

Research on the Design of Central Median Opening During Expressway Reconstruction and Expansion

Miaoqian Zhou¹, Mengdie Liu^{2*}

¹Guangdong Expressway Co., Ltd., Guangzhou 510440, Guangdong, China

²CCCC Second expressway Consultant Co., Ltd., Wuhan 430052, Hubei, China

*Corresponding author: Mengdie Liu, 1193570518@qq.com

Copyright: © 2026 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: To achieve the objective of maintaining traffic flow while carrying out construction in highway reconstruction and expansion projects, traffic diversion is required through openings in the median for traffic maintenance. The design of these openings directly affects traffic safety and operational efficiency. Focusing on highway reconstruction and expansion projects with four lanes maintained during construction, this study considers two typical traffic transition scenarios: bidirectional traffic on both carriageways transitioning to bidirectional traffic on a single carriageway, and bidirectional traffic on the left carriageway transitioning to bidirectional traffic on the right carriageway. Median opening alignments were designed for different operating speeds. A VISSIM-based microscopic traffic simulation was then conducted to evaluate the effects of different opening lengths and alignment configurations on traffic flow from three perspectives: delay, traffic conflict rate, and speed stability. Based on the simulation results, an optimal range of median opening lengths and recommended alignment designs were proposed for four-lane traffic maintenance sections within highway construction zones.

Keywords: Expressway reconstruction and expansion; Central median opening; VISSIM; Alignment design

Online publication: Oct 16, 2026

1. Introduction

China is currently undergoing large-scale highway reconstruction and expansion. Median openings for traffic maintenance are a spatial feature unique to the construction phase of highway reconstruction and expansion projects. When one carriageway is closed during highway construction, median openings are used to divert bidirectional traffic or traffic from one carriageway onto the other carriageway, thereby enabling construction on one carriageway while maintaining traffic on the other. After vehicles pass through the work zone, traffic is guided back to the original carriageway^[1-3]. If the median opening is too short, vehicles may have

insufficient turning radii, require substantial speed reductions and forced lane changes when passing through the opening. This can create a traffic bottleneck, increase traffic conflicts, and pose safety risks. Conversely, although an excessively long opening can alleviate immediate lane-changing pressure, it prolongs the duration of mixed-speed traffic and lateral interference, causing traffic to remain in an unstable weaving state over a longer distance, thereby reducing overall operational efficiency and safety. In addition, excessively long openings increase construction costs^[4]. Moreover, vehicles may travel at relatively high speeds through the median opening, and loss of vehicle control can consequently result in severe traffic crashes^[5].

Therefore, scientifically determining the length and alignment design of median openings for traffic maintenance is of great significance for ensuring traffic safety and operational efficiency in highway construction zones. Accordingly, this study focuses on four-lane highway reconstruction and expansion construction zones and examines the effects of median opening design on traffic operations by analyzing the macroscopic characteristics of traffic flow. The underlying mechanisms through which opening design influences traffic flow are investigated, with the aim of scientifically determining a reasonable opening design that balances safety and operational efficiency.

2. Median opening alignment design

This paper takes the central median openings for fourlane trafficmaintaining expressways as the research object, targeting two typical trafficsequence conversion scenarios: conversion from twoway operation on dual carriageways to twoway operation on a single carriageway, and shift of twoway traffic from the left single carriageway to the right single carriageway. For expressways maintained with fourlane traffic during reconstruction, speedlimit schemes of 60 km/h and 80 km/h are commonly adopted for traffic preservation. In accordance with Technical Standard of Highway Engineering (JTG B012017), the alignment designs and corresponding opening lengths are derived for design speeds of 60 km/h and 80 km/h respectively. Refer **Figure 1–4. Table 1 and 2.**

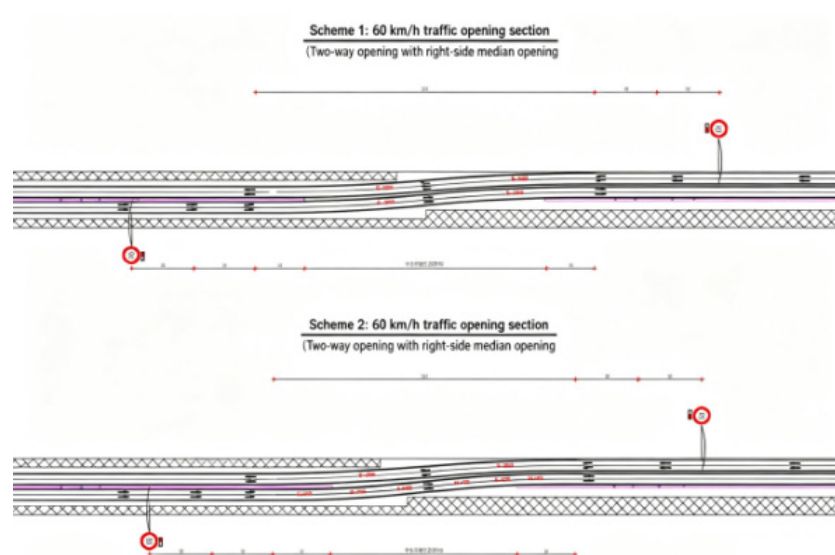


Figure 1. Alignment schemes of central median openings (design speed 60km/h, dual-carriageway to single-carriageway two-way traffic).

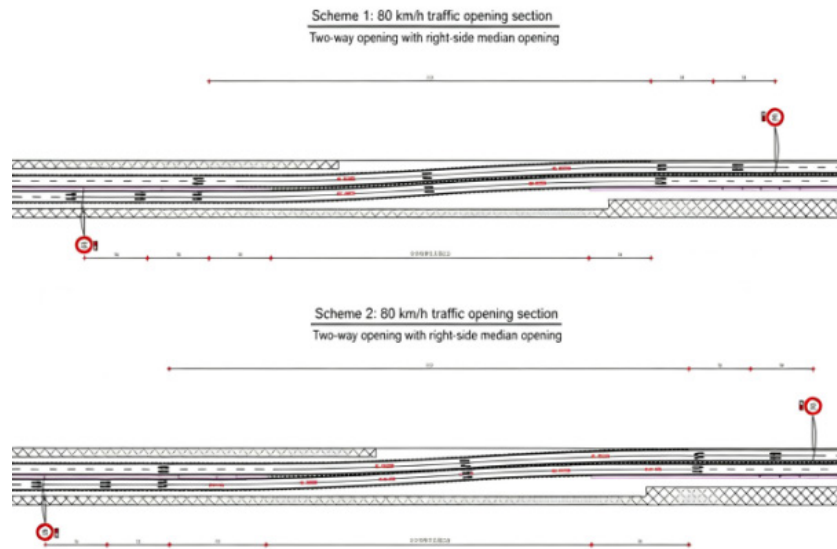


Figure 2. Alignment schemes of central median openings (design speed 80km/h, dual-carriageway to single-carriageway two-way traffic).

Table 1. Alignment design parameters of central median openings (dual-carriageway two-way to single-carriageway two-way traffic)

Design speed V (km/h)	Circular curve radius R (m)	Transition curve length Ls (m)	Hardened central median length L (m)
60	1500	—	196
60	700	50	149
80	2500	—	253
80	2300	70	260

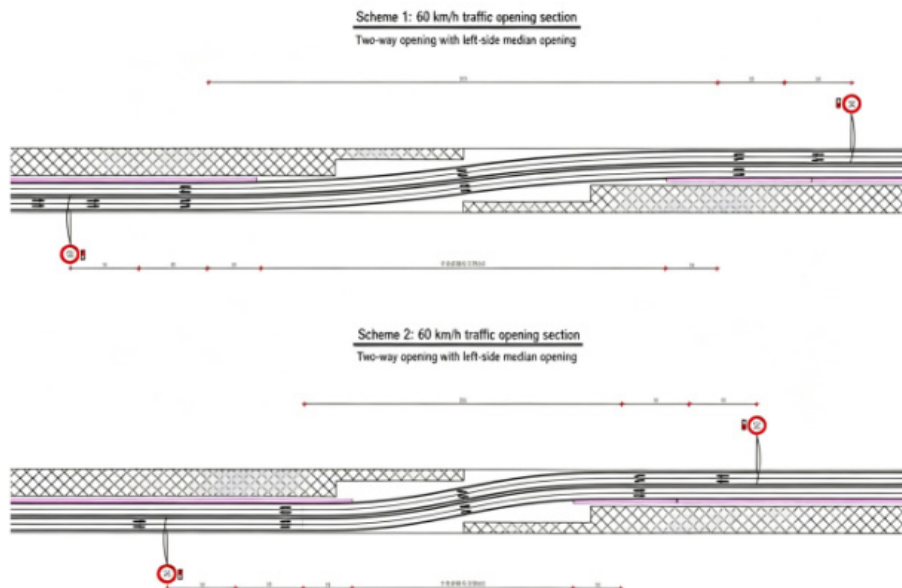


Figure 3. Alignment schemes of central median openings (design speed 60 km/h, left to right single-carriageway two-way traffic).

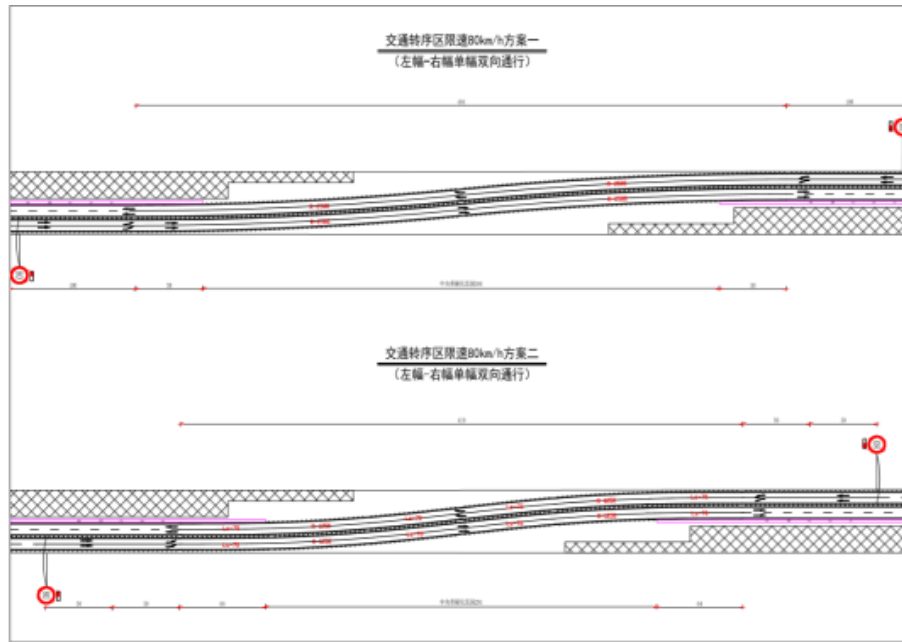


Figure 4. Alignment schemes of central median openings (design speed 80 km/h, left to right single-carriageway two-way traffic).

Table 2. Alignment design parameters of central median openings (left single-carriageway two-way to right single-carriageway two-way traffic)

Design speed V (km/h)	Circular curve radius R (m)	Transition curve length Ls (m)	Hardened central median length L (m)
60	1500	—	297
60	400	50	161
80	2500	—	384
80	1250	70	297

3. VISSIM-based traffic flow simulation analysis

3.1. Experimental design

To investigate the effects of median opening design for traffic maintenance on microscopic traffic flow, a VISSIM-based simulation experiment was developed with three factors: traffic volume, heavy-truck proportion, and median opening length. The effects of median opening design on traffic efficiency, traffic safety, and traffic stability were then analyzed ^[6].

According to vehicle composition data from multiple expressways in China, large buses and medium-sized vehicles account for approximately 3% and 5% of the total traffic volume, respectively, in the traffic composition of highways undergoing reconstruction and expansion. The proportions of these two vehicle types are relatively stable, and traffic management schemes in construction zones generally do not divert large buses or medium-sized vehicles. Therefore, in all scenarios considered in this study, the proportions of large buses and medium-sized vehicles were kept constant at 3% and 5%, respectively, while the proportions of heavy trucks and small vehicles were varied. The specific factor settings are presented in **Table 3**.

Table 3. Variation ranges of influencing factors

Influencing factor	Minimum value	Maximum value	Step size	Number of factor levels
Traffic volume (pcu/h)	300	1500	200	7
Heavy truck proportion (%)*	0	90	10	10
Central median opening length (m)	50	350	50	7

*Note: Heavy truck proportion refers to the percentage of heavy trucks in total PCU.

Full-factor combination tests are carried out in VISSIM. To eliminate random errors, each scheme is simulated 3 times with different random seeds, and the average value of the three simulation runs is adopted as the final result. Total simulation runs: $7 \times 10 \times 7 \times 3 = 1470$ times.

3.2. Traffic efficiency evaluation

Average travel delay is selected as the quantitative indicator to measure the influence of median opening length on traffic capacity. Simulation results show that traffic volume, heavy truck proportion and median opening length all exert significant effects on travel delay, detailed as follows:

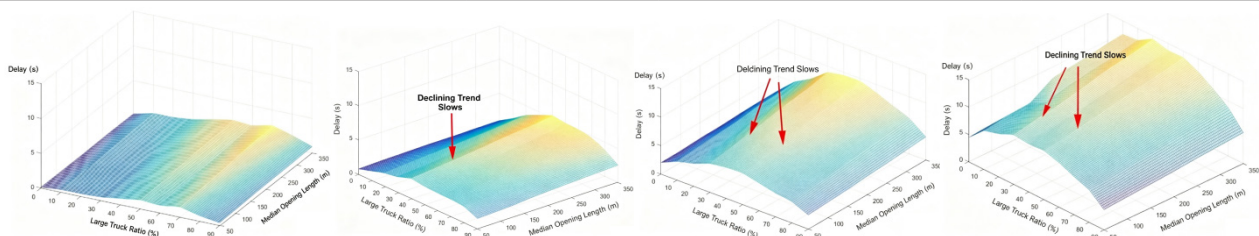
Travel delay rises continuously with the increase of traffic volume.

Under all traffic volume conditions, the relationship between travel delay and heavy truck proportion follows a parabolic curve. Heavy trucks operate at lower speeds than other vehicle types, forcing passenger cars following behind to decelerate frequently and increasing travel delay. When heavy trucks account for an extremely high share, the number of speed reduction events decreases due to homogenized vehicle speeds, and travel delay gradually declines.

Overall, travel delay drops as the median opening length shortens. This phenomenon may be attributed to the lower speed limit at traffic conversion zones compared with regular road sections. With other conditions unchanged, average travel delay decreases as lane number increases. In addition, under certain heavy truck proportion levels, the declining trend of travel delay slows down when the opening length falls to 100–150 m (see **Table 4**, **Figure 5**).

Table 4. Three-way ANOVA results for dependent variable (travel delay)

Source of variation	Sum of squares	Degrees of freedom	Mean square	F-statistic	p-value
Traffic volume	7505	6	2502	205545	0.000
Heavy truck proportion	1449	9	161	13223	0.000
Median opening length	500	6	83	6843	0.000
Three-way interaction	901	468	3.5	284	0.000
Total	29226	1470	—	—	—



a) Traffic volume of 300 pcu/h b) Traffic volume of 700 pcu/h c) Traffic volume of 1100 pcu/h d) Traffic volume of 1500 pcu/h

Figure 5. Fitted 3D surface plot of delay versus heavyvehicle percentage and opening length under different traffic volumes.

3.3. Traffic safety evaluation

Traffic conflict rate is chosen as the core indicator to analyze the influence of median opening length on driving safety in construction zones. Trajectory (.trj) files exported from VISSIM are imported into SSAM (Surrogate Safety Assessment Model) for traffic conflict statistics and analysis. SSAM recommended thresholds are adopted: TTC = 1.5 s, PET = 5.0 s; angle thresholds for rear-end conflicts and crossing conflicts are set to 30° and 90° respectively. Key simulation conclusions are summarized below:

Traffic conflict rate is positively correlated with traffic volume; higher traffic volume leads to poorer safety performance within construction zones.

The correlation between heavy truck proportion and conflict rate is insignificant under low traffic volumes. Under high traffic volumes (1100 pcu/h, 1500 pcu/h), traffic conflict rate first rises then falls as heavy truck proportion increases, peaking at 10%. Heavy trucks have poor dynamic performance and lower operating speeds, widening speed differences between vehicle types and triggering more traffic conflicts. When heavy trucks dominate traffic flow, speed differences shrink and total vehicle count drops, reducing conflict probability after the peak point. At fixed traffic volume, median openings of 100–150 m produce markedly lower conflict rates and better safety performance under high traffic volume and 10% heavy truck proportion (**Figure 6**). Openings shorter than 50 m force sharp vehicle deceleration, creating a large speed differential with upstream traffic and raising conflict risks; overlong openings extend the mixing zone of fast passenger cars and slow heavy trucks, degrading safety. (**Table 5**)

Table 5. Three-way ANOVA results for dependent variable (traffic conflict rate)

Source of variation	Sum of squares	Degrees of freedom	Mean square	F-statistic	p-value
Traffic volume	0.638	6	0.106	41397.135	0.000
Heavy truck proportion	0.144	9	0.016	6251.365	0.000
Median opening length	0.001	6	0.000	78.103	0.000
Three-way interaction	0.329	468	0.001	274.202	0.000
Total	1.841	1470	—	—	—

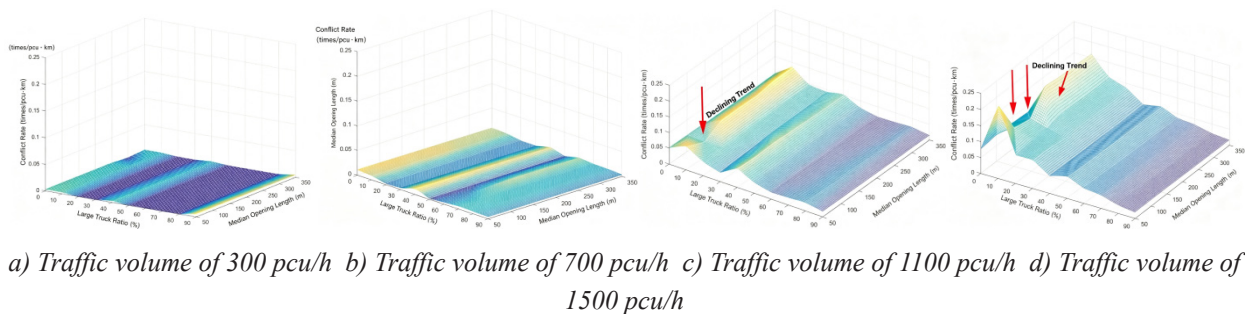


Figure 6. Fitted 3D surface plot of conflict rate versus heavyvehicle percentage and opening length under various traffic volumes.

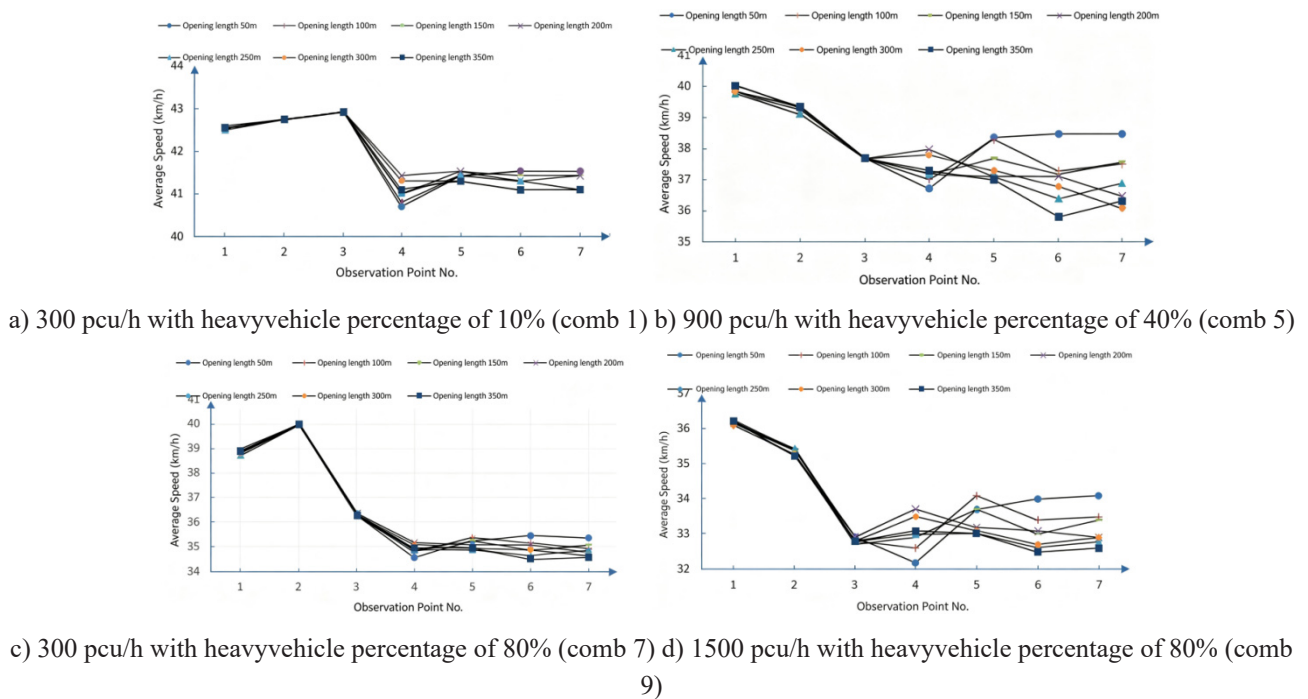
3.4. Traffic stability evaluation

Traffic stability reflects the anti-interference resilience and evolution law of traffic flow in restricted road space. Test analysis is conducted for typical combinations of traffic volume and heavy truck proportion, as listed in **Table 6**.

Table 6. Typical combinations of traffic volume and heavy truck proportion

Combination No.	1	2	3	4	5	6	7	8	9
Traffic volume (pcu/h)	300 (Low)	900 (Medium)	1500 (High)	300 (Low)	900 (Medium)	1500 (High)	300 (Low)	900 (Medium)	1500 (High)
Heavy truck proportion (%)	10 (Low)	10 (Low)	10 (Low)	40 (Medium)	40 (Medium)	40 (Medium)	80 (High)	80 (High)	80 (High)

Average speed curves at each observation point under different median opening lengths are plotted for low traffic + low heavy truck ratio, low traffic + high heavy truck ratio, medium traffic + medium heavy truck ratio and high traffic + high heavy truck ratio (**Figure 7** and **Table 7**).

**Figure 7.** Schematic diagram of average speed variation at each observation point under different opening lengths.**Table 7.** Standard deviation of operating speed for all combinations & opening lengths

Opening length (m)	Comb.1	Comb.2	Comb.3	Comb.4	Comb.5	Comb.6	Comb.7	Comb.8	Comb.9
50	0.83	0.77	1.04	1.05	1.11	1.51	2.06	1.13	1.36
100	0.81	0.73	1.11	1.05	1.04	1.34	2.02	1.09	1.31
150	0.78	0.77	1.11	1.04	1.02	1.46	2.11	1.17	1.34
200	0.72	0.66	0.91	1.08	1.28	1.54	2.10	1.21	1.37
250	0.83	0.76	0.94	1.14	1.23	1.40	2.14	1.34	1.46
300	0.83	0.74	0.93	1.11	1.34	1.51	2.14	1.36	1.36
350	0.86	0.82	1.02	1.15	1.54	1.61	2.23	1.47	1.47

Under low traffic volumes, speed fluctuations at observation points show minor differences across all opening lengths. As traffic volume rises, opening length exerts a prominent influence on speed variation. Standard deviation analysis of speeds at all observation points yields the following conclusions:

For low heavy truck proportions (Combination 1–3), the 200 m opening length delivers optimal traffic stability. For medium heavy truck proportions (Combination 5–6) and high heavy truck proportions

(Combination 7–9), opening lengths of 100–150 m achieve superior speed stability.

4. Conclusions

From the perspectives of engineering economy and vehicle driving stability, when the proportion of small-sized vehicles is high, the median opening for traffic maintenance may be appropriately lengthened. It is recommended to adopt a transition curve combined with a small-radius circular curve in alignment design. This can satisfy vehicle driving requirements while reducing construction workload. In contrast, when heavy vehicles account for a large proportion during maintenance construction, the median divider opening alignment is suggested to be designed directly with a large-radius circular curve.

Considering traffic efficiency, traffic safety, and traffic stability, the recommended length of the median divider opening for two-way four-lane traffic maintenance in work zones is 150–200 m.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Shao C, Ma S, Luo K, et al., 2020, Study on the Length of Median Opening in Expressway Reconstruction and Extension Work Zones. In CICTP 2020, 1233–1245.
- [2] Mohanty M, Dey P, 2022, Operational Effects of U-Turns at Median Opening. *Transportation Letters*, 14(6): 565–577.
- [3] Ran J, Zhan S, Lei Z, et al., 2025, Optimal Opening Length of Median Transition Sections of Expressway Reconstruction and Expansion Based on Multidimensional Evaluation Indicators. In Fifth International Conference on Intelligent Traffic Systems and Smart City (ITSSC 2025). SPIE, 13792: 632–640.
- [4] Ma S, Hu J, Wang R, et al., 2023, Study on the Median Opening Length of a Freeway Work Zone Based on a Naturalistic Driving Experiment. *Applied Sciences*, 13(2): 851.
- [5] Tian W, Li Z, Hao J, et al., 2024, Method for Determining Median Opening Length in Multi-Lane Conversion of Expressway Renovation and Expansion Projects. In Seventh International Conference on Traffic Engineering and Transportation System (ICTETS 2023). SPIE, 13064: 346–355.
- [6] Chen C, Bo Y, 2026, Research on the Reasonable Length of the Median Opening for Five-Lane Traffic Flow During the Reconstruction and Expansion of Expressways//International Conference on Artificial Intelligence and Autonomous Transportation. Springer, Singapore, 103–119.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.