

Spatial heterogeneity in traffic climate and its impact on road safety: a case study of motorcyclists in Vietnam

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Abstract: Motorcyclists in Vietnam face high crash risks due to the dominance of motorcycles and varying traffic conditions. This study investigates how spatial heterogeneity in traffic climate, measured by External Affective Demands (EAD), Functionality (FNC), and Internal Requirements (IRQ), influences road safety among young riders across urban and rural settings. Using survey data from 724 respondents and Partial Least Squares Structural Equation Modelling (PLS-SEM), results show that higher EAD is significantly associated with more crashes, near-crashes, and violations, especially in urban areas. Improved FNC reduces near-crashes and offences, notably in rural contexts. IRQ negatively correlates with crashes, reflecting the protective role of personal responsibility. The findings underscore the need for context-specific safety strategies tailored to traffic climate conditions in diverse environments.

Keywords: Spatial Heterogeneity, Traffic Climate, Road Safety, Young Motorcyclists, Vietnam

1. Introduction

Road traffic accidents remain a major global cause of injury and death, with the World Health Organisation (WHO, 2018) reporting approximately 1.35 million annual fatalities, with over 90% occurring in low- and middle-income countries. In Vietnam, where motorcycles account for nearly 95% of registered vehicles (WHO, 2018), riders comprise around 60% of traffic fatalities (WHO, 2015). Despite this disproportionate risk, few studies explore how contextual factors like traffic climate influence riding behaviours across urban and rural settings (Wu et al., 2021).

Motorcyclists, 80% of Southeast Asia's road users, experience 43% of regional traffic fatalities (WHO, 2018). Although Vietnam has adopted ASEAN-aligned safety measures, challenges persist due to low public awareness, poor compliance, and limited law enforcement (Chou et al., 2022). These challenges underscore the need to understand psychosocial factors like traffic climate, defined as road users' shared perceptions of their traffic environment (Özkan and Lajunen, 2011).

Traffic safety research has progressed from technical solutions to behavioural factors, ergonomic, and cultural approaches (Özkan and Lajunen, 2011). While recent studies show traffic climate affects driver behaviour (Gehlert et al., 2014; Üzümcüoğlu et al., 2020; Zhang et al., 2018), motorcycle-dominated contexts remain underexamined. This neglect persists despite clear urban-rural disparities in infrastructure, enforcement, and user behaviour (Rakauskas et al., 2009; Wu et al., 2021). For example, rural US areas account for 54% of traffic deaths despite only housing 19% of the population (McAndrews et al., 2016); similarly, 65% of Vietnam's traffic accidents occur in rural regions (NTSC, 2015).

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This study applies Öztürk et al.'s (2022) traffic climate model, comprising External Affective Demands (EAD), Functional Aspects (FNC), and Internal Requirements (IRQ), to assess how traffic climate shapes accident risks across urban and rural areas. EAD reflects perceived stress and unpredictability in traffic interactions, FNC captures the perceived efficiency and organisation of the traffic system, and IRQ represents individual responsibility and compliance with traffic rules.

Although traffic climate has been linked to driver attitudes (Üzümçüoğlu et al., 2020; Zhang et al., 2018), few studies examine direct impacts on crashes or violations in motorcycle-dependent nations. Existing research focuses largely on car-centric Western contexts (Gehlert et al., 2014), overlooking Southeast Asia's rider majority. Recent Vietnamese data show EAD increases risk-taking among Vietnamese youth, while IRQ reduces dangerous behaviours Hoang et al. (2025), highlighting the traffic climate's behavioural relevance.

This study explores how traffic climate dimensions interact with urban/rural contexts to influence accident risks, providing (i) empirical evidence for spatial effects, (ii) comparative insights for targeted interventions, and (iii) policy-relevant guidance for ASEAN-aligned road safety strategies.

2. Literature review and hypothesis development

2.1. Traffic climate and its dimensions

Traffic climate builds on the safety climate concept, which reflects how safety is prioritised through policies and practices, shaping behaviour (Zohar and Luria, 2004). According to Özkan and Lajunen (2011), traffic climate refers to road users' perceptions of their traffic environment, shaped by enforcement, infrastructure, policies, and social norms. A positive climate promotes rule adherence and safer interactions. Developing reliable climate measures can improve road safety (Chu et al., 2019).

Traffic climate can be understood through three key dimensions: external affective demands, functionality, and internal requirements (Gehlert et al., 2014). External affective demands refer to the emotional and social expectations placed on road users (e.g., patience and cooperation). Functionality encompasses safety parameters, mobility features, and the structural conditions enabling efficient traffic flow. Internal requirements involve individual competencies, such as navigation skills within transportation networks. These dimensions collectively shape road user-environment interactions and safety outcomes. However, regional differences in the prioritisation of these factors contribute to varying safety performance, highlighting the complexity of traffic climate analysis.

Recent empirical work by Hoang et al. (2025) validates these dimensions in the Vietnamese context. Their findings indicate that external affective demands significantly increase risk-taking tendencies among young motorcyclists, whereas internal requirements reduce such behaviours. Interestingly, functionality showed no significant effect, possibly due to disparities in traffic infrastructure and regulation enforcement between urban and rural areas in Vietnam.

2.2. Hypothesis development

2.2.1. External affective demand and motorcycle safety outcomes

EAD reflects the emotional toll of traffic, such as stress from congestion or unpredictable behaviour (Gehlert et al., 2014). Stressful conditions increase cognitive load, impair decision-making and encourage riskier behaviours, such as speeding, running red lights, or aggressive manoeuvres (Mesken et al., 2007). Under sustained

emotional pressure, riders may experience heightened stress and delayed reaction times, elevating crash and near-miss risks (Chu et al., 2019). Furthermore, frustration in high-demand scenarios can provoke deliberate violations, such as taking illegal shortcuts to evade stressful conditions (Stephens and Groeger, 2009). Hoang et al. (2025) confirmed that EAD predicts risky driving behaviours. There, we hypothesise:

- H1a: Higher EAD is positively associated with the frequency of motorcycle crashes.
- H1b: Higher EAD is positively associated with the frequency of near-crashes.
- H1c: Higher EAD is positively associated with the frequency of traffic violations.

2.2.2. Functionality and motorcycle safety outcomes

FNC captures the efficiency of transportation systems, including road design, traffic flow predictability, and consistency in regulation enforcement (Gehlert et al., 2014). Well-functioning traffic environments reduce uncertainty for riders, promoting compliance with traffic rules and safer riding behaviours (Özkan and Lajunen, 2011). In such settings, motorcyclists are more likely to adhere to speed limits and maintain safe distances, lowering accident risks. Conversely, dysfunctional traffic systems can encourage risky compensatory behaviours. For instance, riders may resort to illegal lane-splitting or running red lights to navigate congestion or avoid hazardous road surfaces (Kazemi and Soltani, 2024). However, Hoang et al. (2025) found no significant link between FNC and risky behaviour in Vietnam, possibly due to regional disparities in infrastructure quality and enforcement.

Hypotheses:

- H2a: Higher FNC is negatively associated with motorcycle crash frequency.
- H2b: Higher FNC is negatively associated with motorcycle near-crash frequency.
- H2c: Higher FNC is negatively associated with the frequency of traffic violations.

2.2.3. Internal requirements and motorcycle safety outcomes

IRQ reflects the cognitive and technical skills needed to navigate traffic safely (Gehlert et al., 2014). High-IRQ environments demand quick decisions and multitasking, which may overload riders and lead to errors that increase the likelihood of crashes and near-crashes (Hancock et al., 1999; Kaber et al., 2012). Furthermore, in high-demand traffic climates, riders may be forced to violate traffic rules to adapt to challenging conditions, increasing traffic violations (Crundall et al., 2012). However, Hoang et al. (2025) found riders perceiving higher IRQ reported fewer risky attitudes and behaviours, suggesting risk awareness fosters caution.

Hypotheses:

- H3a: IRQ is significantly associated with crash frequency.
- H3b: IRQ is significantly associated with near-crash frequency.
- H3c: IRQ is significantly associated with the number of traffic violations.

2.3. Spatial differences in studied factors: urban vs. rural contexts

Although urban and rural areas are economically and demographically interconnected, road safety research often treats them as distinct entities due to their divergent risk profiles. Empirical studies consistently show that rural roads pose greater dangers to users than urban environments (McAndrews et al., 2016). These differences arise from contrasts in infrastructure, traffic dynamics, and user behaviour, factors that collectively define the traffic climate (i.e., perceived system efficiency, safety, and emotional demands) and shape riding outcomes.

Urban settings present complex, high-density environments with frequent intersections, mixed road users (pedestrians, cyclists), and constant visual stimuli (Cox et al., 2017). Pedestrians and traffic signals are particularly hazardous, requiring

sustained vigilance and rapid reactions. Such conditions create persistent emotional pressures, heightening perceived risk, especially from unpredictable pedestrian movements or signal changes (Cox et al., 2017). However, urban areas often offset these challenges with better infrastructure and stricter enforcement, fostering regulatory compliance and reducing severe incidents.

Rural roads, characterised by open spaces and lower traffic volume, can foster a false sense of security (Charlton et al., 2014; Rakauskas et al., 2009). This perception encourages risky behaviours like speeding, as riders underestimate hazards such as sharp curves, roadside ditches, or animal crossings, the latter being a major rural risk factor (Borowsky et al., 2010). Higher speed limits further reinforce this misperception; psychological models suggest users compensate for "safer" environments by reducing vigilance (Wilde, 1998). Unlike urban areas, rural regions often lack robust infrastructure or enforcement, exacerbating the consequences of these behaviours.

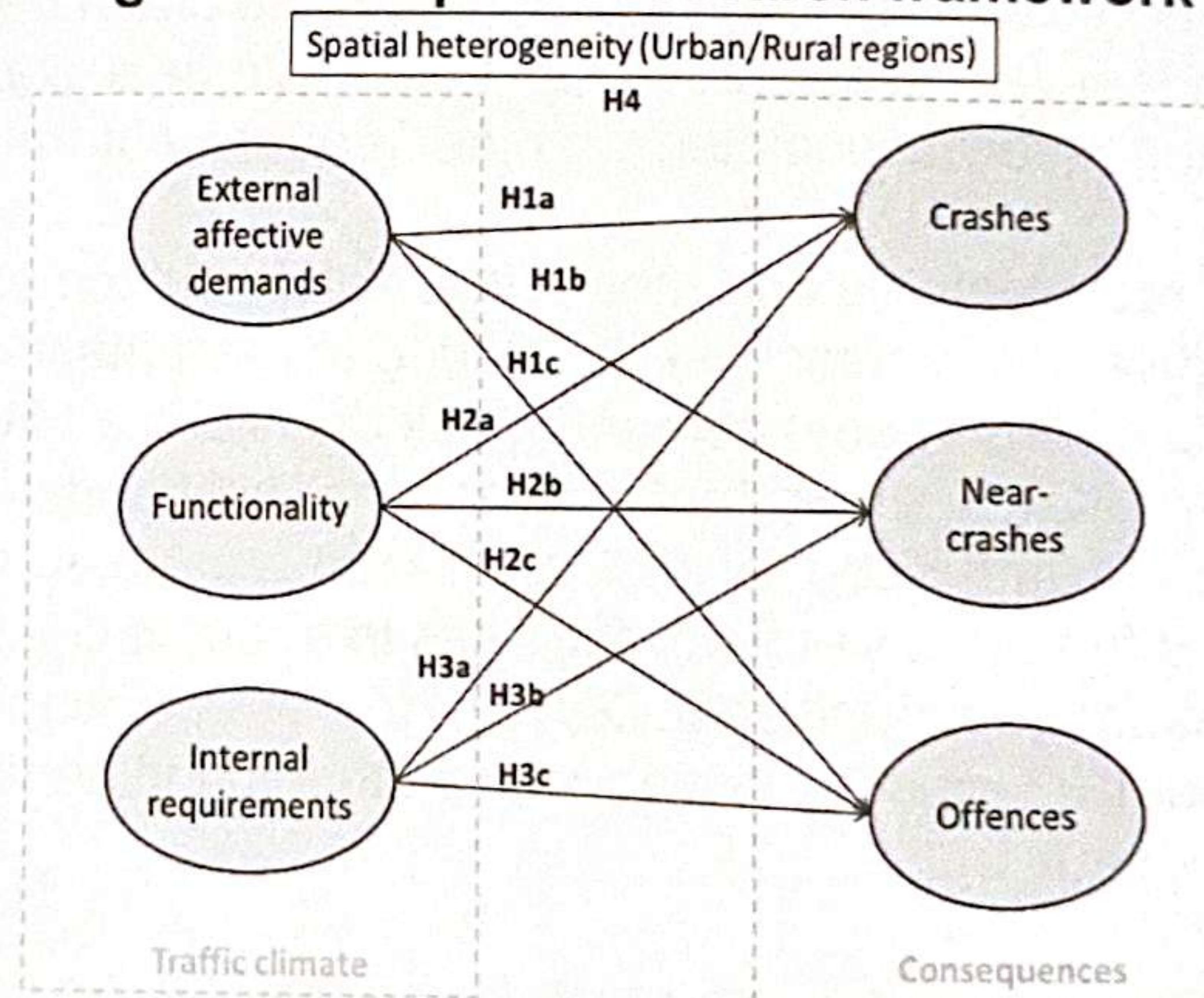
Implications for Riding Outcomes

The traffic climate thus diverges sharply between regions: urban areas combine high emotional demands with strong regulatory control, while rural settings suffer from infrastructural neglect and permissive risk-taking. These disparities likely yield distinct patterns in crash frequency, near-misses, and violations.

H4: Traffic climate differences between urban and rural areas produce varying effects on negative riding outcomes.

Figure 1 below summarises the key research hypotheses discussed above.

Figure 1 : Proposed research framework



3. Methodology

3.1. Measurement of variables

This study utilises Öztürk et al.'s (2022) validated scale to assess three traffic climate dimensions:

- External Affective Demand (EAD): 8 items (e.g., "The traffic system is stressful").
- Functionality (FNC): 5 items (e.g., "The traffic system is organised").
- Internal Requirements (IRQ): 6 items (e.g., "The traffic system requires constant caution").

Responses were recorded on a 5-point Likert scale (1 = Completely disagree to 5 = Completely agree). Negative riding outcomes (crashes, near-crashes, traffic violations) were measured via self-reports, following Trung Bui et al. (2022). Participants recalled incidents over the past 12 months. This approach aligns with prior research (e.g., Hoang et al., 2025) and captures context-specific behavioural patterns.

3.2. Data collection

An online survey targeted young Vietnamese motorcyclists (aged 18-25), a high-risk demographic (Üzümcüoğlu & Özkan, 2019). After filtering incomplete responses, 1,051 valid responses were retained. To ensure a balanced urban/rural comparison, 362 respondents were randomly selected from the rural subset of 689 responses. For the urban subset, all 362 responses were included.

3.3. Data analysis methods

The study employed a two-stage analytical approach using SPSS and SMARTPLS software. First, independent samples *t*-tests were conducted in SPSS to examine significant differences in research variables between urban and rural rider groups. Subsequently, Partial Least Squares Structural Equation Modelling (PLS-SEM) was applied via SMARTPLS to test the hypothesised relationships between traffic climate dimensions and negative riding outcomes. The dataset was partitioned into urban and rural subgroups to account for spatial heterogeneity, enabling a comparative assessment of how traffic climate effects vary across contexts. This multi-group analysis revealed distinct patterns between the full sample and regional subsamples, highlighting the moderating role of urban-rural disparities.

4. Results

4.1. Descriptive statistics

Table 1 presents the demographic characteristics of the sample. A greater proportion of rural respondents fell into the younger age category (18–20), whereas urban respondents were more evenly split across age brackets. Notably, rural riders had more riding experience, with over 60% having ridden for 2–5 years, compared to only 28.2% in urban settings.

Table 1 : Demographic information

Category	Urban		Rural	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Gender				
Male	114	31.5	117	32.3
Female	248	68.5	245	67.7
Age				
18-20	175	48.3	228	63.0
21-24	187	51.7	134	37.0
Riding experience				
Less than 2 years	245	67.7	98	27.1
From 2 - 5 years	102	28.2	220	60.8
Over 5 years	15	4.1	44	12.2

4.2. Measurement model assessment

Table 2 summarises the constructs and their individual measurement items. Regarding traffic climate dimensions, the data suggest that urban respondents reported more negative perceptions across most constructs, except for Functionality, where urban riders evaluated conditions more positively. The independent samples T-test indicates statistically significant differences in Functionality scores between urban and rural groups.

It is important to note that for External Affective Demands (EAD) and Internal Requirements (IRQ), higher values indicate greater perceived emotional demands or required rider effort, thus reflecting more challenging or less favourable traffic conditions. In contrast, higher values in Functionality (FNC) represent a more organised, safer, and efficient traffic system and are interpreted positively.

Table 2 : Constructs and measurements items

		Urban		Rural		p-value
		Mean	SD	Mean	SD	
<i>External affective demands</i>						
EAD1	Aggressive	3.26	1.247	3.18	1.216	0.415
EAD2	Stressful	3.03	1.176	2.99	1.153	0.610
EAD3	Depend on luck	3.15	1.227	3.20	1.207	0.625
EAD4	Putting pressure on you	2.95	1.203	2.89	1.135	0.485
EAD5	Chaotic	3.07	1.262	3.17	1.241	0.327
EAD6	Making irritated	2.92	1.194	2.98	1.199	0.535
EAD7	Time-consuming	2.71	1.172	2.88	1.215	0.054
EAD8	Annoying	2.63	1.170	2.78	1.178	0.094
<i>Functionality</i>						
FNC1	Planned	3.52	1.156	3.31	1.070	0.009
FNC2	Harmonious	3.37	1.112	3.15	1.054	0.005
FNC3	Safe	3.48	1.139	3.20	1.096	0.001
FNC4	Functional	3.55	1.101	3.27	1.088	<0.001
FNC5	Free-flowing	3.46	1.160	3.14	1.108	<0.001
<i>Internal requirements</i>						
IRQ1	Requiring you on the alert	4.05	1.053	3.94	1.153	0.178
IRQ2	Requiring cautiousness	4.12	1.015	4.00	1.135	0.129
IRQ3	Requiring vigilance	4.11	1.029	4.09	1.115	0.808
IRQ4	Requiring experience	3.90	1.061	3.83	1.113	0.412
IRQ5	Requiring patience	3.94	1.004	3.93	1.124	0.917
IRQ6	Requiring skillfulness	3.98	1.001	3.95	1.116	0.700
<i>Crashes</i>						
CRA	The number of crashes you have experienced in the past 12 months.	0.38	0.612	0.31	0.551	0.126
<i>Near-crashes</i>						
NCR	The number of near-crashes you have experienced in the past 12 months.	0.85	0.824	0.76	0.732	0.116
<i>Offences</i>						
OFC	The number of offences you have been involved in over the past 12 months.	0.36	0.684	0.29	0.620	0.191

Table 3 confirms the reliability and validity of the measurement model evaluation. All items demonstrated acceptable levels of outer loadings, Cronbach's alpha, composite reliability, and average variance extracted (AVE). The indicator IRQ2 was removed due to its VIF exceeding the multicollinearity threshold of 10.

Discriminant validity, assessed using the HTMT criterion (Hair Jr et al., 2021), is reported in Table 4. All HTMT values remained below the 0.90 threshold, indicating sufficient discriminant validity among constructs.

Table 3 : Measurement model evaluation

Dimension/Items	Outer loadings	Cronbach's Alpha	Composite Reliability	AVE
EAD	0.773 - 0.853	0.931	0.943	0.674
FNC	0.798-0.942	0.942	0.954	0.808
IRQ	0.899-0.935	0.956	0.943	0.674

Table 4 : HTMT criterion

	CRA	EAD	FNC	IRQ	NCR	OFC
CRA						
EAD	0.082					
FNC	0.021	0.067				
IRQ	0.046	0.271	0.502			
NCR	0.258	0.137	0.098	0.042		
OFC	0.148	0.067	0.138	0.036	0.272	

4.3. Structural model assessment

The structural model was assessed using PLS-SEM. As shown in Table 5, the results support hypotheses H1 to H3 and H5 to H6, based on p-values below 0.05. In contrast, H4, H8, and H9 were not supported.

Notably, the effect of External Affective Demands (EAD) on crashes (H1a), near-crashes (H1b), and offences (H1) was statistically significant and positive. This aligns with findings from Hoang, Bui, and Cools (2025), who demonstrated that higher EAD levels predict stronger risk-taking attitudes, which in turn elevate negative traffic outcomes. Furthermore, the negative relationship between Functionality (FNC) and near-crashes (H2b) and offences (H2c) was also significant. However, FNC did not significantly influence crash occurrence (H2a). The results for Internal Requirements (IRQ) are mixed; only H3a was supported, suggesting a modest protective effect of IRQ on crash frequency.

Table 5 : Measurement model evaluation

		Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values	
H1a	EAD → CRA	0.104	0.107	0.035	2.948	0.003	Supported
H1b	EAD → NCR	0.121	0.123	0.036	3.364	0.001	Supported
H1c	EAD → OFC	0.069	0.071	0.033	2.068	0.039	Supported
H2a	FNC → CRA	0.031	0.032	0.04	0.782	0.434	Rejected
H2b	FNC → NCR	-0.143	-0.143	0.044	3.254	0.001	Supported
H2c	FNC → OFC	-0.152	-0.152	0.041	3.727	<0.001	Supported
H3a	IRQ → CRA	-0.087	-0.089	0.044	1.978	0.048	Supported
H3b	IRQ → NCR	0.078	0.078	0.049	1.581	0.114	Rejected
H3c	IRQ → OFC	0.015	0.014	0.046	0.336	0.737	Rejected

4.4. Urban vs. rural differences

To explore spatial variation, we conducted a multi-group analysis comparing path coefficients across urban and rural subgroups (Table 6). The results indicate that urban riders are more strongly influenced by external affective demands, with H1a and H1b supported only in the urban model. In contrast, in rural settings, Functionality appears more predictive of safety outcomes, as H2b and H2c were significant only in that subgroup. Interestingly, the effect of EAD on traffic offences (H1c) was only significant among rural participants.

These findings reinforce Hoang et al.'s (2025) argument that spatial context meaningfully moderates the influence of traffic climate dimensions, particularly the differential roles of stressors and perceived system coherence in shaping riding behaviours.

Table 6 : Urban vs. rural differences

	Path	Urban		Rural	
		Sample Mean (M)	P Values	Sample Mean (M)	P Values
H1a	EAD → CRA	0.146	0.009	0.073	0.217
H1b	EAD → NCR	0.169	0.002	0.094	0.102
H1c	EAD → OFC	0.039	0.486	0.117	0.019
H2a	FNC → CRA	0.019	0.761	0.063	0.268
H2b	FNC → NCR	0.049	0.460	-0.224	0.001
H2c	FNC → OFC	-0.099	0.062	-0.232	0.001
H3a	IRQ → CRA	-0.108	0.059	-0.083	0.225
H3b	IRQ → NCR	0.055	0.327	0.092	0.250
H3c	IRQ → OFC	-0.067	0.266	0.133	0.074

5. Discussions

5.1. Findings on the main research hypotheses

The structural model results confirm that External Affective Demands (EAD) significantly increase the likelihood of crashes, near-crashes, and traffic offences among young Vietnamese motorcyclists. This finding is consistent with previous work (Hoang et al., 2025), which demonstrated that high perceived EAD promotes risk-taking attitudes. Our study extends this by establishing direct links between EAD and actual safety outcomes, not just behavioural intentions.

These results align with literature highlighting the role of emotional strain in dangerous driving behaviours. For example, Mesken et al. (2007) observed that emotionally charged environments induce errors such as speeding or aggressive manoeuvres. Similarly, Chu et al. (2019) found that stress and frustration in chaotic traffic environments increase crash risk. Gehlert et al. (2014) and Zhang et al. (2018) also identify EAD as a key psychological factor shaping driving behaviour across cultural contexts.

The findings diverge from Chu et al. (2019), who found Internal Requirements (IRQ) to be a stronger predictor than EAD or Functionality (FNC) in China. This may be attributed to contextual differences: Chu et al.'s sample was limited to urban Chinese drivers, while our study encompasses both urban and rural Vietnamese motorcyclists, a group facing greater traffic complexity and vulnerability. Furthermore, the motorcyclist-centric focus of this study reflects the reality that motorcycles account for 95% of vehicles and nearly 60% of road deaths in Vietnam (WHO, 2015; WHO, 2018). Regarding Functionality, results show significant negative associations with near-crashes and offences, but not with actual crashes. This suggests that improved infrastructure and system coherence may help reduce minor incidents or risky behaviour, but are insufficient to prevent all serious accidents, perhaps due to residual emotional or behavioural factors. These findings resonate with prior observations that safe road design and clear signage improve compliance and reduce minor hazards (Özkan & Lajunen, 2011; Kazemi & Soltani, 2024), especially in unpredictable or mixed-use environments like Vietnam.

In terms of Internal Requirements, the model showed a significant negative association only with crash frequency, indicating that riders with stronger self-regulation or heightened perception of system demands are less likely to be involved in severe accidents. However, no significant effect was observed on near-crashes or offences. These mixed results are partly supported by Hancock et al. (1999) and Kaber et al. (2012), who observed that increasing cognitive load may both enhance cautiousness in some riders and overwhelm others, depending on experience and skill. This complexity mirrors the findings of Crundall et al. (2012), which underscore that individual responses to challenging traffic climates can vary substantially.

5.2. Spatial differences: urban vs rural traffic climates

The multi-group analysis reveals substantial variation in how traffic climate dimensions influence safety outcomes across urban and rural contexts, thus supporting Hypothesis 4. In urban environments, EAD was significantly associated with both crashes and near-crashes. This confirms that the high cognitive and emotional burden of navigating dense, chaotic traffic increases accident exposure. This is supported by Cox et al. (2017) and Mesken et al. (2007), who found that urban settings present complex risk landscapes requiring constant vigilance and emotional resilience.

However, no significant relationship was found between EAD and offences in urban areas. This may be explained by the higher visibility of law enforcement and digital

surveillance in cities, which curbs violations despite stressful conditions (Chou et al., 2022; Wu et al., 2021).

Conversely, in rural areas, EAD significantly predicted traffic violations, suggesting that the lack of effective enforcement allows emotionally triggered behaviours, such as speeding or dangerous overtaking, to manifest in non-compliance. These findings echo those by Borowsky et al. (2010) and Charlton et al. (2014), who describe rural riders' tendencies to misjudge risks in seemingly "safe" environments. Wilde's (1998) risk homeostasis theory also explains this behaviour, noting that road users often adjust vigilance based on perceived threat levels.

Most notably, Functionality played a more prominent role in rural areas, significantly reducing near-crashes and offences. This underscores the importance of infrastructural upgrades in rural settings, such as road maintenance, signage, and intersection planning. This reflects conclusions by McAndrews et al. (2016) and Rakauskas et al. (2009), who argue that rural areas are disproportionately affected by poor enforcement and hazardous road design.

Interestingly, Functionality had no significant impact in urban areas, possibly due to already established systems offering limited room for improvement, thus confirming a saturation effect, where marginal gains yield minimal behavioural change.

5.3. Practical implications

This research highlights the urgent need for context-specific road safety strategies in low- and middle-income countries. In particular, the findings reinforce the practical validity of the Traffic Climate Scale (Öztürk et al., 2022) in Vietnam's motorcycle-dominated landscape, expanding its utility beyond the car-centric models common in Europe or North America.

Given that young riders aged 18–25 are overrepresented in traffic incidents (Üzümcüoğlu & Özkan, 2019; Trung Bui et al., 2022), targeted interventions must focus on reducing emotional burden and improving their perception of system functionality. In line with Benzaman et al. (2022), who demonstrate a link between perceived safety culture and performance outcomes, our findings suggest that interventions should combine infrastructure with behavioural reinforcement.

Recommended actions include:

- Urban areas: Implement traffic flow improvements, digital enforcement tools, and stress-reducing policies such as separated motorcycle lanes and intelligent signal systems (Chou et al., 2022).
- Rural areas: Prioritise basic road maintenance, signage upgrades, and consistent enforcement presence—measures which have been shown to reduce risky behaviour when functionality is improved (Wu et al., 2021; Kazemi & Soltani, 2024).
- National strategies: Develop AI-assisted monitoring systems and driver penalty points schemes to enhance enforcement (Chou et al., 2022) and promote awareness campaigns tailored to regional traffic conditions.

5.4. Methodological Reflections and Future Directions

Although this study employed robust analytical techniques and drew on a large, diverse sample, certain limitations remain. While valuable for capturing subjective perceptions, self-reported data are prone to recall bias or social desirability effects (Carsten & Jamson, 2011). Future studies might incorporate simulator-based designs to capture real-time behaviour in controlled yet immersive environments. However, as Yang et al. (2014) note, simulator settings often fail to replicate real-world stressors, potentially limiting ecological validity.

Longitudinal research could also track how changes in traffic infrastructure or policy interventions alter rider perceptions and outcomes over time. Further cross-national comparisons, such as between Vietnam and other ASEAN states, could illuminate how cultural and regulatory differences shape traffic climate perception and risk.

6. Conclusion

This study provides compelling empirical evidence of the significant role that traffic climate dimensions, namely External Affective Demands (EAD), Functionality (FNC), and Internal Requirements (IRQ), play in influencing road safety outcomes among young motorcyclists in Vietnam. By adopting a spatial lens that compares urban and rural settings, the research contributes novel insights into how regional disparities in traffic environments shape rider behaviour and accident risk.

The findings reaffirm that perceived emotional stress and unpredictability in traffic (EAD) consistently predict crashes, near-crashes, and violations. This confirms previous work by Hoang et al. (2025) and extends it by demonstrating direct effects on safety outcomes across spatial contexts. In contrast, Functionality (FNC)—capturing perceived efficiency, clarity, and organisation of the traffic system—reduces near-crashes and traffic offences, particularly in rural areas where infrastructural deficits are more pronounced. Although Internal Requirements (IRQ) showed a modest protective effect against crashes, it did not significantly influence near-misses or violations, underscoring the need to complement individual responsibility with systemic improvements.

The study highlights the critical need for context-specific interventions. In urban settings, where the traffic environment is dense and complex, interventions should focus on reducing affective stress through intelligent traffic systems, enhanced regulation, and better integration of vulnerable road users. Conversely, in rural areas, where infrastructure is often lacking and enforcement is weak, investments in road maintenance, signage, and regulatory consistency are paramount. These conclusions support prior observations by McAndrews et al. (2016), Rakauskas et al. (2009), and Charlton et al. (2014) regarding the persistent risks and false perceptions of safety in rural regions.

Furthermore, the study validates the Traffic Climate Scale (Öztürk et al., 2022) as a reliable tool for evaluating rider perceptions in low- and middle-income countries and confirms its applicability across diverse spatial contexts. Partial Least Squares Structural Equation Modelling (PLS-SEM) allowed for rigorous testing of hypothesised relationships and regional moderation effects, offering robust statistical support for policy recommendations.

While self-reported survey data offer valuable insights into rider experience, limitations remain. Carsten and Jamson (2011) note that such methods may suffer from recall or reporting bias. Although useful for capturing behaviour under controlled conditions, driving simulators face challenges in replicating real-world risk and stress levels (Yang et al., 2014). Future research should explore mixed-method approaches, combining self-report, observational, physiological, and simulator data, to deepen the understanding of traffic climate perceptions and their behavioural consequences. Ultimately, this research advances the theoretical understanding of traffic climate while offering practical guidance for policymakers aiming to reduce motorcycle-related crashes in Vietnam and similar contexts. By acknowledging spatial heterogeneity in traffic environments and rider perceptions, authorities can develop regionally tailored safety policies rather than implementing uniform solutions. Such an approach is likely to be more effective in mitigating crash risk and enhancing safety culture, particularly among young motorcyclists, who remain one of the most vulnerable road user groups.

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