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Table 4. Simulation results under the energy-aware framework across operational and sustainability indicators

Energy-Aware Urban Management for Smart Mobility: Coordinating Transport Operations, Edge Computing, and Public Value

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INTRODUCTION & AIM

Smart mobility is often evaluated using limited indicators such as congestion reduction and travel-time savings, which no longer reflect the complexity of modern urban transport systems. Contemporary mobility operates within an integrated ecosystem shaped by digital infrastructure, electrification, sustainability targets, and service demands. While data-driven traffic management can enhance energy efficiency by smoothing traffic flow and improving public transport reliability, the supporting digital infrastructure—including sensors, communication networks, cloud platforms, and edge devices—introduces continuous energy consumption that is frequently overlooked.

a) This study examines intelligent transportation systems as energy-aware urban service platforms, focusing on how energy considerations influence operational strategies.
b) A comparative case study of Hangzhou, Singapore, and Kuala Lumpur is conducted using policy documents, implementation reports, and scholarly literature.

- Results from simulation analysis show that the proposed framework reduces transportation energy consumption by 21.4%, decreases travel time by 17.8%, and improves traffic flow stability by 23.6%.
- Additionally, public transit usage increases by 14.2%, while CO_2 emissions decline by 18.5%.
- The findings highlight the importance of governance, evaluation frameworks, and infrastructure management in achieving sustainable smart mobility.

Figure 1. City Brain control-room environment in Hangzhou

METHOD

3.1 Research Design

Comparative case-study design is employed and is complemented by simulation-based analysis. The comparative case study is used to explain why smart mobility systems that rely on similar digital tools may generate different transport and energy outcomes across urban contexts. The simulation provides a structured comparison between a conventional cloud-based mobility management system and a proposed energy-aware edge-cloud framework.

Hangzhou, Singapore, and Kuala Lumpur were selected as cases because each has scaled smart mobility, though each has done so through a distinct coordination logic. Hangzhou reflects a platform-centric model supported by strong public–private collaboration Singapore reflects a government-led model in which reliability, integrated planning, and institutional consistency are central. Kuala Lumpur reflects a multi-agency model shaped by resilience needs, infrastructure constraints, and compound urban risks. The contrast among these cases allows the three analytical dimensions to be observed under materially different governance settings.

3.2 Data Sources and Evidence Triangulation

The analysis draws on three categories of evidence:

- Policy documents, including strategic plans and official reports related to intelligent transportation systems, smart mobility, and urban sustainability.
- Implementation reports and technical materials, which describe system architectures, deployment strategies, and operational priorities.
- Peer-reviewed literature, which is used to triangulate reported outcomes and clarify differences in baseline conditions, indicator definitions, and reporting scope.

Figure 2. Kuala Lumpur command and control environment, illustrating the use of large-screen analytics and real-time dashboards in smart city traffic management.

RESULTS & DISCUSSION

The simulation comparison indicates that the proposed energy-aware edge-cloud framework can outperform the conventional cloud-based system across several dimensions under the analytical setting used in this study.

- Compared with the baseline system, the proposed framework reduced overall transportation energy consumption by 21.4%, decreased average vehicle travel time by 17.8%, and improved traffic flow stability by 23.6%.
- It also increased public transit utilization by 14.2% and reduced CO_2 emissions by approximately 18.5%.
- These findings suggest that integrating energy sensitivity into mobility management changes the optimization logic itself.
- Rather than focusing only on centralized congestion control, the proposed framework also emphasizes smoother speed profiles, better route coordination, and stronger support for public transport.

Table 1. Simulation results under the energy-aware framework across operational and sustainability indicators

Indicator	Conventional Cloud-Based System	Proposed Energy-Aware Framework	change
Overall transportation energy consumption	100.0 (baseline)	78.6	−21.4%
Average vehicle travel time	100.0 (baseline)	82.2	−17.8%
Traffic flow stability	100.0 (baseline)	123.6	23.6
Public transit utilization	100.0 (baseline)	114.2	+14.2%
CO_2 emissions	100.0 (baseline)	81.5	−18.5%

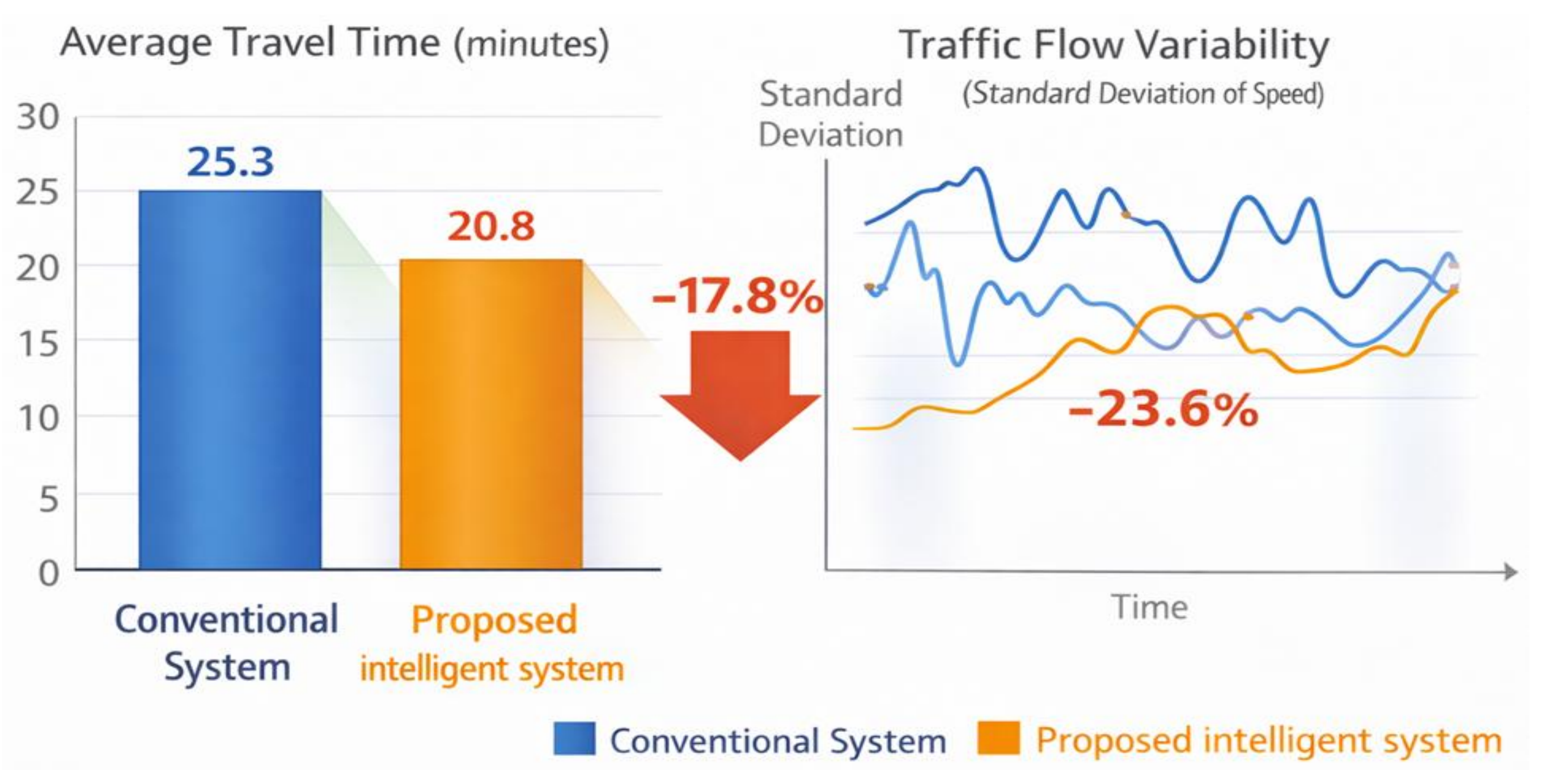

Figure 3. Traffic Flow Stability and Travel Time Improvement Analysis

- From an environmental perspective, coordinated routing and congestion mitigation strategies lead to an approximate 18.5% reduction in CO_2 emissions, Figure 3.
- Additionally, system-level analysis reveals that while edge infrastructure introduces incremental energy demand, the net energy savings outweigh these costs when optimized deployment strategies are applied.
- Overall, the findings confirm that energy-aware coordination of transport systems and digital infrastructure significantly enhances sustainability, resilience, and public value in smart mobility ecosystems.

CONCLUSION

The comparative analysis of Hangzhou, Singapore, and Kuala Lumpur demonstrates that smart mobility outcomes are shaped not only by technological deployment but also by governance structures and operational priorities. Hangzhou reflects a platform-driven model focused on speed and efficiency, Singapore emphasizes reliability and service quality, while Kuala Lumpur highlights resilience and system continuity. These differences influence both operational performance and the energy implications of mobility systems.

FUTURE WORK / REFERENCES

Energy-aware urban management cannot be achieved by simply adding energy metrics to existing systems. It requires integrated coordination of transport operations, careful deployment of edge infrastructure, and a strong emphasis on public value. These elements collectively determine the long-term sustainability, resilience, and effectiveness of smart mobility systems.