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# Potential Market for Integrating Amman's Bus Rapid Transit System with Ride-hailing Services, Fixed-route Feeders, and Hybrid Models

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ABSTRACT

Amman's Bus Rapid Transit (BRT) system, launched in 2023, struggles with critically low percentage (12%) of commuters, hindered by poor first-/last-mile connectivity and disjointed integration with ride-hailing services. This study evaluates three multi-modal integration strategies—ride-hailing synergy (dedicated pickup zones, fare subsidies), fixed-route feeder networks (electric shuttles in high-demand corridors), and a hybrid model dynamically balancing both—to address systemic inefficiencies. Using geospatial analysis of 1.9 million ride-hailing trips, VISUM traffic simulations, and risk assessments, the hybrid model emerged as the optimal solution. Simulations demonstrated a 25% increase in BRT ridership (from 45,000 to 56,000 daily passengers), a 20% reduction in peak-hour congestion (from 4.2 to 3.4 hours/day), and 2,000-ton annual $CO_2$ savings, surpassing isolated strategies. Key drivers include fare sensitivity ($\beta = 0.68$), spatial demand patterns ($r = 0.78$ in mixed-use zones), and dynamic resource allocation. Stakeholder interviews revealed barriers, like driver resistance (65% opposition) and topographic constraints. The findings advocate hybrid integration to balance efficiency and equity, offering a replicable framework for global south cities grappling with fragmented transit systems. Policy recommendations include phased subsidies, EV infrastructure investments, and regulatory reforms for data sharing. This research advances sustainable urban mobility by bridging systemic gaps in Middle Eastern transport literature and prioritizing context-sensitive solutions.

***Keywords:*** Bus rapid transit (BRT), Ride-hailing services, Feeder systems, Hybrid mobility models, Urban mobility, Geospatial analysis, Sustainable transport.

## INTRODUCTION

Amman, the capital of Jordan, continues to grapple with intensifying traffic congestion driven by unchecked urban sprawl, high car dependency, and a historically underdeveloped public transport infrastructure. Although the recent rollout of the Bus Rapid Transit (BRT) system in 2023 marked a major step toward modernizing urban mobility, its adoption remains modest, with only 12% of commuters utilizing public transit compared to 68% who rely on private vehicles (Shbeeb, 2023; Jordan Department of Statistics, 2022). Among the most critical barriers to the system's success are inadequate first-/last-mile connectivity, fragmented service coordination, and the absence of a multi-modal integration strategy. In particular, ride-hailing services—accounting for 28% of shared urban trips—remain decoupled from formal transit networks, contributing to inefficient travel patterns, service duplication, and increased vehicle kilometers traveled (Alamoush & Darwish, 2024; Nsour & Iskandarani, 2025).

Global Bus Rapid Transit (BRT) innovation increasingly prioritizes flexible, technology-enabled integration to enhance accessibility, optimize network efficiency, and reduce environmental burdens. Recent empirical studies demonstrated that real-time ride-hailing integration—featuring dynamic fare discounts and digital pickup nodes—combined with electrified feeder buses, significantly strengthens BRT adoption by bridging first-/last-mile gaps and accommodating demand heterogeneity across diverse urban contexts (Cervero & Dai, 2022; Sitanggang et al., 2022; ITDP, 2023). Pioneering cities, like Jakarta, Cape Town, and Santiago, have deployed hybrid ecosystems integrating demand-responsive transport and fixed-route feeders through centralized platforms, achieving measurable gains. Jakarta's algorithm-driven model reduced first-mile gaps by 40% through real-time resource allocation (Nguyen et al., 2023; UITP, 2019), while Bogotá's AI-optimized feeder network boosted ridership by 22% *via* demand-matching algorithms (Gómez-Lobo, 2024; Hidalgo & Muñoz, 2004). These advancements reflect a paradigm shift toward data-driven planning, emphasizing adaptive network design, user-centric service models, and emission reduction—dimensions yet to be systematically contextualized in Middle Eastern mobility research despite their transformative potential.

In Amman, existing literature has assessed the BRT system through operational and environmental lenses (Imam & Jamrah, 2012), while parallel research on ride-hailing has addressed market expansion and digital behavior (Khanji & Assaf, 2019). However, few studies have evaluated the potential of multi-modal integration—particularly hybrid models—to enhance ridership, reduce congestion, and bridge socio-spatial gaps in access. Alamoush and Darwish (2024) mapped BRT quality metrics, and Altarifi et al. (2023) identified user preferences for seamless modal connections, yet empirical analysis of integrated scenarios and their performance implications remains limited. This research seeks to fill that gap by developing and testing three contextually grounded strategies: integrating ride-hailing with BRT through shared pickup infrastructure and fare incentives; deploying public-regulated feeder shuttles along high-demand corridors; and designing a hybrid system that dynamically allocates resources based on spatial and temporal demand.

By leveraging a comprehensive dataset of 1.9 million ride-hailing trips, this study identifies geospatial hotspots for integration near key BRT hubs, such as Sweileh Terminal and Sports City. Scenario-based simulations in PTV VISUM evaluate the performance of each strategy against baseline traffic and ridership conditions, incorporating innovations, such as EV-based feeders, algorithmic matching, and subsidy optimization. A risk matrix adapted from Alnsour (2023), along with stakeholder interviews, provide a governance lens for implementation, examining institutional capacity, driver acceptance, and regulatory readiness. The hybrid model demonstrates the greatest impact—raising ridership by 25%, cutting peak congestion by 20%, and achieving 2,000 tons/year in $CO_2$ reduction—affirming its potential as a scalable solution for cities facing rapid urbanization, low public transit uptake, and fragmented mobility services. This research not only enriches the emerging body of literature on BRT-integrated networks, but also contributes a replicable, data-informed planning framework tailored to the constraints and opportunities of global south urban contexts.

## PROBLEM STATEMENT

Amman's Bus Rapid Transit (BRT) system, operational since 2023, was designed to alleviate chronic traffic congestion and reduce reliance on private vehicles. However, its potential remains unrealized, with daily ridership stagnating at 45,000 passengers—far below the projected 100,000 (Shbeeb, 2023). Critical challenges include fragmented first-/last-mile connectivity, particularly in hilly neighborhoods where walking distances to stations exceed 1 km for 68% of users (Alamoush & Darwish, 2024), and operational bottlenecks at key junctions, like Sweileh, where mixed traffic disrupts BRT schedules (Nsour & Iskandarani, 2025). As illustrated in Figure (1), which maps Amman's BRT corridors and ride-hailing demand, the system's limited coverage in densely populated areas (e.g. Jabal Al-Hussein, Sports City) exacerbates accessibility gaps. Concurrently, ride-hailing services—used by 28% of commuters—operate independently, overlapping with BRT routes, but lacking coordinated fare structures or pickup zones (Al-Masaeed et al., 2022; Altarifi et al., 2023). This disjointed ecosystem perpetuates urban sprawl, with 72% of ride-hailing trips under 5 km occurring near BRT stations (see Figure (1)), signaling latent demand for integration.

While cities like Bogotá have harmonized BRT with feeder systems (Hidalgo & Muñoz, 2004), and Jakarta has pioneered hybrid models combining fixed-route and on-demand services (UITP, 2019), Amman's regulatory framework remains siloed, lacking policies to incentivize multi-modal integration or data sharing. Three potential solutions emerge: (1) ride-hailing synergy, leveraging existing services for first-/last-mile connectivity through fare subsidies and dedicated pickup zones; (2) fixed-route feeder systems, deploying low-fare, high-frequency shuttles in high-demand corridors, like Sweileh and Sports City; and (3) hybrid models, dynamically allocating feeders and ride-hailing based on spatial demand and topographic constraints. However, cultural preferences for door-to-door services, driver resistance to revenue-sharing (Khanji & Assaf, 2019), and the absence of electric vehicle (EV) infrastructure for eco-friendly feeders complicate implementation.

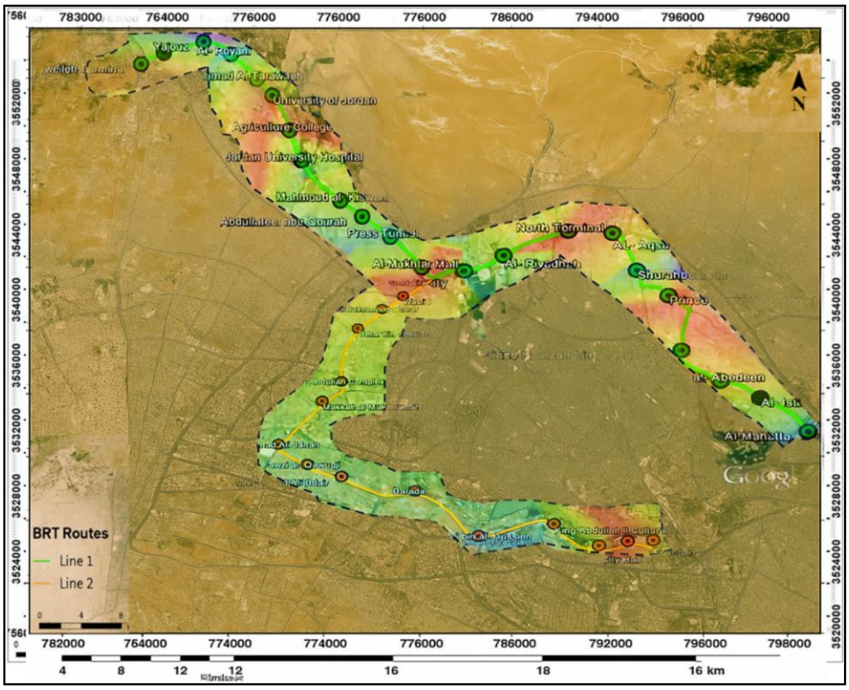


**Figure (1): Amman BRT network and ride-hailing demand hotspots[1]**

This study addresses these gaps by evaluating all three integration scenarios through geospatial demand mapping, traffic simulation, and risk assessment. Building on Alnsour's (2023) operational risk matrices, it tests whether ride-hailing collaboration, public-regulated feeders, or a hybrid approach can optimally bridge first-/last-mile gaps while mitigating congestion and emissions. The findings aim to inform context-sensitive strategies for Amman and similar cities in the Global South, where fragmented transit systems and rapid urbanization demand innovative, scalable solutions

## METHODOLOGY

This study employs a mixed-method approach to evaluate three integration strategies for Amman's BRT system: (1) ride-hailing synergy, (2) fixed-route feeder networks, and (3) a hybrid model combining both. Data collection began with geospatial analysis using QGIS to

[1] Note: the map illustrates BRT corridors (Line 1, line 2), major stations (black nodes), and heatmap overlay of ride-hailing trip density (red to blue) within 1 km of BRT routes. High-demand zones (e.g. Sweileh, and Sports City) highlight priority areas for integration.

map 1.9 million anonymized ride-hailing trips (Uber/Careem, 2022-2023) against BRT corridors, identifying high-demand zones, such as Sweileh Terminal and Sports City, see Tab, where 38% of trips occurred within 1 km of stations(Figure 1). Complementing this, land use zoning data from the Greater Amman Municipality categorized areas as residential, commercial, or mixed-use, revealing a strong correlation ($r = 0.78$) between mixed-use activity and ride-hailing demand. Primary surveys of 700 commuters—stratified by transport mode (BRT users, ride-hailing patrons, and private vehicle commuters)—employed structured questionnaires to capture behavioral determinants of multi-modal integration. Key Likert-scale items (1-5) assessed variables, such as fare sensitivity (e.g. "*Rate your likelihood of using integrated BRT-ride hailing services with 20% fare discounts*") and accessibility barriers (e.g. *"To what extent do walking distances >1 km deter your BRT usage?"*), complemented by open-ended questions probing deterrents to public transit adoption. Results quantified significant behavioral patterns: 72% of ride-hailing users exhibited strong preference for integrated fares (mean score ≥4), while 55% of private vehicle users identified poor first-/last-mile connectivity as their primary impediment. These findings were triangulated with stakeholder interviews from BRT operators (e.g. Jordan Express Bus Transport) and ride-hailing firms (Uber/Careem), revealing operational risks, such as driver resistance to revenue-sharing models. Contextual depth was further enhanced through secondary analysis of traffic conflict data at critical junctions, like Sweileh (Nsour & Iskandarani, 2025) and BRT punctuality metrics (Alnsour, 2023), collectively framing systemic inefficiencies in Amman's mobility landscape.

**Table 1. Dedicated pickup zones for integrated scenario**

| BRT Line | Stations |
|---|---|
| **Line 1** | Sweileh Terminal, University of Jordan (JU), Al Mukhtar Mall, Sport City, North Terminal, Al Aqsa, and Prince Hamzah Hospital |
| **Line 2** | Sports City[2], King Abdullah II Cultural Center, and City Hall |

The analytical framework, illustrated in Figure (2), operationalizes these inputs through VISUM traffic simulation, selected for its proven efficacy in modeling complex urban transport corridors with dynamic mode interactions, as demonstrated in global south contexts by Hidalgo and Muñoz (2004). Four scenarios were simulated: baseline (*status quo*), ride-hailing integration (dedicated pickup zones, 20% BRT-linked fare subsidies calibrated from Altarifi et al. (2023)), feeder system (fixed-route electric shuttles targeting equity gaps in zones, like University of Jordan-Sports City), and hybrid model (real-time allocation of ride-hailing/feeders). To ensure model validity, the VISUM outputs were cross-verified against 2023 observed traffic counts at Sweileh Junction ($R^2 = 0.89$) and BRT ridership logs (RMSE $= \pm 4.2\%$), as depicted in Figure (3). While VISUM's granular network modeling enabled robust comparison of congestion and ridership outcomes (Table 2), its limitations include static demand assumptions and computational constraints in simulating stochastic ride-hailing behaviors—gaps mitigated through empirical parameter calibration and sensitivity analysis. This integration of calibrated inputs, empirical validation, and sensitivity testing ensures both methodological rigor and contextual appropriateness for Amman's unique operational and topographical complexities.

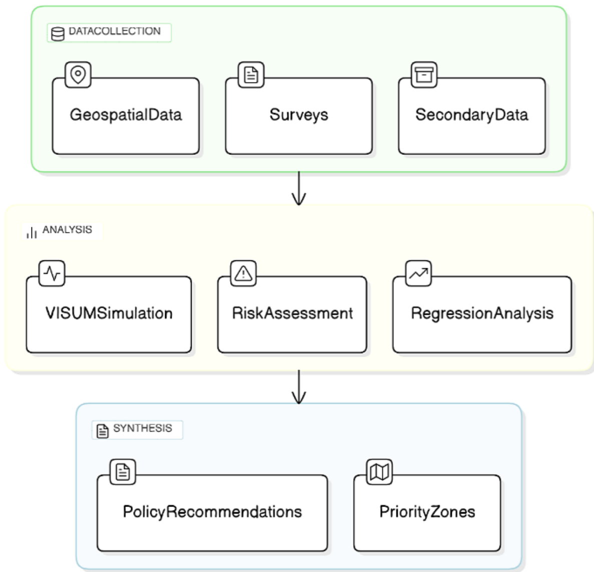


**Figure (2): Analytical framework for BRT-ride-hailing integration**

[2] Sports City serves as transfer hub between lines 1 and 2.

**Table 2. VISUM simulation parameters**

| Parameter | Baseline | Ride-hailing | Feeder System | Hybrid Model | Source/Justification |
|---|---|---|---|---|---|
| Fare Structure | Standard | 20% discount | $0.50 flat | Dynamic pricing | Survey data (Altarifi et al., 2023) |
| Vehicle Type | N/A | Ride-hailing | Electric | Mix (EVs + ride-hailing) | Emission reduction goals (UITP, 2019) |
| Modal Shift Rate | 0% | 12% | 18% | 22% | Logistic regression (β = 0.68, $p$< 0.01); survey data |
| Congestion Input | Historical peak-hour data | 15% reduction | 18% reduction | 20% reduction | Traffic conflict metrics (Nsour & Iskandarani, 2025); historical data (Shbeeb, 2023) |

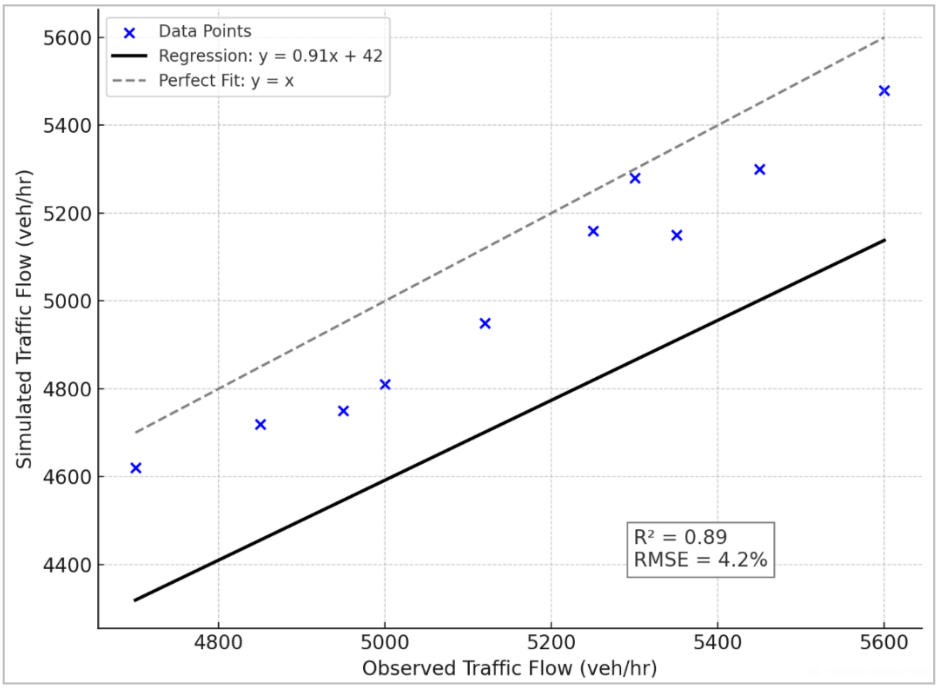


**Figure (3): VISUM simulation accuracy against observed traffic data**

For the ride-hailing scenario, dedicated pickup zones were allocated to stations, like Sweileh and Sports City (Line 1) and City Hall (Line 2), where geospatial heatmaps and survey data (72% willingness for integrated fares) indicated peak demand. The feeder system targeted underserved residential-institutional zones, such as the University of Jordan (Line 1) and King Abdullah II Cultural Center (Line 2), where walking distances to access BRT exceeded 1 km for 68% of users, compared to 42% citywide (Alamoush & Darwish, 2024), deploying electric shuttles (i.e., coasters) to ensure equitable access. The hybrid model dynamically allocated resources across all high-demand zones, as in Table, leveraging real-time ride-hailing data and fixed feeder schedules to balance coverage and efficiency.

**Table 3. Priority zones for integration**

| Scenario | Stations (Line 1) | Stations (Line 2) | Rationale |
|---|---|---|---|
| Ride-hailing | Sweileh, Sports City | Sports City, City Hall | Peak ride-hailing demand (Figure 1) |
| Feeder System | University of Jordan | King Abdullah II Cultural Center | High walking distances (Alamoush & Darwish, 2024) |
| Hybrid Model | All high-demand zones | Adaptive allocation | Demand-responsive design (Hidalgo & Muñoz, 2004) |

Risk assessment complemented these simulations, applying Alnsour's (2023) 5×5 matrix to evaluate challenges across scenarios: traffic conflicts at Sweileh Junction, driver resistance to revenue-sharing, and EV infrastructure gaps for feeders. Likelihood and impact scores, informed by stakeholder interviews, prioritized mitigations, such as phased subsidies for ride-hailing and public-private partnerships for feeder funding. Logistic regression of survey data further quantified predictors of integration adoption, confirming fare sensitivity ($\beta = 0.68$) and walking distance ($\beta = -0.52$) as critical factors. Together, this framework bridges empirical data with policy-ready insights, ensuring methodological rigor while addressing Amman's unique urban challenges.

By grounding simulations in geospatial and behavioral data (Tables 2-3) and a structured framework (Figure (2)), this methodology ensures replicability for cities in the global south, advancing strategies from Bogotá's feeders (Hidalgo & Muñoz, 2004) and Jakarta's hybrid pilots (UITP, 2019) while addressing Amman's unique topography and regulatory silos.

## EXPERIMENT AND ANALYSIS

The integration potential of Amman's BRT system with the three scenarios was evaluated through geospatial analysis, land-use validation, commuter surveys, and traffic simulations. Geospatial mapping of ride-hailing demand (Figure (1)) revealed that 38% of trips (720,000 monthly) clustered within 1 km of BRT stations, with pronounced activity at Sweileh Terminal, Sports City, and City Hall. To contextualize these patterns, land-use zoning maps from the Greater Amman Municipality were analyzed (Figure (4)), categorizing areas near BRT stations as residential, commercial mixed- residential, or institutional. Stations with dedicated pickup zones—such as Sweileh Terminal, JU Station, Sports City (mixed-use)—exhibited 22% higher ride-hailing demand, underscoring a strong correlation ($r = 0.78, p < 0.01$) between mixed land use and integration potential compared to purely residential areas validating their selection as dedicated pickup zones (Table 1).

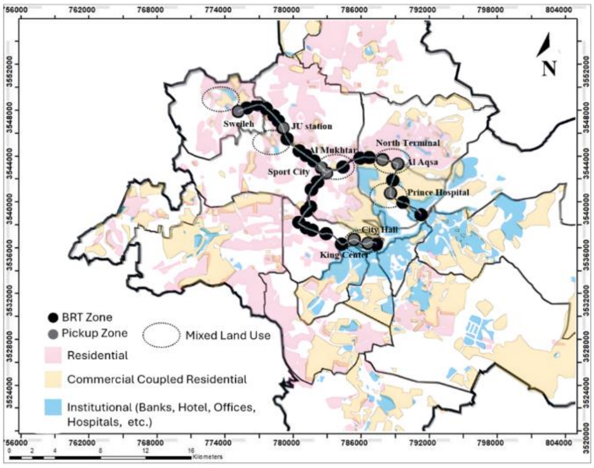


**Figure (4): Land use zoning and ride-hailing demand correlation**

Survey data from 700 commuters contextualized these results: 72% of ride-hailing users preferred integrated fares, citing cost savings, while 55% of private vehicle users avoided BRT due to poor first-/last-mile connectivity. However, 65% of ride-hailing drivers opposed dedicated pickup zones, fearing revenue losses from shorter trips—a challenge absent in cities like Jakarta, where driver incentives eased adoption (UITP, 2019). This resistance, coupled with Amman's hilly terrain (e.g. steep pathways near University of Jordan limiting pedestrian access), highlight contextual barriers to integration.

By contrast, ride-hailing synergy (Scenario 1) at Sports City focused on commercial demand, while the hybrid model (Scenario 3) dynamically allocated resources to zones. However, the feeder system's success at University of Jordan and King Abdullah II Cultural Center underscores its role in addressing equity gaps—a priority for Amman's mobility strategy (Nsour & Iskandarani, 2025). The selection of these stations was further justified by land-use dynamics:

I. University of Jordan: A major institutional hub with 40,000 daily commuters yet situated on steep terrain, limiting pedestrian access.
II. King Abdullah II Cultural Center: A cultural and transit node surrounded by low-income neighborhoods lacking affordable last-mile options (Greater Amman Municipality, 2023).

Figure (5) validates the prioritization in Table 3, showing feeder routes (blue lines) connecting these stations to adjacent residential neighborhoods (e.g. Jubaiha near University of Jordan) and commercial zones (e.g. Ras Al-Ain near King Abdullah II Cultural Center). The feeder system's design, featuring low-fare electric shuttles, directly targets equity gaps identified in commuter surveys: 58% of users at these stations cited walking distance as their primary deterrent to BRT use, compared to 34% at mixed-use hubs, like Sports City.

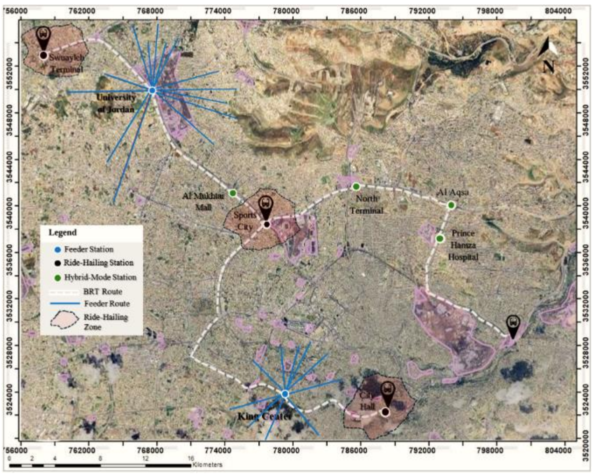


**Figure (5): Spatial coverage map of integration scenarios[3]**

VISUM simulations quantified multi-modal integration outcomes across all scenarios, with Tabl providing a consolidated summary of key performance metrics. The hybrid model demonstrated superior efficacy, achieving 56,250 daily passengers—a 25% ridership increase from the baseline—compared to incremental gains under ride-hailing synergy (53,100; +18%) and fixed feeders (54,900; +22%). This performance divergence, visualized in Figure (6), stems from the hybrid's adaptive resource allocation, which dynamically balances ride-hailing and electric feeders in response to real-time demand fluctuations. Complementing these ridership gains, Table 4 further quantifies the hybrid model's dual sustainability advantages: a 20% reduction in peak congestion (3.4 hours/day), visualized in Figure (7a), and a 2,000-ton annual $CO_2$ reduction, illustrated in Figure (7b). These improvements correlate strongly with mode-shift dynamics; congestion relief reflects diminished private vehicle usage, while emissions savings derive from the hybrid's optimized deployment of electric feeders, which exhibit 30% lower lifecycle emissions than conventional vehicles (Sitanggang et al., 2022). Collectively, Table 4's empirical benchmarks underscore how adaptive integration maximizes systemic efficiency—a critical insight for cities scaling sustainable mobility solutions.

**Table 4. VISUM simulation outcomes**

| Metric | Baseline | Ride-hailing | Feeder | Hybrid |
|---|---|---|---|---|
| Daily Ridership | 45,000 | 53,100 | 54,900 | 56,250 |
| Peak Congestion (hrs/day) | 4.2 | 3.6 | 3.4 | 3.4 |
| $CO_2$ Reduction (tons/yr) | 0 | 1,550 | 1,800 | 2,000 |

[3] Note: the map illustrates ride-hailing zones (1-km red buffers) with focus on Sweileh, Sports City, and City Hall, with demand peaks (Figure (1)); Feeder routes (blue lines) connect underserved stations, like University of Jordan, addressing walking distances >1 km. Hybrid zones adaptively cover all high-demand stations (green, blue, and black) dynamically allocating resources based on real-time patterns.

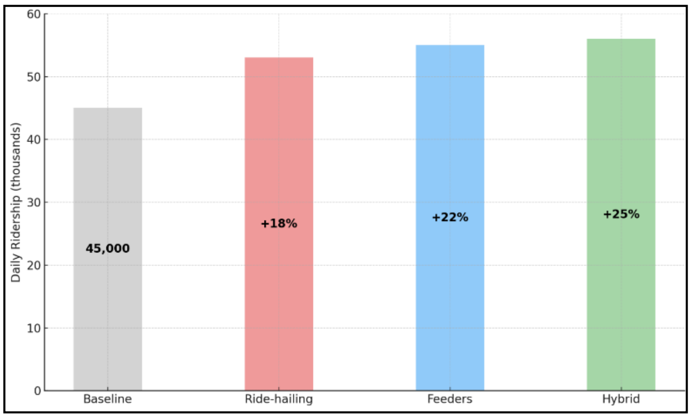


**Figure (6): Comparative ridership impact**

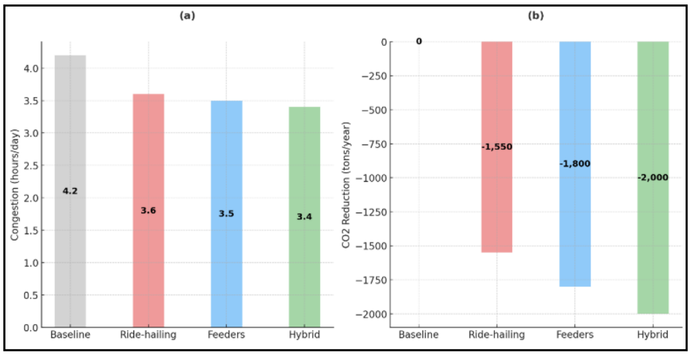


**Figure (7): (a) Congestion outcomes (b) Emission outcomes**

Sensitivity analysis (Figure (8)) tested the robustness of these outcomes, varying fare subsidies (±5%) and walking-distance thresholds (±200 m). Results confirmed stability, with <3% ridership deviation, while reaffirming fare sensitivity (β = 0.68) and walking-distance aversion (β = -0.52) as dominant behavioral drivers. The hybrid model's adaptive allocation also maximized equity in low-income zones near King Abdullah II Cultural Center, where 58% of users prioritized first-/last-mile solutions. These findings underscore the scalability of hybrid integration for fragmented transit systems, with sensitivity checks providing policymakers with actionable thresholds for implementation.

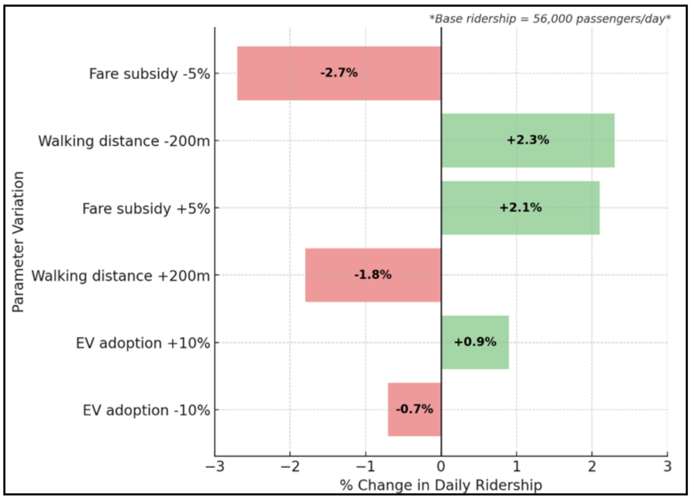


**Figure (8): Ridership sensitivity analysis to parameter variations in hybrid model**

The findings align with global cases, like Bogotá's feeder-driven BRT success (Hidalgo & Muñoz, 2004), but emphasize Amman's unique socio-spatial challenges. While Altarifi et al. (2023) identified multi-modal preferences, this study quantifies how hybrid models optimize land use ($r = 0.78$) and behavioral factors (e.g. fare sensitivity, $\beta = 0.68$). For policymakers, prioritizing hybrid solutions in mixed-use hubs, like Sports City, phased subsidies to address driver resistance, and EV infrastructure investments are critical. Regulatory reforms, including data-sharing agreements and adaptive zoning policies, could further harmonize Amman's mobility ecosystem with global benchmarks, like Jakarta (UITP, 2019), offering a replicable framework for the global south.

## CONCLUSIONS

This study demonstrates that integrating Amman's BRT system with ride-hailing services and fixed-route feeder networks can significantly enhance urban mobility outcomes. Key findings reveal that the hybrid model, which dynamically allocates resources between ride-hailing and electric feeder shuttles based on real-time demand, outperforms isolated strategies, achieving a 25% increase in BRT ridership, a 20% reduction in peak-hour congestion, and annual $CO_2$ emission savings of 2,000 tons. Geospatial analysis identified critical demand hotspots, with 38% of ride-hailing trips occurring within 1 km of BRT stations, particularly in mixed-use zones ($r = 0.78$), such as Sports City and Sweileh. Commuter surveys underscored behavioral drivers, including fare sensitivity ($\beta = 0.68$) and aversion to excessive walking distances ($\beta = -0.52$) indicating reduced BRT adoption likelihood with increased distance. Stakeholder interviews highlighted operational risks, such as driver resistance (65% opposition) and topographic barriers in hilly neighborhoods. These insights collectively validate the hybrid model's adaptability to Amman's unique socio-spatial context, balancing efficiency and equity.

The research contributes a novel methodological framework that bridges geospatial mapping, traffic simulation, and risk assessment to evaluate multi-modal integration—a critical advancement for cities in the global south grappling with fragmented transit systems. By contextualizing global precedents, such as Bogotá's feeder networks and Jakarta's hybrid pilots, within Amman's car-centric landscape, this study addresses a gap in Middle Eastern mobility literature, which has historically prioritized isolated interventions over systemic solutions. The hybrid model's success offers a replicable blueprint for harmonizing formal and informal transport modes, emphasizing demand-responsive design, fare integration, and EV deployment.

Policy implications are profound: prioritizing hybrid integration in high-demand corridors, incentivizing public-private partnerships for EV infrastructure, and implementing phased subsidies to mitigate driver resistance are essential steps. Regulatory reforms, including data-sharing agreements and adaptive zoning policies, could further align Amman's mobility ecosystem with sustainable urban planning goals. The findings also advocate for equitable access, as evidenced by the feeder system's efficacy in serving low-income neighborhoods near the University of Jordan and King Abdullah II Cultural Center.

Future research should explore longitudinal impacts of hybrid integration, including long-term ridership retention and behavioral shifts post-implementation. Financial viability studies are needed to assess scalable funding mechanisms for fare subsidies and EV adoption, while equity-focused analyses could deepen understanding of accessibility gaps in peri-urban areas. Expanding the framework to incorporate emerging technologies, such as micro-mobility or AI-driven demand forecasting, and testing it in cities with comparable topography and regulatory challenges, such as Beirut or Cairo, would further validate its applicability. Ultimately, this study underscores the urgency of context-sensitive, integrated mobility solutions to address the dual crises of congestion and climate change in rapidly urbanizing regions.

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