Fearless Riders, Fearful Cities?

How Infrastructure Perception, Perceived Safety and Perceived Risk Relate to E-Bike Riders' Intrusion into Motor-Vehicle Lanes

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Introduction

E-bikes are increasingly used for low-emission short- and medium-distance urban travel, but their safety benefits may be compromised when riders enter mixed-traffic environments. In this study, **e-bike lane intrusion behaviour (LIB)** refers to riders entering motor-vehicle lanes despite the availability of bicycle lanes, thereby exposing themselves to faster and heavier traffic and weakening the protective benefits of dedicated bicycle-lane provision. Existing studies have mainly examined cycling infrastructure, route choice, or general risky riding, while e-bike LIB has received less attention as a distinct and preventable form of mixed-traffic exposure. This study therefore investigates how **infrastructure perception (IP), perceived safety (PS)**, **perceived risk (PR)**, and **Theory of Planned Behaviour (TPB)** constructs are associated with riders' e-bike LIB.

Electric scooter (e-scooter)

- **Is a license plate required:** No
- **Lane to be used:** bicycle lane
- **Speed Range:** ≈ 0-25 km/h
- **Price:** ≈ 1,000-3,000 RMB (≈ 150-430 USD)
- **Battery Capacity:** ≈ 0.28-0.36 kWh

Electric moped (e-moped)

- **Is a license plate required:** Yes
- **Lane to be used:** motor vehicle lane
- **Speed Range:** ≈ 0-50 km/h
- **Price:** ≈ 3,000-6,000 RMB (≈ 430-850 USD)
- **Battery Capacity:** ≈ 1.2 kWh

Electric motorcycle (e- motorcycle)

- **Is a license plate required:** Yes
- **Lane to be used:** motor vehicle lane
- **Speed Range:** ≈ 0-100 km/h
- **Price:** > 5,000 RMB (> 700 USD)
- **Battery Capacity:** ≈ 1.4-2.3 kWh

Research Object — Electric bike (e-bike)

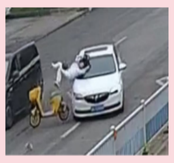
Throttle-controlled
The main vehicle model in China
It can be propelled directly by a throttle without the rider pedaling.

- **Is a license plate required:** Yes
- **Lane to be used:** bicycle lane
- **Speed Range:** ≈ 0-25 km/h
- **Price:** ≈ 1,000-3,000 RMB (≈ 150-430 USD)
- **Battery Capacity:** ≈ 0.8-1.0 kWh

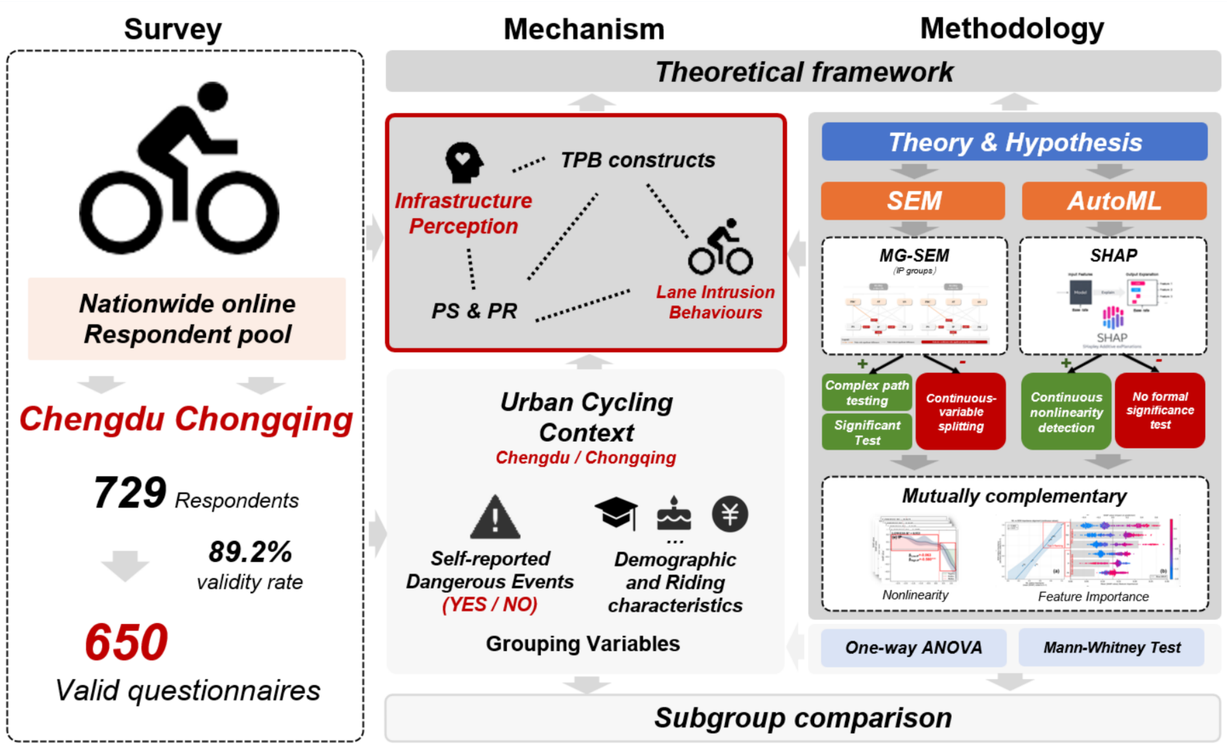
Pedal-assisted
The motor provides assistance only when the rider is pedaling.

- **Is a license plate required:** No
- **Lane to be used:** bicycle lane
- **Speed Range:** ≈ 0-25 km/h
- **Price:** ≈ 1,000-3,000 RMB (≈ 150-430 USD)
- **Battery Capacity:** ≈ 0.6 kWh

E-bike LIB

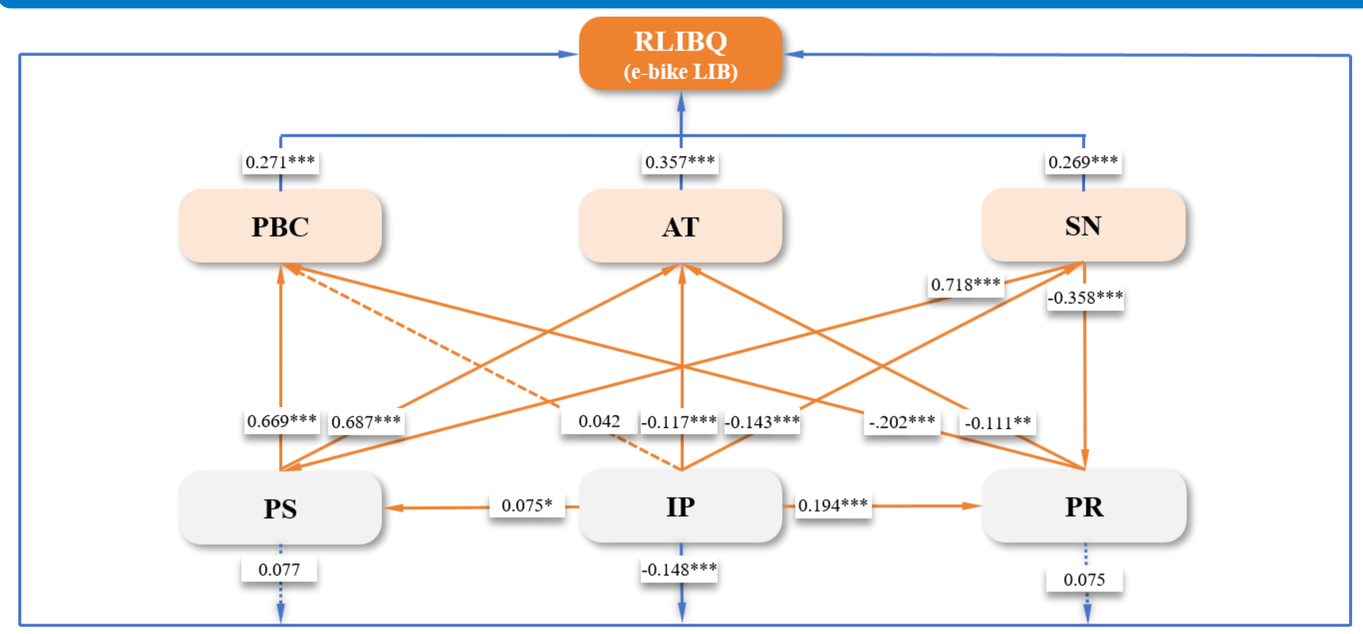


Methods



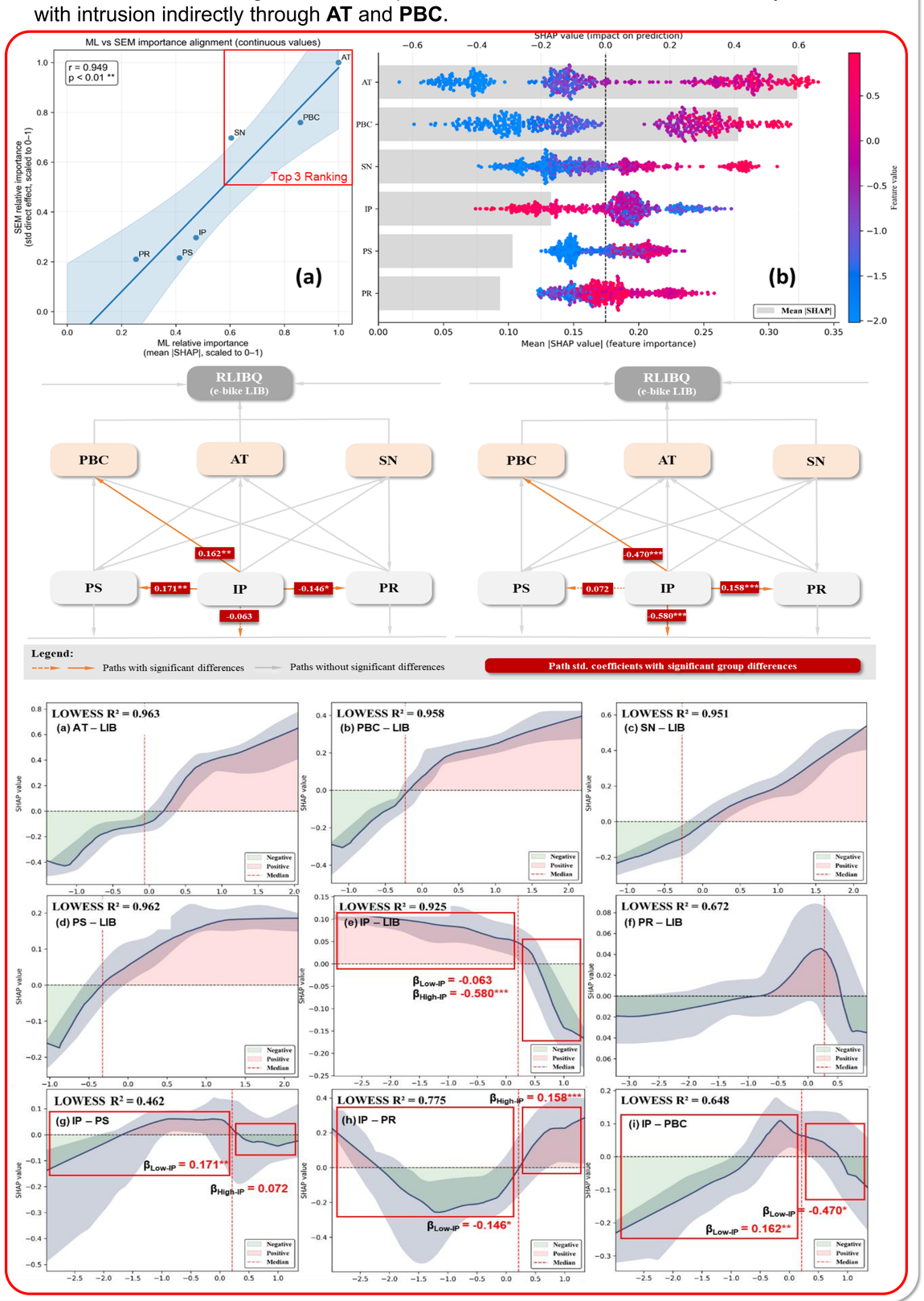
- **SEM** and **AutoML–SHAP** were used as complementary approaches.
- **Subgroup comparisons** linked psychological variables and intrusion behaviour to **city context** and **dangerous-event experience.**
- **Chengdu** (a flatter and more cycling-supportive context) and **Chongqing** (a mountainous and space-constrained context) provided a clear city-context contrast.

Results



SEM Modelling

- The SEM showed good model fit and explained substantial variance in e-bike LIB (**R^2 = 0.68**).
- **Attitude (AT), Perceived Behavioural Control (PBC)**, and **Subjective Norms (SN)** were positively associated with **e-bike LIB**.
- **AT** showed the strongest direct association, suggesting that favourable evaluations of intrusion play a central role.
- **IP** was negatively associated **with e-bike LIB** and was also linked to **AT, SN, PS, and PR.**
- **PS** and **PR** were not significant direct predictors of **e-bike LIB**, but were mainly associated with intrusion indirectly through **AT** and **PBC**.

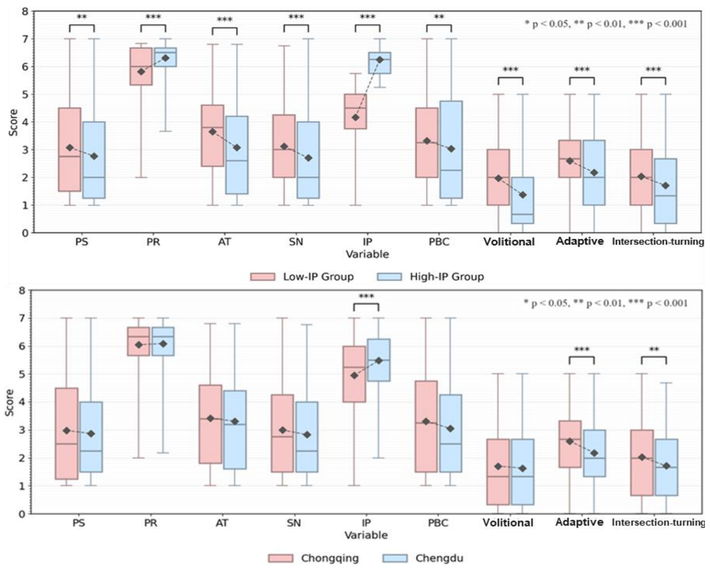


Non-linear Relationship (AutoML & MG-SEM Modelling)

- Higher infrastructure perception was generally associated with lower lane intrusion, but the reduction became much stronger only at higher IP levels.
- At lower-to-moderate IP levels, improved infrastructure perception may increase perceived safety and behavioural control while reducing perceived risk.
- Riders may feel safer and more capable of mixing with motor traffic before the bicycle-lane environment becomes sufficiently attractive and normative to discourage intrusion.

Group Comparisons

- IP-based and city-context comparisons reveal a **consistent pattern**.
- Lower-IP riders or contexts show both higher lane-intrusion frequencies and distinct psychological profiles.
- Even when bicycle lanes are formally available, **weaker perceived continuity, comfort, and orderliness may make intrusion more psychologically acceptable.**
- **Riders with self-reported dangerous events** showed **higher intrusion scores, stronger pro-intrusion attitudes** and **social norms, lower perceived risk, and lower infrastructure perception.**



Variables	Self-reported dangerous events Median (Q1, Q3)		Significance		
	Yes (n =345)	No (n =305)	U	z	p
Volitional	**1.67 (0.67, 3.00)**	**1.00 (0.33, 2.33)**	**64271.00**	**4.88**	**<0.001*** **
Adaptive	**2.67 (1.67, 3.33)**	**2.00 (1.33, 3.00)**	**64637.50**	**5.03**	**<0.001*** **
Intersection-turning	**2.00 (1.67, 2.33)**	**1.33 (0.67, 2.33)**	**62223.00**	**4.02**	**<0.001*** **
PS	2.67 (1.33, 4.33)	2.00 (1.33, 4.33)	56631.00	1.68	0.091
PR	**6.17 (5.67, 6.67)**	**6.33 (5.67, 6.67)**	**46030.00**	**-2.76**	**0.006** **
AT	**3.80 (1.80, 4.80)**	**2.80 (1.60, 4.20)**	**60766.50**	**3.41**	**0.001** **
PBC	3.25 (1.75, 4.50)	2.50 (1.25, 4.50)	56322.00	1.55	0.120
SN	**2.75 (1.75, 4.50)**	**2.25 (1.25, 3.75)**	**62414.50**	**4.10**	**<0.001*** **
IP	**5.25 (4.25, 6.25)**	**5.50 (4.75, 6.25)**	**45596.50**	**-2.94**	**0.003** **

Discussion & Implications

1 Lane Activation

In weaker riding environments, governance should move beyond lane provision and improve the actual use of available dedicated bicycle lanes.

2 Psychological Pathway Intervention

Interventions should go beyond risk warnings by weakening riders' perceived convenience, controllability, and social normalisation of motor-lane intrusion. In areas where infrastructure perception improves but remains insufficiently mature and stable, particular attention should be paid to potential overconfidence and risk underestimation.

3 Perception-oriented Design

Under constrained physical conditions, visual guidance and management visibility should be enhanced to make existing bicycle facilities feel more continuous, orderly, and reliable, while strengthening riders' sense of being recognized and protected.

4 Intersection Crossing Optimization

Strengthen e-bike guidance at intersections through clearer crossing markings, left-turn waiting areas, and signal coordination, reducing diagonal crossings and the incentive to avoid two-stage crossings.