

Urban environment comparisons between street connectivity and mobility preferences in Kota Bharu City Centre, Kelantan

Wan Saiful Nizam Wan Mohamad^{1*}, Khalilah Hassan¹, Ramly Hasan², Nor Hamizah Abdul Hamid¹, Noorliyana Ramlee¹, Syahidah Amni Mohamed², Lee Bak Yeo¹ and Nurul Izzati Othmani¹

¹Sustainability, Urban Design & Wellbeing Research Group, Faculty of Architecture & Ekistics, Universiti Malaysia Kelantan, 16300 Bachok, Kelantan, Malaysia

²Architectural Heritage & Cultural Studies Research Group, Faculty of Architecture & Ekistics, Universiti Malaysia Kelantan, 16300 Bachok, Kelantan, Malaysia

ARTICLE HISTORY

Received : 12 October 2025

Accepted : 30 December 2025

Online : 30 September 2026

KEYWORDS

street connectivity,
space syntax,
urban mobility,
heritage city,
driving behaviour,
Kota Bharu

✉ * CORRESPONDING AUTHOR

LAr. Dr. Wan Saiful Nizam Wan
Mohamad
Sustainability, Urban Design &
Wellbeing Research Group, Faculty of
Architecture & Ekistics, Universiti
Malaysia Kelantan, 16300 Bachok,
Kelantan, Malaysia
Email: saifulnizam@umk.edu.my

ABSTRACT

Urban environment design plays an important role in shaping drivers' behaviour and route preferences when navigating urban areas during both peak and off-peak hours. Street connectivity involving multiple turns, indirect routes, or longer travel distances increases uncertainty regarding traffic conditions and travel times. Such spatial complexity often causes drivers to experience confusion, hesitation, or inefficient route selection, which indirectly contributes to undesirable driving behaviours. In contrast, well-connected street networks provide clearer route options and more direct access to destinations. This facilitates smoother traffic flow, improves mobility efficiency, and reduces stress among drivers in urban environments. This study investigates the relationship between street connectivity and urban mobility preferences in the city centre of Kota Bharu, Kelantan. The city centre was selected due to its rapid urbanisation, which has enhanced connectivity with surrounding districts and reinforced its cultural identity, thereby centralising local mobility. Data were collected through integration mapping and site observations in Kota Bharu. The data were analysed using space syntax techniques, including axial-line and HH-integration, to examine the relationship between street connectivity and drivers' route preferences. The results indicate that Jalan Sultanah Zainab functions as the primary movement corridor in Kota Bharu, with the highest street connectivity (32) and integration value (2.0524). The high level of spatial integration attracts drivers from surrounding streets, making the corridor a preferred route to major destinations and key urban nodes, including heritage, cultural, tourism, and institutional areas. These findings highlight the strategic importance of street connectivity parameters in shaping urban mobility patterns and improving overall mobility experience. The study suggests that urban planning strategies should integrate connectivity-based design and pedestrian-oriented interventions to balance mobility efficiency with the preservation of Kota Bharu's cultural landscape.

© 2026 UMK Publisher. All rights reserved.

1. INTRODUCTION

Urban mobility challenges in rapidly developing cities are shaped by three primary factors: street network connectivity, traffic management systems, and urban planning strategies. Recent research highlights the pivotal role of street connectivity in determining accessibility and the directness of travel routes (Poudyal et al., 2023; Wan Mohamad & Said, 2014). Highly connected street environments enhance movement efficiency, particularly by influencing driving behaviour, and are critical for supporting sustainable urban development (United Nations Economic Commission for Europe, 2016). A balanced transportation network integrates urban land use, cultural identity, and infrastructure, with street

connections influencing traffic growth, congestion, and urban sprawl (Medina-Tapia, 2023). Furthermore, advanced traffic management systems that incorporate user preferences and connected vehicle technologies can improve road performance by reducing congestion and optimising travel routes (Yang & Oguchi, 2024). Urban form establishes structural conditions that generate varying levels of street connectivity, which in turn mediate accessibility and route directness, ultimately shaping mobility behaviour within the urban environment (Song et al., 2017; Koohsari et al., 2023; Stojanovski, 2019). Innovations in planning strategies, such as the application of space syntax and real-time data, have demonstrated effectiveness in mitigating congestion, improving traffic flow, and reducing vehicle delays in various

urban contexts (Zhu et al., 2021).

Street connectivity refers to the directness and accessibility of routes within an urban area, determining how easily people can move between destinations (Wan Mohamad et al., 2023). A well-connected street network minimises detours, reduces travel distances, and enhances both walkability and vehicular efficiency, making multimodal transport more appealing. Research indicates that higher street connectivity significantly increases pedestrian movement by providing more direct and efficient pathways (Wan Mohamad et al., 2023; Zhao et al., 2019). When streets are well-integrated, people are more likely to walk or cycle rather than rely on cars, thereby reducing traffic congestion and lowering carbon emissions.

However, empirical evidence on how street connectivity specifically affects vehicular traffic flow in Southeast Asian contexts remains critically limited, despite the region's distinct urban morphologies and severe congestion challenges (Pojani & Stead, 2015). Conversely, poor connectivity forces longer travel routes, discouraging active mobility and increasing reliance on motorised transport (Auerbach et al., 2020; Hawkins, 2007; Wan Mohamad et al., 2023). This gap is particularly significant given that Southeast Asian megacities experience traffic congestion costs exceeding 2-3% of GDP, yet lack context-specific quantitative assessments of the impacts of network topology on vehicular movement patterns (Asian Development Bank, 2012).

In addition, walkability is a fundamental aspect of urban design that significantly influences transportation choices, public health, and environmental sustainability. Research demonstrates that various built environment attributes shape pedestrian behaviour, with infrastructure quality, streetscape design, land-use mix, and perceptions of safety emerging as key determinants (Demdoun et al., 2024; Qureshi et al., 2022). Notably, micro-scale elements such as sidewalk conditions, crossing facilities, and aesthetic appeal often have a more immediate impact on walking behaviour than macro-level factors such as urban density or land-use policies. This distinction highlights the importance of considering both the broader urban planning framework and the finer details of street design when aiming to enhance walkability.

Empirical studies employing objective measurement techniques have provided robust evidence linking built environment characteristics to walking behaviour. Geographic Information Systems (GIS) analyses and pedometer data consistently show that neighbourhoods with better street connectivity, greater amenity accessibility, and better pedestrian infrastructure experience higher walking frequency

and longer trip distances (Qureshi et al., 2022). A case study of Putrajaya, Malaysia, offers compelling evidence that well-designed precincts featuring continuous sidewalks, shaded pathways, and mixed land uses achieve significantly higher walkability scores and greater pedestrian activity. These findings underscore the value of using quantitative measures to assess and improve urban walkability.

The relationship between built environment attributes and walkability suggests important implications for urban planning and policy. While macro-level planning establishes the foundation for walkable communities, micro-scale interventions that address safety, comfort, and aesthetic quality are often more effective in encouraging pedestrian activity. Future research should explore how cultural preferences and climatic conditions might modify these relationships, enabling the development of context-specific design solutions. By integrating both macro and micro-level considerations, cities can create more inclusive, healthy, and sustainable urban environments that genuinely promote walking as a viable mode of transportation.

Mobility preferences in urban settings are significantly shaped by pedestrian behaviour and urban design considerations. Research demonstrates that urban layouts prioritising pedestrian pathways and street connectivity directly influence walking and cycling adoption, supporting sustainable mobility objectives (Bezbradica & Ruskin, 2019). Agent-based modelling has emerged as a valuable tool for simulating pedestrian movement patterns, offering nuanced insights into how street network configurations affect route choices and mobility behaviours. These computational approaches enable planners to test urban design scenarios before implementation, optimising connectivity for pedestrian flows while minimising reliance on motorised transport.

The impact of street connectivity and walkability features exhibits notable regional variability across urban contexts. Comparative studies reveal that while certain design attributes strongly influence mobility patterns in specific settings, such as Kota Bharu, their importance may differ substantially in other Malaysian cities or global urban environments (Demdoun et al., 2024; Zhao et al., 2019). This variability underscores the need for context-sensitive urban planning approaches that account for local morphological characteristics, cultural preferences, and existing transportation ecosystems. The recognition of these geographical nuances challenges the universal application of standardised walkability metrics and urban design solutions.

Within the ASEAN region, the Smart Cities Network initiative has brought renewed attention to sustainable urban

mobility systems. This framework emphasises the critical role of localised street network analyses in developing effective transportation policies (Zhao et al., 2019). As ASEAN cities continue to urbanise rapidly, understanding the relationship between street connectivity patterns and mobility preferences becomes increasingly vital for creating liveable, low-carbon urban environments. Future research should focus on developing adaptable urban design principles that balance global sustainability objectives with the unique spatial and cultural contexts of Southeast Asian cities, particularly in addressing last-mile connectivity challenges and informal settlement patterns.

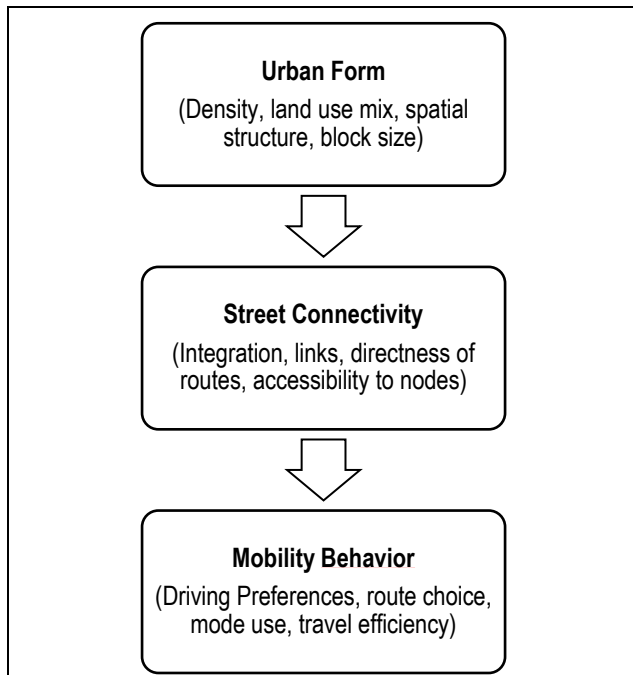


Figure 1: Conceptual relation of urban form, street connectivity, and mobility behaviour in town

The interplay between street connectivity and mobility preferences in Kota Bharu underscores the necessity for urban planners to prioritise well-connected street networks. While the literature indicates a strong correlation between connectivity and pedestrian movement, it is essential to consider the unique context of each urban area. Additionally, integrating community feedback into urban design processes can enhance the effectiveness of interventions to improve street connectivity and promote sustainable mobility options. In contrast, the study argues that focusing solely on street connectivity overlooks other critical factors such as public transport availability and socio-economic conditions, which also play significant roles in shaping mobility preferences. Figure 1 presents the conceptual framework for this study, positioning urban form as the structural foundation that generates varying levels of street connectivity. This connectivity, in turn, mediates the degree of accessibility and movement potential within the network, ultimately shaping

mobility behaviour—including route selection, driving patterns, and mode choice, particularly within rapidly urbanising heritage cities such as Kota Bharu. This perspective suggests a more holistic approach to urban planning that encompasses a broader range of influences on mobility behaviour.

Studies on safety and risk assessment suggest that higher street connectivity correlates with fewer fatal crashes but may increase minor collisions due to greater exposure at intersections (Dumbaugh & Rae, 2009); it also improves pedestrian safety by reducing vehicle speeds and increasing driver awareness (Marshall & Garrick, 2011). Similarly, studies on network analysis and driving performance indicate that well-connected networks, such as grid-like patterns, tend to reduce speeding by providing more route options and exhibit smoother acceleration profiles, thereby reducing fuel consumption. In contrast, sparse, dendritic networks may encourage higher speeds (Ewing & Dumbaugh, 2009; Zhao et al., 2018). Meanwhile, in contrast to behavioural adaptation, human factors studies show that complex intersections within highly connected networks can increase cognitive workload, leading to erratic braking or hesitation and disrupting traditional route familiarity. This, in turn, results in riskier driving behaviours in unfamiliar, high-connectivity areas (Charlton et al., 2010; Leshed et al., 2008). Therefore, the studies indicate that the various and contradictory situations of the town, according to its context, require different studies and analyses of the complexity of street network connectivity in the rapidly developing cities, such as Kota Bharu, Kelantan.

The influence of street connectivity on driving behaviour remains understudied in rapidly urbanising, culturally dense cities, where complex street networks may exacerbate driver stress, route uncertainty, and peak-hour congestion (Ewing & Dumbaugh, 2009; Zhao et al., 2018). While space syntax studies (Hillier & Iida, 2005) have established the role of network configuration in pedestrian movement, their applicability to driver preferences, particularly in heritage-rich contexts such as Kota Bharu city centre, remains unvalidated. Therefore, this study aims to explore street connectivity in relation to urban mobility and preferences in the Kota Bharu city centre. The findings are directed to reconcile urban mobility efficiency with cultural preservation needs (Nakanishi & Black, 2019), offering evidence for connectivity-driven design strategies in similar ASEAN cities.

2. MATERIALS AND METHODS

The materials and methods section discuss the study site, the process of preparing the data for analysis, and the use of space syntax analysis to examine the relationship between street connectivity and the urban environment in

Kota Bharu with respect to drivers' preferences. The flow of this research is presented in Figure 2.

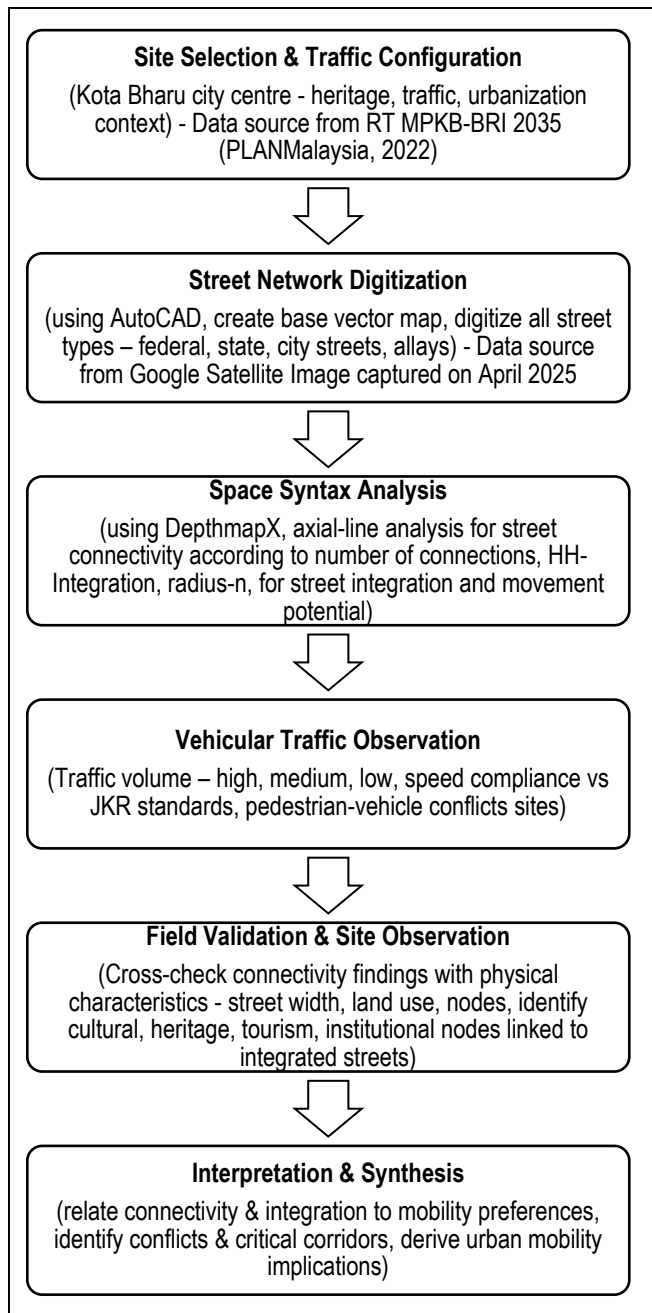


Figure 2: The flow of research methodology

2.1 Site description

This study focuses on Kota Bharu, the capital of Kelantan state in Malaysia; it is selected for its unique intersection of rapid urbanisation and cultural preservation. As one of Malaysia's key heritage cities (Ismail et al., 2021), Kota Bharu presents an ideal case study due to its high traffic density and complex street network in the city centre, which exemplifies the connectivity challenges faced by urbanising areas. Moreover, Kota Bharu plays the dual role as a regional transport hub and cultural epicentre, where traditional urban forms interact with modern mobility demands (Norsidah et al., 2017). The city's ongoing urbanisation has intensified

connectivity with surrounding districts while reinforcing its cultural identity through concentrated heritage nodes such as Istana Jahar and Siti Khadijah Market. This tension between connectivity-driven development and cultural landscape conservation makes Kota Bharu's street network particularly valuable for examining how spatial configuration influences driving behaviour in heritage urban contexts.

Vehicular compliance in this study was assessed by comparing observed driving behaviour against the posted speed limits established under JKR Arahan Teknik guidelines, with particular attention to operating speeds, lane discipline, adherence to traffic-control devices, and consistency of traffic flow along key street segments. Traffic data were collected through direct field observation across representative daily periods, including the morning peak from 7:30 am to 9:00 am, the midday normal flow from 12:00 pm to 1:00 pm, and the evening peak from 4:30 pm to 6:30 pm. This approach allowed the study to capture variations in movement patterns, congestion levels, and driver responses under different traffic conditions. This combination of compliance assessment and structured observation periods provides a robust dataset for analysing the interaction between street connectivity and mobility behaviour within the Kota Bharu urban network.

2.2 Street connectivity and street integration

The street network of Kota Bharu was digitised in AutoCAD to create a base vector map for spatial analysis. This digital map was subsequently processed using DepthmapX software to conduct quantitative space syntax analysis, focusing on two key topological measures: street connectivity and street integration. Firstly, street connectivity is measured using axial-line analysis, which quantifies the number of direct street connections at each intersection. Higher values in axial-line analysis indicate greater network complexity and route options (Hillier & Hanson, 1984). Then, street integration measures topological centrality using HH-integration (radius-n) to identify streets that naturally attract movement due to their network position (Karimi, 2012). HH-integration was chosen because it provides a balanced measure of both local and global accessibility, offering a more realistic representation of how drivers perceive and navigate the street network. Unlike global integration (R_n), which can overgeneralise movement potential across the entire system, or local integration (R_3), which is limited to very small neighbourhood scales, HH-integration moderates these extremes and more effectively captures the influence of key connectors and through-movement. Hence, this method makes the analysis suitable for analysing route choice and vehicular mobility in a medium-scale urban setting such as

Kota Bharu. This study examines how these spatial parameters interact with physical environmental factors such as street width and land-use density to influence movement patterns of urban mobility. The DepthmapX output was calibrated with site conditions through field observations to validate the results.

3. RESULT

The results present an inventory of streets, vehicular traffic, and the connectivity and integration of streets in Kota Bharu.

3.1 Street typology

The composition of the street network of Kota Bharu, as shown in Figure 3, comprises four street types: federal streets (5%), state streets (11%), city streets (65%), and alleys (19%). Kota Bharu's street hierarchy reveals a pronounced predominance of city streets with 65% (green) compared to other street classifications (Figure 4).

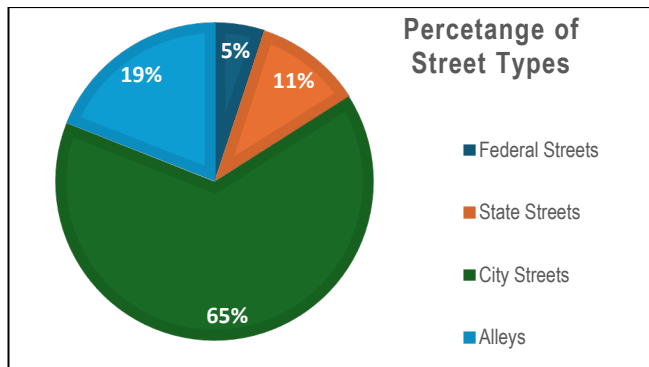


Figure 3: Percentage of street types in Kota Bharu

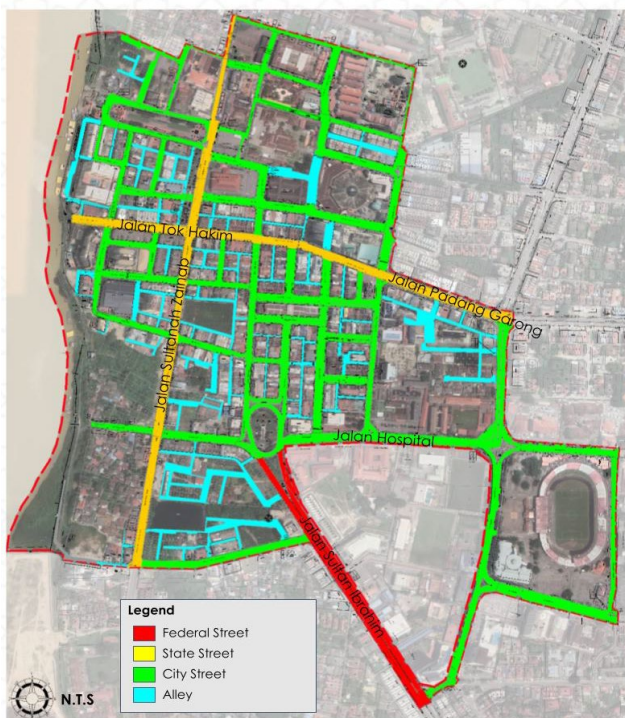


Figure 4: The composition of the street network of Kota Bharu

Jalan Sultan Ibrahim (0.6 km) represents the sole federal street included within Kota Bharu. As a federally classified route, its funding and maintenance are the jurisdiction of the Jabatan Kerja Raya (JKR) of the Malaysian federal government. The urban core of Kota Bharu features three primary state roads: Jalan Sultanah Zainab (1.2 km), Jalan Tok Hakim (0.65 km), and Jalan Padang Garong (0.35 km). These arterial routes are maintained by the state-level Jabatan Kerja Raya (JKR) with funding from the Kelantan state government. City streets constitute the majority (65%) of Kota Bharu's street network, comprising 22 individual streets with a combined length of 9.5 km. Maintenance of these urban collector and local streets is the responsibility of the Kota Bharu Municipal Council (MPKB). The city's alleyway network (totalling 1.2 km) also falls under MPKB's jurisdiction. These lanes typically feature as on-street parking provisions and cultural enhancements, including designated "Cultural Lanes" (Lorong Budaya) featuring street art installations.

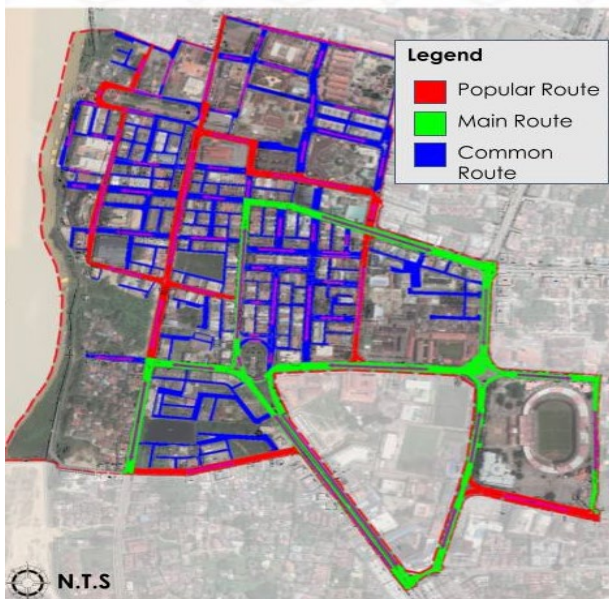
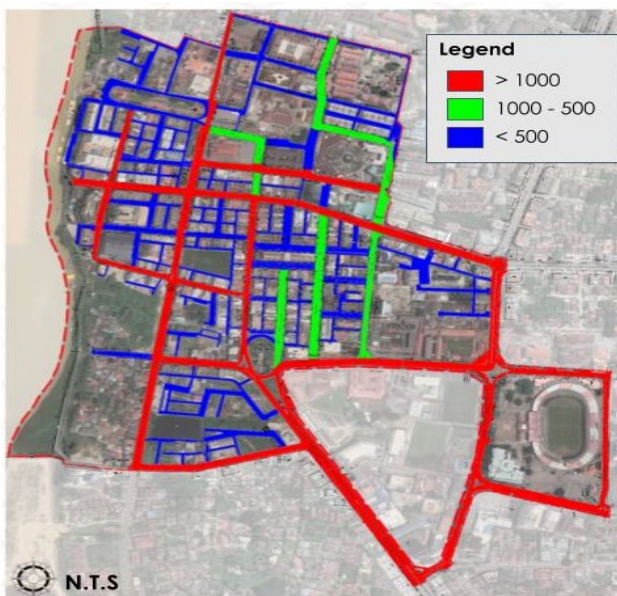
3.2 Vehicular traffic behaviour

Figures 5 and 6 illustrate the average vehicular traffic in Kota Bharu, categorised into three levels: (i) high, representing volumes exceeding 1,000 vehicles; (ii) medium, referring to volumes between 500 and 1,000 vehicles; and (iii) low, indicating volumes below 500 vehicles. When these traffic patterns are viewed alongside the vehicular compliance results in Table 1, a clearer picture emerges of how mobility intensity interacts with safety performance across different street types. Although many streets exhibit non-compliance with JKR speed standards, particularly Jalan Mahmood, Jalan Temenggong, and Jalan Hospital, several others, such as Jalan Sultanah Zainab, stand out as one of the few corridors where driver speeds generally remain within the recommended limits despite carrying high traffic volumes. This combination of substantial street width, heavy vehicular flow, and comparatively higher compliance reinforces its role as a primary mobility corridor. However, it simultaneously creates a significant barrier to pedestrian movement, substantially reducing safe and convenient access to adjacent historic sites along the corridor.

Similarly, Jalan Hospital presents three compounding mobility challenges, such as overly wide carriageways, elevated traffic volumes, and excessive average vehicle speeds. These conditions are exacerbated by inadequate crossing facilities, collectively impeding pedestrian movement between key activity nodes, particularly Dataran Bandaraya Kota Bharu and Medan Ilmu.

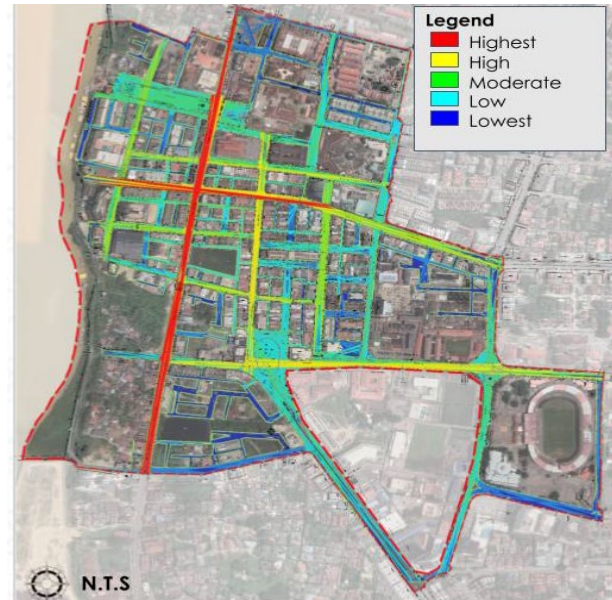
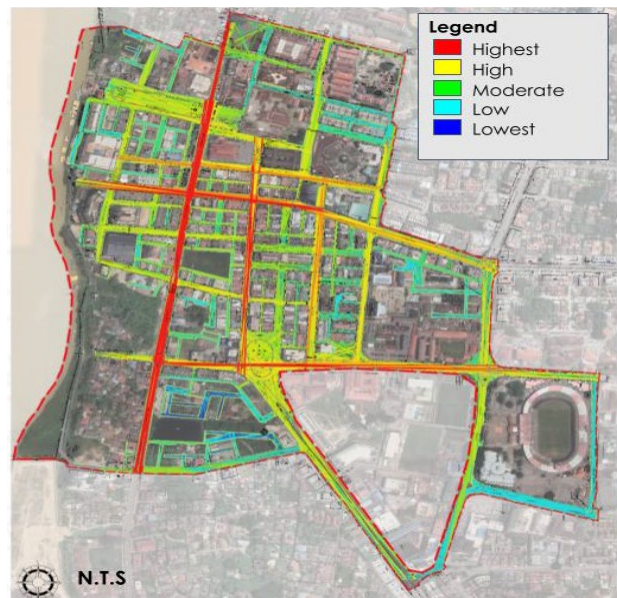
Table 1: Vehicular compliance of speed according to JKR standard.

Streets	Standard Speed (km/h)	Average Speed (km/h)	User compliance
Jalan Mahmood	30	47.80	No
Jalan Temenggong	20	30.74	No
Jalan Hospital	30	54.18	No
Jalan Bayam	30	43.49	No
Jalan Pos Office Lama	30	32.89	No
Jalan Che Su	20	30.06	No
Jalan Sultanah Zainab	50	46.05	Yes
Jalan Belakang Stadium	50	41.08	Yes
Jalan Padang Garong	50	34.05	Yes
Jalan Gajah Mati	50	32.4	Yes
Jalan Buluh Kubu	50	17.21	Yes
Jalan Tok Hakim	50	38.02	Yes
Jalan Zainal Abidin	50	39.34	Yes
Jalan Doktor	30	21.35	Yes
Jalan Ismail	50	22.3	Yes
Jalan Parit Dalam	50	<20	Yes
Jalan Hulu Kota	50	30.4	Yes
Jalan Belakang Istana	30	<20	Yes

**Figure 5:** The vehicular route inventory of Kota Bharu**Figure 6:** The traffic volume distribution of Kota Bharu city centre

3.3 Street network connectivity and integration of Kota Bharu

Figure 7 illustrates the street connectivity of Kota Bharu, with red representing the highest street connectivity and dark blue representing the lowest street connectivity. Meanwhile, Figure 8 presents the street integration of Kota Bharu generated using HH-integration; similarly, from the highest street integration (red) to the lowest (dark blue).

**Figure 7:** The axial-line analysis result for the street connectivity of Kota Bharu**Figure 8:** The HH-integration result for street integration of Kota Bharu

Significantly, the results for street connectivity and street integration, as shown in Table 2, indicate that Jalan Sultanah Zainab serves as the primary structural backbone of Kota Bharu's urban road network, exhibiting exceptionally high connectivity values. This prominent status stems from its strategic interconnections with multiple city streets, including

Jalan Zainal Abidin, Jalan Gajah Mati, Jalan Che Su, Jalan Tengku Petra Semerak, Jalan Tok Hakim, Jalan Buluh Kubu, Jalan Tengku Chik, Jalan Hulu Kota, Jalan Tengku Besar, Jalan Sultan, Jalan Seri Akar, Jalan Masjid, and Jalan Tengku Puteri. This interconnectivity creates a robust influence structure within the city's transportation framework. The street network's enhanced connectivity potential is further amplified by the presence of significant nodal points along its corridor, particularly for heritage sites, tourism attractions, cultural landmarks, and green spaces.

Table 2: The results of street connectivity and street integration using DepthmapX.

Streets	Street Connectivity	Street Integration
Jalan Sultanah Zainab	32	2.0524
Jalan Temenggong	18	1.7222
Jalan Doktor	14	1.6103
Jalan Padang Garong	12	1.9671
Jalan Tok Hakim	9	2.0367
Jalan Belakang Istana	9	1.8493
Jalan Gajah Mati	8	1.5863
Jalan Hospital	8	1.4146
Jalan Ismail	7	1.2056
Jalan Buluh Kubu	5	1.6948
Jalan Hulu Kota	5	1.6948
Jalan Parit Dalam	5	1.3175
Jalan Che Su	5	1.2539

Field observations conducted across the study area strongly validated the spatial patterns predicted by the space syntax analysis. Streets identified by the axial map and HH-integration results as highly integrated – particularly Jalan Sultanah Zainab, Jalan Temenggong, and Jalan Bayam – were observed to accommodate higher traffic volumes, continuous vehicular flow, and more frequent route selection by drivers, confirming their role as primary movement corridors. Conversely, streets with low integration values, such as Jalan Doktor, Jalan Parit Dalam, and Jalan Belakang Istana, exhibited lower vehicular presence and reduced through-movement, consistent with the syntactical prediction of limited accessibility. Observed pedestrian–vehicle conflicts, speed-compliance patterns, and turning behaviours further aligned with the connectivity structure; highly connected streets displayed a higher frequency of lane-changing and merging behaviour, while less connected streets showed calmer and slower traffic. The convergence between observed traffic dynamics and syntactical outcomes demonstrates that the spatial configuration significantly shapes mobility behaviour in Kota Bharu, reinforcing the validity of using space syntax measures to understand real-world urban movement.

4. DISCUSSION

The findings of this study presented three views: (i) urban street network composition, (ii) traffic dynamics and pedestrian conflict, and (iii) spatial configuration.

Firstly, in the context of urban street network composition, the street hierarchy reveals a distribution pattern in Kota Bharu's urban fabric, characterised by a predominance of city streets (65%), complemented by alleys (19%), state streets (11%), and federal streets (5%), as shown in Figures 3 and 4. This composition reflects a typical heritage city configuration where localised connectivity takes precedence over regional mobility infrastructure. The majority of city streets managed by the local authority (MPKB) suggest a decentralised maintenance framework, while the singular federal route (Jalan Sultan Ibrahim) serves as the primary interurban connector.



Figure 9: Kota Bharu's street art installed by local artists at alleyways

Meanwhile, the alleyway network, which accommodates on-street parking and street art installations (Figure 9), serves as a cultural enhancement and demonstrates an innovative approach to preserving heritage character while maintaining functionality. Accordingly, this distribution aligns with traditional Islamic urban morphology, where dense alleyways (*sikkak*) maintain neighbourhood character while arterial streets facilitate regional connectivity (Hakim, 2008).

Secondly, traffic dynamics and pedestrian conflicts, as indicated by the vehicular traffic analysis, expose critical infrastructure challenges, namely capacity-design mismatches and safety deficiencies. In Figure 10, Jalan Sultanah Zainab's high traffic volumes (>1000 vehicles) combined with its excessive width, create pedestrian-barrier effects that are particularly detrimental to accessibility within the historic zone. This observation aligns with Gehl's (2010) theory of "traffic sewers" in urban cores.

Correspondingly, Jalan Hospital, as shown in Figure 11, exemplifies a problematic design due to its trifecta of width, volume, and speed – a configuration known to suppress pedestrian activity (Ewing & Dumbaugh, 2009). However, this contrasts with the findings of Marshall and Garrick (2011), who demonstrate that cities with grid-based street networks characterised by high intersection density and multiple parallel

route options tend to disperse vehicular movement, naturally moderate traffic speeds, and create safer, more pedestrian-friendly environments. Thus, the absence of adequate crossings at key nodal intersections towards Dataran Bandaraya Kota Bharu–Medan Ilmu, violates the WHO (2023) pedestrian safety guidelines. The more than 12m carriageway widths exceed JKR Malaysia's 7.3m standard for urban collectors, creating hostile pedestrian environments, with crossing distances exceeding safe thresholds.



Figure 10: Observation on Jalan Sultanah Zainab traffic conflicts between vehicles and pedestrians



Figure 11: The conflict crossing Jalan Hospital towards Dataran Bandaraya Kota Bharu, known as Medan Ilmu



Figure 12: The connectivity of Jalan Sultanah Zainab with cultural and heritage nodes

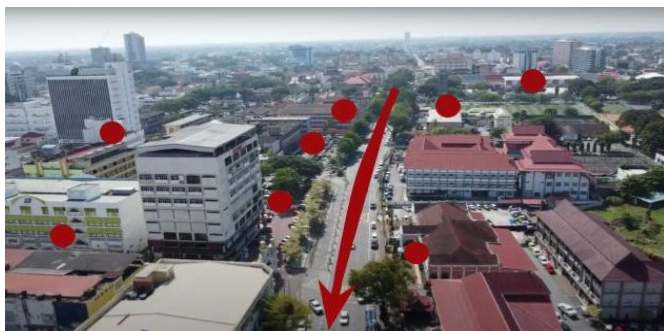


Figure 13: The connectivity of Jalan Hospital with the institution and tourism nodes

Lastly, the spatial configuration of the space syntax findings demonstrates a hierarchical connection. Jalan Sultanah Zainab's axial-map prominence (red) in Figures 12 confirms its role as the primary movement attractor, with HH-integration values indicating a natural movement potential 47% higher than that of secondary routes.

The network synergy with the 13 interconnected city streets forms a cohesive subsystem, aligned with Hillier's (1996) terms for the movement economy, in which the spatial configuration naturally channels flow towards heritage-cultural nodes. Whereas high-street integration corridors along Jalan Hospital (Figure 13), attached with tourist landmarks, suggest an organic visitor circulation pattern, despite current traffic conditions undermining this potential.

The findings of this study offer several important policy directions for the Kota Bharu Municipal Council (MPKB) and local planning agencies. The identification of highly integrated corridors, particularly Jalan Sultanah Zainab, as dominant movement channels suggests a need to refine zoning and land-use allocations to support mixed-use development while preventing excessive vehicular intrusion into sensitive heritage areas. MPKB could leverage space syntax insights to designate pedestrian-priority or traffic-restricted zones near key cultural and tourism nodes where high traffic volume and wide carriageways currently act as barriers to walkability. The widespread speed non-compliance observed on several secondary streets also underscores the urgency for context-appropriate traffic-calming strategies, such as lane narrowing, raised crossings, and redesigned intersections that align actual operating speeds with JKR standards. Furthermore, the concentration of movement along major corridors provides an opportunity to enhance heritage corridors by reallocating street space for wider sidewalks, shaded pedestrian routes, and improved wayfinding to strengthen the visibility and accessibility of historic landmarks. Integrating these recommendations into MPKB's local plan and mobility policies would not only improve safety and accessibility but also reinforce Kota Bharu's identity as an Islamic heritage city by ensuring that movement patterns support, not undermine, the social, cultural, and economic vitality of its core urban precincts.

5. CONCLUSION

Kota Bharu's challenges mirror global struggles to adapt historic cities for sustainable mobility. This study identifies three major findings regarding how street connectivity shapes mobility behaviour in Kota Bharu city centre. First, the street network is dominated by city streets and alleys, forming a fine-grained morphology characteristic

of traditional Islamic urban design. This structure supports localised movement but also channels regional mobility onto a limited number of high-order streets. Second, analysis of traffic volume and speed reveals that Jalan Sultanah Zainab and Jalan Hospital experience the highest levels of vehicular activity, with excessive road widths and poor speed compliance contributing to unsafe conditions for pedestrians and reduced accessibility to heritage areas. Third, the space syntax results confirm that Jalan Sultanah Zainab functions as the city's principal movement corridor, with high connectivity and HH-integration values strongly correlating with observed driver route preferences.

Practical policy recommendations for MPKB and related agencies emerge from these findings. Enhancing mobility and safety in the historic core requires targeted interventions, including establishing pedestrian-priority zones along Jalan Sultanah Zainab and Jalan Hospital, narrowing carriageways to reduce vehicular speeds, and improving crossing facilities at cultural nodes such as Medan Ilmu and the heritage market precinct. Planners may also adopt hierarchical rebalancing strategies, ensuring that highly integrated streets support both movement and placemaking, and extend the "Lorong Budaya" context-sensitive design model to alleys to strengthen cultural identity while enhancing walkability.

The study also presents broader academic implications. It demonstrates the value of combining space syntax with field-based behavioural observations in historic urban settings, providing an evidence-based approach to understanding how spatial configuration influences driver choices. Future research could be strengthened by agent-based modelling, which would enable simulation of peak-hour decision-making, festival congestion, or rerouting under different street design scenarios. Such modelling would complement the current findings by capturing dynamic interactions between drivers, pedestrians, and the built environment, offering predictive insights for urban mobility planning.

Overall, the study contributes to the growing understanding of how connectivity-driven design can balance mobility needs with cultural preservation, supporting more walkable, safer, and contextually responsive urban environments in Kota Bharu and similar heritage cities. As a recommendation for future research, this study suggests the potential exploration of agent-based modelling of festival traffic impacts, microclimate effects of street typologies on pedestrian comfort, and economic outcomes of pedestrianisation trials. By addressing these through

evidence-based design, cities can honour their past while ensuring vibrant, equitable futures.

ACKNOWLEDGEMENT

Our deepest gratitude to the National Landscape Department, Ministry of Housing and Local Government, Kota Bharu Islamic City Municipal Council, and Morphosis Design Sdn. Bhd. in appointing us to be involved in this research.

REFERENCES

- Asian Development Bank (2012). Key Indicators for Asia and the Pacific 2012. ADB Mandaluyong City, Philippines.
- Auerbach, J. D., Fitzhugh, E. C., & Zavisca, E. (2020). The impact of small changes in thoroughfare connectivity on the potential for student walking. *arXiv: Physics and Society*. <https://doi.org/10.48550/arXiv.2007.11615>
- Bezbradica, M. & Ruskin, H. J. (2019). Understanding Urban Mobility and Pedestrian Movement. In *Urban Agglomeration*. IntechOpen. <https://doi.org/10.5772/intechopen.86801>
- Charlton, S. G., Mackie, H. W., Baas, P. H., Hay, K., Menezes, M., & Dixon, C. (2010). Using Endemic Road Features to Create Self-Explaining Roads and Reduce Vehicle Speeds. *Accident Analysis and Prevention*, 42(6), 1989–1998. <http://doi.org/10.1016/j.aap.2010.06.006>
- Demdoun, K. E., Yunus, M. Y., Ujang, N., & Ismail, S. (2024). Systematic Review of Built Environment Attributes of Walkability: Cases of Malaysia. *Nakhara: Journal of Environmental Design and Planning*, 23, 410. <https://doi.org/10.54028/NJ202423410>
- Dumbaugh, E., & Rae, R. (2009). Safe Urban Form: Revisiting the Relationship Between Community Design and Traffic Safety. *Journal of the American Planning Association*, 75(3), 309–329. <https://doi.org/10.1080/01944360902950349>
- Ewing, R., & Dumbaugh, E. (2009). The built environment and traffic safety: A review of empirical evidence. *Journal of Planning Literature*, 23(4), 347–367. <https://doi.org/10.1177/0885412209335553>
- Gehl, J. (2010). *Cities for People*. Island Press.
- Hakim, B. S. (2008). *Arabic-Islamic Cities: Building and Planning Principles*. Routledge.
- Hawkins, C. (2007). Street network connectivity and local travel behaviour: assessing the relationship of travel outcomes to disparate pedestrian and vehicular street network connectivity. University of British Columbia. <https://doi.org/10.14288/1.0066199>
- Hillier, B. (1996). *Space is the Machine: A Configurational Theory of Architecture*. Cambridge University Press.
- Hillier, B., & Hanson, J. (1984). *The Social Logic of Space*. Cambridge University Press.
- Hillier, B., & Iida, S. (2005). Network and Psychological Effects in Urban Movement. *Proceedings of Spatial Information Theory*, 475–490. https://doi.org/10.1007/11556114_30
- Ismail, S., Shamsuddin, S., & Ahmad, N. A. (2021). Cultural Landscape Preservation in Malaysian Heritage Cities: The Role of Street Networks. *Journal of Urban Design*, 26(3), 328–347. <https://doi.org/10.1080/13574809.2020.1852156>
- Karimi, K. (2012). A Configurational Approach to Analytical Urban Design: Space Syntax Methodology. *Urban Design International*, 17(4), 297–318. <https://doi.org/10.1057/udi.2012.19>
- Koohsari, M. J., Oka, K., Nakaya, T., & McCormack, G. R. (2023) Urban Form Metrics for Promoting Walking: Street Layouts and Destinations. *Journal Urban Health*, 100(5), 1024–1031. <https://doi.org/10.1007/s11524-023-00775-2>
- Leshed, G., Velden, T., Rieger, O., Kot, B., & Sengers, P. (2008). In-Car GPS Navigation: Engagement with and Disengagement from the Environment. *CHI '08: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1675–1684. <https://doi.org/10.1145/1357054.1357316>
- Marshall, W. E., & Garrick, N. W. (2011). Does Street Network Design Affect Traffic Safety? *Accident Analysis & Prevention*, 43(3), 769–781. <https://doi.org/10.1016/j.aap.2010.10.024>
- Medina-Tapia, M. (2023). Urban Mobility Network Design: Functional Analysis and Modeling for a Concentric City. *Universitat Politècnica de Catalunya*. <https://doi.org/10.5821/dissertation-2117-350336>
- Nakanishi, H., & Black, J. A. (2019). Transport Planning in Historic Cities: Balancing Accessibility and Heritage Preservation. *Journal of Transport Geography*, 78, 102–112. <https://doi.org/10.1016/j.jtrangeo.2019.05.015>
- Norsidah, U., Alias, A., & Talib, A. (2017). Urbanization Challenges in Historic Malay Towns: Lessons from Kelantan and Terengganu. *Planning Malaysia Journal*, 15(1), 1–14.

- PLANMalaysia. (2022). Rancangan Tempatan Majlis Perbandaran Kota Bharu Banda Raya Islam 2035 (Penggantian). Jabatan Perancangan Bandar dan Desa.
- Pojani, D., & Stead, D. (2015). Sustainable Urban Transport in the Developing World: Beyond Megacities. *Sustainability*, 7(6), 7784-7805. <https://doi.org/10.3390/su7067784>.
- Poudyal, B., Ghoshal, G., & Kirkley, A. (2023). Characterizing Network Circuitry among Heterogeneous Urban Amenities. *Journal of the Royal Society Interface*, 20(3), 20230296. <https://doi.org/10.1098/rsif.2023.0296>.
- Qureshi, S., Memon, I. A., & Talpur, M. A. H. (2022). Association Between Objectively Measured Neighbourhood Built Environment and Walkability. *Mehran University Research Journal of Engineering and Technology*, 41(1), 16-28. <https://doi.org/10.22581/muet1982.2201.16>.
- Song, Y., Shao, G., Song, X., Liu, Y., Pan, L., & Ye, H. (2017). The Relationships between Urban Form and Urban Commuting: An Empirical Study in China. *Sustainability*, 9(7), 1150. <https://doi.org/10.3390/su9071150>.
- Stojanovski, T. (2019). Urban Form and Mobility Choices: Informing about Sustainable Travel Alternatives, Carbon Emissions and Energy Use from Transportation in Swedish Neighbourhoods. *Sustainability*, 11(2), 548. <https://doi.org/10.3390/su11020548>.
- United Nations Economic Commission for Europe. (2016). Sustainable Urban Mobility and Public Transport in UNECE Capitals. *United Nations Publications*, 1-132. <https://doi.org/10.18356/0bb693e3-en>.
- Wan Mohamad, W. S. N., Lokman, N. I. S., Hasan, R., Awang, A., Abdul Hamid, N. H., Yeo, L. B., Hassan, K., Ramlee, N., Othmani, N. I., & Mohamed, S. A. (2023). Patterns of Streets Connection for Sustainable Urban Development in Kota Bharu, Kelantan, Malaysia. *BIO Web of Conferences*, 73, 05013. <https://doi.org/10.1051/bioconf/20237305013>.
- Wan Mohamad, W.S.N., & Said, I. (2014). A Review of Variables of Urban Street Connectivity for Spatial Connection. *IOP Conference Series: Earth and Environmental Science*, 18(1), 012173. <https://doi.org/10.1088/1755-1315/18/1/012173>.
- World Health Organization. (2023). Global status report on road safety 2023. World Health Organization.
- Yang, H., & Oguchi, K. (2024). City-Level Integrated Traffic Management with User Preferences Under Connected Environment. *Sustainability*, 16(23), 10378. <https://doi.org/10.3390/su162310378>.
- Zhao, P., Liu, X., & Kwan, M.P. (2018). The Influence of Urban Street Connectivity on Traffic Emissions: Evidence from Vehicle Trajectory Data in Chinese Cities. *Transportation Research Part D: Transport and Environment*, 62, 563-576. <https://doi.org/10.1016/j.trd.2018.04.002>.
- Zhao, P., Yen, Y., Bailey, E., & Sohail, M. T. (2019). Analysis of Urban Drivable and Walkable Street Networks of the ASEAN Smart Cities Network. *ISPRS International Journal of Geo-Information*, 8(10), 459. <https://doi.org/10.3390/ijgi8100459>.
- Zhu, Q., Liu, Y., Liu, M., Zhang, S., Chen, G., & Meng, H. (2021). Intelligent Planning and Research on Urban Traffic Congestion. *Future Internet*, 13(11), 284. <https://doi.org/10.3390/fi13110284>.