence-based guidance for implementing time-window regulations, urban consolidation centers, and low-emission zones in rapidly urbanizing environments.

Nevertheless, this research is limited by its qualitative scope and single-case focus, which may constrain generalizability. Future studies should integrate traffic simulations, longitudinal air quality data, and cross-city comparisons to provide stronger empirical foundations. Moving forward, Surabaya must prioritize coordinated freight reforms that balance economic growth with sustainability. Such initiatives will not only improve mobility and public health but also establish Surabaya as a regional model of sustainable urban freight governance.

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