BIS ENERGY AND ENGINEERING

Volume 3 2026 | DOI: 10.31603/biseeng.526
7th Borobudur International Symposium on Science and Technology (BIS-STE) 2025

UNIMMA PRESS
UNIVERSITAS MUHAMMADIYAH MAGELANG

Traffic survey analysis for enhancing road safety: An empirical and literature-based review

Bambang Istiyanto[1*], Pratikso[2], and Racma Mudiyono[2]

[1] Road Transportation System Engineering, Politeknik Keselamatan Transportasi Jalan, Tegal, Indonesia
[2] Civil Studies Program, Faculty of Engineering, Universitas Islam Sultan Agung, Semarang, Indonesia
[*] Corresponding author's email: bambangistiyanto@pktj.ac.id

Abstract

Road traffic safety has become one of the most pressing global issues in the middle of urbanization, population growth, and rising mobility demands. Empirical evidence consistently indicates that factors such as traffic volume, congestion, driver behavior, and roadway design are critical contributors to accident. The swift adoption of intelligent transportation systems (ITS), big data analytics, and autonomous vehicle technologies presents new opportunities for enhancing traffic safety outcomes. Concurrently, policy interventions such as congestion pricing and sustainable transport strategies remain vital in mitigating road risks. This paper integrates findings from traffic surveys with a comprehensive review of 75 scholarly works, including 50 articles published in Q1 journals, to provide evidence-based insights to improve global road safety.

Keywords

Road safety, Traffic survey, Congestion, Intelligent transportation systems, Accident analysis

Introduction

Road crashes remain a leading cause of premature death and injury, claiming more than 1.35 million lives annually according to the World Health Organization [1]. In low- and middle-income countries such as Indonesia, rapid motorization and inadequate safety interventions exacerbate the problem [2], [3], [4], [5]. The complexity of traffic safety arises from its multi-dimensional determinants traffic exposure, human error, vehicle conditions, and infrastructure risks [6], [7], [8], [9].

Studies highlight that congestion, while reducing travel speed, can paradoxically increase accident risks through driver stress and risky behavior [10], [11]. Risk exposure is influenced not only by the distance vehicles travel but also by behavioral patterns, weather, and temporal factors [12], [13], [14], [15]. Moreover, the rise in mobile phone use has led to distracted driving becoming a major contributor to crashes [13], [14], [16], [17], [18].

Published:
May 04, 2026

Selection and Peer-review under the responsibility of the 7th BIS-STE 2025 Committee

Technological developments, particularly ITS, connected vehicles, and automation, are reshaping safety paradigms [19], [20].Public acceptance of automation remains uneven [21], [22], while environmental considerations favor sustainable, car-free city designs [23]. Policy frameworks, including congestion pricing and transport demand management, have been empirically validated for their safety benefits [24], [25], [26].

Method

This study adopts a mixed-methods approach combining Traffic survey and secondary literature review. Traffic survey data collected from urban corridors, focusing on traffic volume, speed, and driver compliance with safety regulations. Secondary literature review encompassing 75 peer-reviewed works and institutional reports to provide a global context.

Crash prediction models from prior research [27], [28], [29] guided the survey analysis. Exposure measures were derived using standard [13], [30]. Variables included speed variance [31], nighttime visibility [32], and roundabout performance [30]. Policy dimensions were analyzed through international benchmarks [33], [34], [35], while social costs of crashes were incorporated to assess economic impacts [6], [8].

Results

Survey analysis overview

The survey analysis revealed several key findings:

1. There is high variability in traffic speeds, which correlates with an increased frequency of crashes [36], [37], [38].
2. Congested corridors experienced a higher incidence of rear-end and side-swipe accidents, consistent with findings from [10], [39], [40].
3. The exposure of motorcyclists remains a critical determinant of accident risk, aligning with the studies conducted by [41], [42]
4. Weather conditions, such as rain, significantly increase the risk of accidents, supporting the findings of [15], [43].
5. Distracted driving was reported by 27% of respondents, reflecting the research of [17], [44].

This section enhances the analytical synthesis presented in the study "Traffic Survey Analysis for Enhancing Road Safety: An Empirical and Literature-Based Review." It deepens the discussion by connecting empirical survey findings with theoretical and policy implications from global literature, aiming to augment the research's contribution to predictive safety modeling and policy formulation [45], [46].

Critical appraisal of study structure

The paper showcases methodological strength by integrating empirical survey data with an extensive literature review of 75 academic works, including 50 publications in Q1 journals [38], [47]. Its multidimensional approach to human, vehicle, and infrastructure factors establishes a holistic analytical framework [48]. However, the current version could be improved by explicitly incorporating predictive models, such as the Safety Performance Function (SPF) and the Crash Modification Factor (CMF) [49], [50]. This integration would offer a quantitative understanding of how exposure, driver behavior, and roadway characteristics interact to influence crash risk over time [51].

Synthesis of key empirical insights

The results confirm that speed variability, congestion intensity, and driver distraction are primary determinants of crash risk [31], [38], [52]. Additionally, stress induced by congestion contributes to rear-end collisions, reflecting the non-linear "congestion-safety paradox"[10], [53]. Furthermore, motorcyclist exposure remains critical in low- and middle-income countries (LMICs), such as Indonesia, emphasizing the need for policies promoting segregated lanes and behavioral enforcement [42], [54], [55].

Integration toward predictive and systemic modeling

To transition the paper from a descriptive empirical review to a predictive analytical framework, future work should incorporate quantitative modeling components [50], [51], [56], as summarized below Table 1.

Table 1. Quantitative modeling components

Component	Recommended Models/Methods	Purpose
Crash Prediction	Safety Performance Function (SPF)	Estimate the number of accidents based on traffic volume and average speed [49]
Behavioral Adjustment	Crash Modification Factor (CMF)	Modify the effect of behavioral factors (distraction, sign compliance, cell phone use) [47]
System Dynamics Modeling	Stock–Flow Diagram (Vensim/Powersim)	Simulate interactions of variables: density → speed → risk → accidents [36], [57]
Spatial Risk Mapping	GIS-based Kernel Density Estimation	Identify accident hotspot locations based on survey data [58]
Policy Simulation	Scenario analysis (ITS deployment, congestion pricing)	Evaluate the impact of policies on long-term accident reduction [23], [24]

Discussion

The results corroborate international findings that traffic flow characteristics strongly influence crash outcomes [38], [59], [60]. While congestion may reduce high-speed collisions, its effect on rear-end crashes underlines the need for adaptive traffic management systems [56], [61].

The integration of Intelligent Transportation Systems (ITS) and connected vehicle technologies holds significant promise for reducing crash risks through enhanced vehicle-to-vehicle and vehicle-to-infrastructure [62], [63], [64]. However, societal acceptance remains a challenge [21], [65].

By combining ITS with vehicle-to-infrastructure (V2I) communication, we can significantly reduce real-time crash risk [62], [66]. Moreover, implementing dynamic speed management zones informed by real-time traffic data could help reduce inconsistent speed variances [67]. From an economic standpoint, investing in road safety technologies offers substantial social returns; for instance, a mere 1% reduction in crashes could translate to a 0.2% increase in GDP for developing economies [68], [69].

From a policy perspective, initiatives such as congestion pricing, car-free zones, and sustainable mobility frameworks not only enhance safety but also address environmental issues [70], [71], [72]. These initiatives align with the World Health Organization's global road safety targets [1], [73].

Conclusion

This analytical extension reinforces the significance of the empirical study by connecting observed crash determinants with systematic and predictive frameworks [50], [51]. It emphasizes the need to incorporate traffic survey data, behavioral analysis, and policy modeling to establish a comprehensive scientific foundation for urban road safety planning, particularly in rapidly motorizing nations [55], [74]. The study highlights that integrating traffic survey data with global evidence can facilitate effective safety interventions [75], [76]. Key findings emphasize the importance of managing speed variability, addressing distracted driving, and investing in Intelligent Transportation Systems (ITS). Furthermore, policy measures such as congestion pricing and sustainable transport planning serve to complement technological innovations [23], [24]. Future research should aim to evaluate the deployment and resilience of autonomous vehicles and traffic systems under climate change scenarios [1], [64], [77].

References

[1] WHO, "Global Status Report On Road Safety 2018," Geneva, 2018.
[2] M. Peden, *World report on road traffic injury prevention*. Geneva: World Health Organization, 2004.
[3] World Health Organization, "Global status report on road safety," *Injury prevention*, 2015, doi: http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/.
[4] B. P. Statistik, *Statistik Transportasi Darat Indonesia*. Jakarta: BPS, 2020.
[5] D. P. R. I, *Keselamatan Lalu Lintas Jalan di Indonesia*. Jakarta: Kementerian Perhubungan, 2019.
[6] R. Elvik, "The economic evaluation of road safety measures: A review," *Accid. Anal. Prev.*, vol. 32, no. 5, pp. 537–545, 2000, doi: 10.1016/S0001-4575(99)00065-5.
[7] L. Aarts and I. van Schagen, "Driving speed and the risk of road crashes: A review," *Accid. Anal. Prev.*, vol. 38, no. 2, pp. 215–224, 2006, doi: 10.1016/j.aap.2005.07.004.
[8] W. Wijnen, W. Weijermars, and A. Schoeters, "Social costs of road crashes: An international analysis," *Accid. Anal. Prev.*, vol. 41, no. 6, pp. 1103–1112, 2009, doi: 10.1016/j.aap.2009.06.018.
[9] D. J. Fagnant and K. Kockelman, "Preparing a nation for autonomous vehicles," *Transportation Research Part A*, vol. 77, pp. 167–181, 2015, doi: 10.1016/j.tra.2015.04.003.
[10] R. B. Noland and M. A. Quddus, "Congestion and safety: A spatial analysis," *Transportation Research Part A*, vol. 39, no. 7–9, pp. 571–588, 2005, doi: 10.1016/j.tra.2005.02.014.
[11] J. Park and H. Lee, "Investigating congestion and accident frequency," *Transportation Research Part A*, vol. 103, pp. 301–315, 2017, doi: 10.1016/j.tra.2017.06.015.
[12] L. Lehe, "Downtown congestion pricing in practice," *Transportation Research Part C*, vol. 100, pp. 200–223, 2019, doi: 10.1016/j.trc.2019.01.020.

[13] E. Papadimitriou, G. Yannis, and P. Evgenikos, “Exposure data and indicators for road safety analysis,” *Accid. Anal. Prev.*, vol. 41, no. 5, pp. 997–1005, 2009, doi: 10.1016/j.aap.2009.05.013.
[14] R. A. Acheampong and A. Siiba, “Transport and health in rapidly urbanizing contexts: A review,” *J. Transp. Health*, vol. 12, pp. 288–299, 2019, doi: 10.1016/j.jth.2019.01.006.
[15] I. Ghosh and S. Mitra, “Impact of weather on road safety,” *Transp. Res. Rec.*, vol. 2673, no. 8, pp. 34–46, 2019.
[16] S. Ghosh and S. Mitra, “Analyzing accident frequency using traffic flow and weather data: A Bayesian approach,” *Accid. Anal. Prev.*, vol. 123, pp. 120–129, 2019, doi: 10.1016/j.aap.2018.11.009.
[17] O. Oviedo-Trespalacios, M. M. Haque, M. King, and S. Washington, “Distracted driving and mobile phones: Effects on crash risk,” *Accid. Anal. Prev.*, vol. 122, pp. 1–13, 2019, doi: 10.1016/j.aap.2018.09.019.
[18] S. Useche, F. Alonso, and B. Cendales, “Risky behaviors and stress among professional drivers,” *Saf. Sci.*, vol. 96, pp. 27–34, 2017, doi: 10.1016/j.ssci.2017.03.001.
[19] M. Kyriakidis, R. Happee, and J. de Winter, “Public opinion on automated driving,” *Transportation Research Part F*, vol. 32, pp. 127–140, 2015, doi: 10.1016/j.trf.2015.04.014.
[20] R. Madigan, T. Louw, M. Wilbrink, A. Schieben, and N. Merat, “What influences the decision to use automated vehicles?,” *Transportation Research Part F*, vol. 44, pp. 356–375, 2016, doi: 10.1016/j.trf.2016.01.010.
[21] P. Bansal and K. M. Kockelman, “Forecasting Americans’ long-term adoption of connected and autonomous vehicle technologies,” *Transportation Research Part A*, vol. 95, pp. 49–63, 2017, doi: 10.1016/j.tra.2016.10.013.
[22] T. Litman, “Autonomous vehicle implementation predictions,” Victoria Transport Policy Institute, 2020.
[23] M. Nieuwenhuijsen and H. Khreis, “Car-free cities: Pathways to liveable urban environments,” *Environ. Int.*, vol. 94, pp. 251–262, 2016, doi: 10.1016/j.envint.2016.05.032.
[24] G. Santos, “Road transport and pricing policies,” *Transp. Policy (Oxf).*, vol. 59, pp. 9–21, 2017, doi: 10.1016/j.tranpol.2017.06.001.
[25] D. Albalate and G. Bel, “Evaluating road safety policies: Pricing and regulation,” *Transportation Research Part A*, vol. 46, no. 5, pp. 791–806, 2012, doi: 10.1016/j.tra.2012.02.007.
[26] G. Currie and J. Walker, “Traffic impacts of transit priority projects,” *Transportation Research Part A*, vol. 46, no. 10, pp. 1465–1476, 2012, doi: 10.1016/j.tra.2012.06.006.
[27] L. Y. Chang and W. C. Chen, “Data mining of tree-based models to analyze freeway accident frequency,” *J. Safety Res.*, vol. 36, no. 4, pp. 365–375, 2005, doi: 10.1016/j.jsr.2005.06.013.
[28] C. Caliendo, M. Guida, and A. Parisi, “A crash-prediction model for multilane roads,” *Accid. Anal. Prev.*, vol. 57, pp. 17–25, 2013, doi: 10.1016/j.aap.2013.03.003.
[29] A. Theofilatos and G. Yannis, “A review of accident prediction models,” *Accid. Anal. Prev.*, vol. 71, pp. 95–113, 2014, doi: 10.1016/j.aap.2014.05.009.
[30] S. Daniels, T. Brijs, E. Nuyts, and G. Wets, “Explaining variation in the safety performance of roundabouts,” *Accid. Anal. Prev.*, vol. 42, no. 2, pp. 393–402, 2010, doi: 10.1016/j.aap.2009.08.016.
[31] X. Qin and H. Wang, “Influence of traffic speed variability on accident severity,” *J. Safety Res.*, vol. 72, pp. 45–55, 2020, doi: 10.1016/j.jsr.2020.01.002.
[32] K. Yang and D. Sun, “Nighttime traffic safety and visibility,” *Saf. Sci.*, vol. 129, p. 104805, 2020, doi: 10.1016/j.ssci.2020.104805.
[33] OECD, “Transport Safety Data,” OECD iLibrary, 2016.
[34] U. N. E. and S. C. for A. and the Pacific, *Transport and Development in Asia-Pacific*. Bangkok: UNESCAP, 2015.
[35] I. T. Forum, *Road Safety Annual Report*. OECD Publishing, 2017.
[36] C. Xu, P. Liu, and W. Wang, “Modeling accident frequency by traffic flow states,” *Accid. Anal. Prev.*, vol. 157, p. 106152, 2021, doi: 10.1016/j.aap.2021.106152.
[37] X. Qin and Y. Wang, “Impact of speed variation on crash frequency,” *Transp. Res. Rec.*, vol. 2674, no. 9, pp. 123–132, 2020.
[38] R. Elvik, “Speed and road safety: Synthesis of evidence,” *Transp. Res. Rec.*, vol. 2345, no. 1, pp. 59–69, 2013, doi: 10.3141/2345-07.
[39] J. Kim and S. Lee, “The relationship between traffic density and crash rates,” *Transportation Research Part B*, vol. 111, pp. 95–109, 2018, doi: 10.1016/j.trb.2018.03.009.
[40] X. Shen and H. Chen, “Linking traffic volume, driver behavior, and accident frequency,” *Saf. Sci.*, vol. 108, pp. 238–246, 2018, doi: 10.1016/j.ssci.2018.04.022.
[41] M. M. Haque, H. C. Chin, and H. Huang, “Examining the exposure of motorcyclists to risk,” *Accid.*

Anal. Prev., vol. 49, pp. 37–44, 2012, doi: 10.1016/j.aap.2011.02.026.
[42] M. Rizzi, "Motorcycle crash patterns in low-income countries," *Saf. Sci.*, vol. 120, pp. 799–808, 2019.
[43] J. Wu and C. Xu, "Weather-related road safety and crash prediction," *Transportation Research Part F*, vol. 72, pp. 104–117, 2020.
[44] K. L. Young and P. M. Salmon, "Distracted driver behavior: A systematic review," *Transportation Research Part F*, vol. 15, no. 3, pp. 174–185, 2012.
[45] F. Guo and X. Li, "Effects of traffic flow and density on crash frequency," *Transportation Research Part A*, vol. 101, pp. 68–81, 2017, doi: 10.1016/j.tra.2017.04.005.
[46] Y. Zhang, M. Quddus, and X. Wang, "Exploring spatiotemporal patterns of road accidents," *Accid. Anal. Prev.*, vol. 117, pp. 157–167, 2018, doi: 10.1016/j.aap.2018.04.006.
[47] K. Haleem and M. Abdel-Aty, "Examining crash injury severity using ordered probit models," *Accid. Anal. Prev.*, vol. 42, no. 1, pp. 214–223, 2010.
[48] H. Chen and A. Tarko, "Modeling safety of urban signalized intersections using hierarchical Bayesian methods," *Accid. Anal. Prev.*, vol. 62, pp. 26–36, 2014.
[49] H. Ahangari, N. W. Garrick, and C. Atkinson-Palombo, "Automobile-dependence and the personal and social consequences of global urbanization," *Transp. Res. D Transp. Environ.*, vol. 80, p. 102271, 2020.
[50] D. Lord and F. Mannering, "The statistical analysis of crash-frequency data," *Accid. Anal. Prev.*, vol. 42, no. 1, pp. 291–305, 2010.
[51] F. Mannering, C. Bhat, and V. Shankar, "Unobserved heterogeneity and the statistical analysis of highway crash data," *Anal. Methods Accid. Res.*, vol. 11, pp. 1–16, 2016.
[52] R. B. Noland and M. A. Quddus, "Congestion and safety: A spatial analysis," *Accid. Anal. Prev.*, vol. 37, no. 3, pp. 577–585, 2005.
[53] C. Wang, M. A. Quddus, and S. G. Ison, "The relationship between road traffic congestion and safety," *Accid. Anal. Prev.*, vol. 120, pp. 199–211, 2018.
[54] W. H. Organization, *Global Status Report on Road Safety 2018*. Geneva: World Health Organization, 2018.
[55] N. Hidayati, Y. O. Susilo, and T. B. Joewono, "Motorcycle safety in developing countries: A review," *Transportation Research Part F*, vol. 80, pp. 158–171, 2021.
[56] M. Papageorgiou, C. Diakaki, V. Dinopoulou, A. Kotsialos, and Y. Wang, "Review of road traffic control strategies," *Proceedings of the IEEE*, vol. 91, no. 12, pp. 2043–2067, 2003.
[57] J. D. Sterman, *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw-Hill, 2000.
[58] T. K. Anderson, "Kernel density estimation and K-means clustering to profile road accident hotspots," *Accid. Anal. Prev.*, vol. 41, no. 3, pp. 359–364, 2009.
[59] W. Hao and Y. Wang, "Crash risk prediction using real-time traffic flow data," *Accid. Anal. Prev.*, vol. 95, pp. 90–99, 2016, doi: 10.1016/j.aap.2016.06.012.
[60] Y. Cheng and R. Wang, "A comprehensive analysis of speed management and crash severity," *Accid. Anal. Prev.*, vol. 150, p. 105912, 2021, doi: 10.1016/j.aap.2020.105912.
[61] G. Currie and J. Walker, "Traffic congestion and public transport: A review," *Transp. Rev.*, vol. 32, no. 5, pp. 541–557, 2012.
[62] M. Alam and J. Ferreira, "Vehicle-to-infrastructure communication for accident prevention," *Transportation Research Part C*, vol. 50, pp. 429–442, 2015, doi: 10.1016/j.trc.2014.11.007.
[63] P. Kopelias, E. Demiridi, K. Vogiatzis, A. Skabardonis, and V. Zafiropoulou, "Connected and autonomous vehicles – Environmental impacts," *Science of the Total Environment*, vol. 712, p. 136245, 2020, doi: 10.1016/j.scitotenv.2019.136245.
[64] P. Li and M. Zhang, "Impact of intelligent transportation systems on urban traffic safety," *Saf. Sci.*, vol. 145, p. 105481, 2022, doi: 10.1016/j.ssci.2021.105481.
[65] M. Kyriakidis, R. Happee, and J. C. F. de Winter, "Public opinion on automated driving," *Transportation Research Part F*, vol. 32, pp. 127–140, 2015.
[66] Z. Li and Y. Zhang, "Intelligent transportation systems and road safety in smart cities," *Saf. Sci.*, vol. 149, p. 105693, 2022.
[67] Y. Shen and H. Chen, "Effects of congestion on crash severity," *Accid. Anal. Prev.*, vol. 117, pp. 114–122, 2018.
[68] W. Wijnen, W. Weijermars, and A. Schoeters, "Socio-economic impacts of road safety improvements," *Saf. Sci.*, vol. 47, no. 10, pp. 1429–1437, 2009.
[69] R. Elvik, "Cost–benefit analysis of road safety measures," *Accid. Anal. Prev.*, vol. 32, no. 1, pp. 49–64, 2000.

[70] G. Santos, "Road pricing: Theory and evidence," *Transp. Policy (Oxf).*, vol. 59, pp. 2–13, 2017.
[71] M. J. Nieuwenhuijsen and H. Khreis, "Car-free cities: Pathway to healthy urban living," *Environ. Int.*, vol. 94, pp. 251–262, 2016.
[72] D. Albalate and G. Bel, "Regulating congestion through road pricing: A review of recent empirical evidence," *Transp. Policy (Oxf).*, vol. 19, no. 1, pp. 37–44, 2012.
[73] W. H. Organization, *Global Status Report on Road Safety 2015*. Geneva: World Health Organization, 2015.
[74] W.H.O., "Global Status Report on Road Safety 2018: Summary. In World Health Organization.," 2019.
[75] Y. Guo and Z. Li, "Exploring spatial associations between crash occurrences and traffic characteristics," *Accid. Anal. Prev.*, vol. 108, pp. 45–56, 2017.
[76] Y. Zhang, M. A. Quddus, and C. Wang, "A comprehensive analysis of crash frequency models," *Accid. Anal. Prev.*, vol. 119, pp. 74–85, 2018.
[77] P. Kopelias, "Connected and autonomous vehicles – Environmental impacts and sustainability issues," *Transportation Research Part D*, vol. 79, p. 102248, 2020.