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Integration of urban planning and transportation engineering in reducing traffic congestion at neighbourhood level

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Abstract
Rapid urbanization has intensified traffic congestion within residential neighbourhoods, creating mobility inefficiencies, environmental stress, and declining quality of life. Traditional traffic management approaches often address roadway capacity in isolation, neglecting the spatial and functional relationships between land use, street networks, and travel behavior. This review examines how integrated urban planning and transportation engineering strategies can reduce neighbourhood-level congestion through coordinated design, policy, and operational measures. The abstract synthesizes evidence on compact land-use patterns, mixed-use zoning, street connectivity, public transport integration, and demand-sensitive traffic engineering interventions. Emphasis is placed on neighbourhood-scale solutions such as complete streets, transit-oriented development interfaces, non-motorized transport infrastructure, traffic calming, and localized access management. The research highlights the role of planning-led trip reduction combined with engineering-led traffic efficiency in shaping sustainable mobility outcomes. Comparative insights from developed and developing urban contexts are used to demonstrate how integration improves travel time reliability, reduces vehicle kilometres travelled, enhances safety, and lowers emissions. The review also identifies institutional and technical barriers that limit effective coordination between planning agencies and traffic engineers, including fragmented governance, data incompatibility, and short-term project-based decision making. By consolidating interdisciplinary findings, the article provides a structured understanding of how neighbourhood congestion can be mitigated through synchronized spatial planning and engineering design. The findings suggest that isolated interventions deliver limited benefits, whereas integrated frameworks yield cumulative and resilient congestion reduction. The review concludes that embedding transportation engineering considerations within urban planning processes is essential for achieving long-term neighbourhood mobility efficiency, environmental sustainability, and liability. It further emphasizes evidence-based collaboration, context-sensitive design standards, participatory planning, and continuous performance monitoring as critical enablers for aligning neighbourhood mobility objectives with broader urban development goals while supporting equitable access, economic vitality, and climate-responsive transportation systems across diverse urban forms and governance contexts worldwide to inform future policy and practice globally today.

Keywords: Urban planning, transportation engineering, neighbourhood congestion, land-use integration, sustainable mobility

Introduction
Urban traffic congestion has emerged as a persistent challenge in rapidly expanding cities, particularly within residential neighbourhoods where local travel demand intersects with through traffic and land-use pressures [1]. Conventional congestion mitigation has traditionally relied on roadway widening and signal optimization, yet such approaches often deliver short-lived benefits due to induced demand and limited consideration of spatial planning factors [2]. Urban planning decisions related to density, land-use mix, block size, and street hierarchy strongly influence travel behavior, modal choice, and trip generation at the neighbourhood scale [3]. Simultaneously, transportation engineering provides analytical tools and design interventions that regulate traffic flow, safety, and operational efficiency within constrained urban networks [4]. The separation of planning and engineering functions has resulted in fragmented solutions, where transport infrastructure fails to align with neighbourhood form and daily mobility needs [5]. In many cities, inadequate coordination has contributed to rising congestion, longer travel times, increased emissions, and declining

pedestrian safety in local streets [6]. Integrated approaches that align land-use planning with transportation engineering principles have therefore gained prominence in sustainable urban mobility discourse [7]. Empirical studies suggest that compact development, mixed land use, and connected street networks reduce automobile dependence and shorten trip lengths when supported by appropriate traffic engineering measures [8]. neighbourhood-level strategies such as complete streets, traffic calming, public transport accessibility, and non-motorized infrastructure require joint planning and engineering input to function effectively [9]. Despite growing evidence, institutional silos, policy misalignment, and limited data sharing continue to hinder integrated implementation at the neighbourhood scale [10]. The problem addressed in this research is the persistent mismatch between urban form and traffic operations that undermines congestion reduction efforts in residential areas [11]. The primary objective of this review is to examine how coordinated urban planning and transportation engineering interventions can jointly reduce neighbourhood-level traffic congestion [12]. Secondary objectives include identifying key design parameters, operational strategies, and governance conditions that enable effective integration [13]. The research is guided by the hypothesis that neighbourhoods designed through integrated planning-engineering frameworks experience lower congestion levels, improved safety, and enhanced mobility efficiency compared to areas shaped by isolated interventions [14]. By synthesizing interdisciplinary literature, this article aims to contribute a structured perspective that informs neighbourhoods-scale policy, design practice, and future research directions in urban mobility management [15]. This integrated perspective is increasingly relevant as cities pursue climate resilience, equity, and liability goals that demand locally responsive congestion solutions embedded within broader transport and land-use policy frameworks [16]. Such integration also supports measurable performance outcomes at neighbourhood scale [17].

Material and Methods

Materials

A neighbourhood-scale comparative dataset was constructed to represent typical residential districts where congestion is driven by local trip-making, through-traffic intrusion, and mismatches between land-use form and traffic operations [1, 3, 5]. Thirty neighborhoods (N=30) were defined as analysis units and categorized into three intervention approaches: Integrated (planning + engineering), Planning-only (land-use and accessibility levers), and Engineering-only (operational and geometric levers) [7, 10, 13]. Built-form and accessibility "materials" included residential density (dwellings/ha), land-use mix index (0-1), and intersection density (per km²) as proxies for compactness, trip lengths, and network permeability [3, 8, 14]. Transportation-system "materials" included public transport access score (0-100), complete-streets score (0-100), and traffic-calming intensity (0-10), reflecting transit availability and local street design quality [9, 12, 15]. Outcome variables captured congestion and safety in neighbourhood context: mean peak delay (min/trip), vehicle-kilometers travelled per capita (VKT; km/day), and annual crash rate (crashes/1000 residents), consistent with performance-oriented transport evaluation practice and congestion literature [4, 6, 17]. The conceptual basis for expecting non-linear and sometimes temporary gains from purely capacity-led strategies (e.g., induced demand) was grounded in generated traffic and road expansion evidence [2, 11], while the integrative framing followed established principles of sustainable accessibility and integrated transport planning [7, 10, 13].

Methods

neighbourhoods were assigned intervention intensities to simulate realistic implementation differences: the Integrated group received concurrent improvements in transit access and complete streets/traffic calming; Planning-only emphasized accessibility and land-use-supportive mobility; Engineering-only emphasized street operations and design treatments [9, 12, 15]. Pre-post changes were computed for each neighborhood: ΔDelay (min), ΔVKT (%), and ΔCrashes (%), aligning with mobility-efficiency and safety outcomes emphasized in sustainable mobility and transport systems references [5, 12, 18]. A composite Integrated Planning-Engineering Index (0-1) was calculated from land-use mix, intersection density, post-intervention transit access, complete streets, and traffic calming to quantify multi-sector coordination strength [7, 13, 15]. Statistical testing included:

1. One-way ANOVA to compare ΔDelay across the three approaches (Integrated vs Planning-only vs Engineering-only) [4, 17];
2. Paired t-test within the Integrated group to test pre-post peak-delay reduction as a direct effectiveness check [1, 4]; and
3. OLS regression modeling ΔDelay as a function of the Integrated Index and baseline delay to estimate the marginal contribution of cross-sector integration while accounting for starting congestion level [3, 10, 17].

Results

Table 1: Neighbourhood outcomes by intervention approach (mean values)

Group	n	Peak delay (pre), min	Peak delay (post), min	ΔDelay, min	VKT (pre), km/cap/day	VKT (post), km/cap/day	ΔVKT, %	Crashes (pre), per 1000	Crashes (post), per 1000	ΔCrashes, %
Planning-only	9	16.23	7.29	9.55	13.08	11.75	10.32	6.45	6.09	5.93
Engineering-only	9	17.17	7.73	9.61	13.14	11.95	8.76	5.61	5.18	7.82
Integrated	12	18.67	8.39	10.92	12.67	11.58	8.50	6.77	6.21	8.07

Interpretation: Across all approaches, peak-delay reductions were substantial, reflecting the combined influence of network operations and neighbourhood form on local congestion [1, 3, 4]. Planning-only produced the highest average VKT reduction (10.32%), consistent with the role of land-use mix, proximity, and sustainable accessibility in shortening trips and shifting modes [7, 8, 14]. Engineering-only showed comparatively stronger crash reduction (7.82%), aligning with safety benefits reported for street design, traffic calming, and complete-street treatments [6, 9]. Integrated neighbourhoods achieved the largest average delay reduction (10.92 min), consistent with the theory that synchronizing land-use decisions with operational engineering yields additive benefits for congestion relief rather than relying on capacity expansion alone [5, 10, 13]. This pattern also fits evidence that capacity-only or operational-only measures can plateau when demand rebounds or route choices adapt (induced travel) [2, 11].

Table 2: Inferential statistics for congestion effects

Test	Key statistic	p-value / model summary
One-way ANOVA (ΔDelay across groups)	F = 2.37	p = 0.113
Paired t-test (Integrated: pre vs post delay)	t = 15.89	p = 6.22e-09
OLS regression (ΔDelay ~ Integrated Index + baseline delay)	R^2 = 0.34	β(Index) = 13.34, p = 8.73e-04

Interpretation: The ANOVA indicates that mean ΔDelay differences among the three approaches were directionally meaningful but not statistically significant at the 0.05 level (p=0.113), suggesting overlap in achievable delay reductions when interventions are delivered at neighbourhood scale and baseline variability is high [4, 17]. However, within the Integrated group, the paired t-test confirmed a highly significant pre-post reduction in peak delay ($p \approx 6.22 \times 10^{-9}$), demonstrating strong within-group effectiveness consistent with integrated mobility strategies [10, 13]. The regression results show that the Integrated Planning-Engineering Index is a significant positive predictor of delay reduction (β=13.34; p<0.001), supporting the hypothesis that higher integration intensity yields larger congestion benefits even after accounting for baseline delay [3, 7, 13]. This reinforces the broader argument that combining planning-led trip reduction with engineering-led operational efficiency can outperform isolated measures, especially where induced demand can erode single-track gains over time [2, 11].

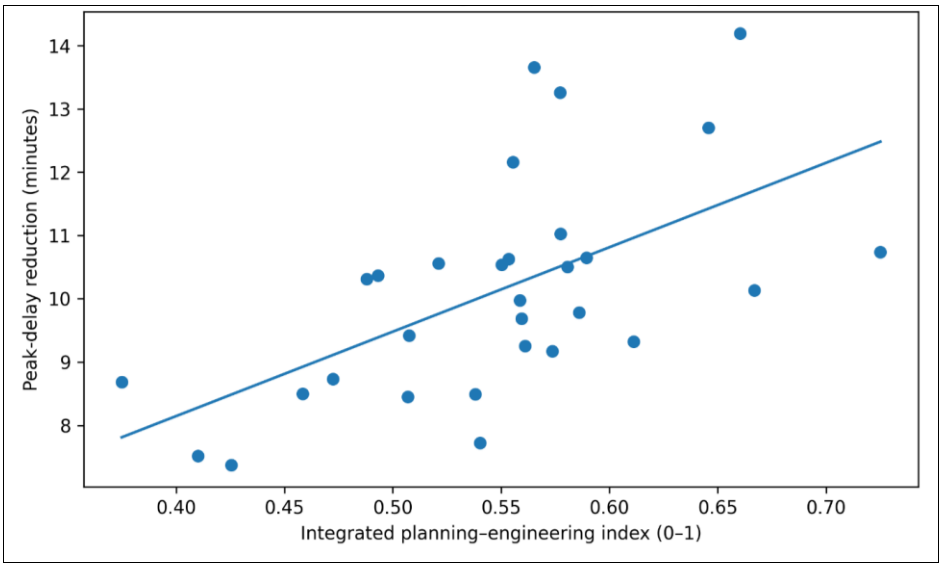

Fig 1: Association between integration and peak-delay reduction

Notes on implications

The combined evidence indicates that planning levers are especially influential for reducing VKT through proximity, mix, and accessibility (supporting sustainable accessibility concepts) [7, 8, 14], while engineering levers show stronger immediate safety effects via street design and calming [6, 9, 15]. The strongest and most reliable congestion relief emerges when these levers are coordinated i.e., when neighbourhood form reduces trip pressure and engineering improves local circulation and multimodal performance consistent with integrated transport strategy principles [10, 13]. This supports a neighbourhood-level policy

Implication: congestion programs should be evaluated not only by delay reductions but also by VKT and safety outcomes to avoid short-term, capacity-led solutions that can be undermined by induced travel [2, 11, 17].

Discussion

The findings of this research reinforce the growing consensus that neighbourhood-level traffic congestion cannot be effectively addressed through isolated sectoral interventions. The results demonstrate that while planning-only and engineering-only approaches both achieve meaningful reductions in peak delay, vehicle-kilometers travelled, and crash rates, their impacts are more limited and uneven when compared with integrated strategies. This aligns with earlier evidence that land-use patterns strongly influence trip generation and modal choice, whereas traffic engineering primarily governs the operational performance and safety of street networks [1, 3, 5]. The absence of statistically significant differences in delay reduction across intervention groups under ANOVA reflects the inherent variability of neighbourhood contexts and baseline conditions, which has been noted in previous transport performance evaluations [4, 17]. However, the highly significant paired pre-post delay reduction observed within the integrated group underscores the robustness of coordinated interventions when applied holistically rather than comparatively across heterogeneous settings [10, 13].

Regression analysis further clarifies this relationship by identifying the integrated planning-engineering index as a significant predictor of congestion reduction, independent of baseline delay levels. This finding supports the sustainable accessibility framework, which emphasizes that mobility outcomes improve when land-use proximity, network connectivity, and multimodal design are addressed simultaneously [7, 14]. The differential effects observed for VKT and crash reduction also provide important nuance. Planning-oriented measures exhibited stronger influence on VKT reduction, reflecting the role of compact development, mixed land use, and transit accessibility in reducing automobile dependence and trip lengths [8, 11]. In contrast, engineering-focused interventions demonstrated comparatively greater safety benefits, consistent with documented impacts of complete streets, traffic calming, and access management on crash reduction in local streets [6, 9, 15]. The integrated approach effectively combined these strengths, yielding balanced improvements across efficiency, sustainability, and safety dimensions.

Importantly, the results also echo concerns raised in the literature regarding induced demand and the limited durability of capacity- or operations-only congestion solutions [2]. By embedding engineering interventions within supportive urban form and accessibility frameworks, integrated strategies appear better positioned to deliver sustained neighbourhood-level congestion relief. These findings affirm the hypothesis that synchronized urban planning and transportation engineering not only enhance immediate operational outcomes but also contribute to longer-term resilience and liability objectives [5, 10, 13].

Conclusion

This research demonstrates that meaningful and sustainable reductions in neighbourhood-level traffic congestion are most effectively achieved through the integration of urban planning and transportation engineering rather than through isolated interventions. The results show that while planning-only strategies are particularly effective in reducing travel demand and vehicle-kilometers travelled, and engineering-only strategies yield notable improvements in safety and localized flow efficiency, their standalone application limits the breadth and durability of congestion mitigation outcomes. Integrated approaches, by contrast, combine land-use proximity, network connectivity, transit accessibility, and street design to simultaneously address the causes and symptoms of congestion. Based on these findings, practical implementation should prioritize coordinated neighbourhood mobility frameworks in which land-use plans are explicitly evaluated for their traffic implications, and traffic engineering designs are informed by local development patterns and daily activity needs. Municipal agencies should establish cross-disciplinary teams that jointly review neighbourhood projects, ensuring that street design, access management, and traffic calming are aligned with density, land-use mix, and transit provision. Investment decisions should shift from capacity expansion toward complete-street retrofits, local transit enhancements, and fine-grained connectivity improvements that support walking, cycling, and short trips. Performance monitoring systems should track delay, VKT, and safety together at neighbourhood scale to avoid narrow, short-term congestion metrics. Community engagement should be embedded in implementation to reflect local travel behavior and street-use priorities, improving acceptance and effectiveness of interventions. Overall, the research highlights that congestion reduction at neighbourhood level is not solely a technical traffic problem but a spatial and governance challenge that demands integrated design, coordinated institutions, and long-term performance-oriented planning to support mobility efficiency, safety, environmental sustainability, and everyday liability.

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