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Research Article

Predicting slow driving intentions to mitigate wildlife-vehicle collisions in Malaysia: A theory of planned behavior perspective

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Abstract

Research to understand wildlife-vehicle collisions has predominantly focused on spatial patterns and wildlife behaviors. Yet, as collisions also involve drivers, the human factors are important too, and very few studies focus on the human dimension aspects of wildlife roadkill. Based on the theory of planned behavior, the present study examined the influence of driving attitude, driving norm (reflecting subjective norms), and perceived driving control (demonstrating perceived behavior control) on intention to drive slowly, in three scenarios involving possible wildlife-vehicle collisions. An online survey was conveniently distributed to a sample of drivers in Malaysia to collect data (n = 270). The study found driving attitude as the most important factor influencing driving intentions, followed by driving norm and perceived driving control, based on the significant results and β values. Driving norm and perceived driving control were not influential for intention to drive slowly in the third scenario. The present study also found that the influence on driving intention is unique depending on the situation. Specifically, the three psychological factors were more influential in scenarios encountering familiar stimuli (warning signage and common wildlife) than the more unfamiliar trigger (uncommon wildlife species). Practically, the study offers insight into how to mitigate wildlife-vehicle collisions, focusing on the use of technology and artificial intelligence, including improving education that addresses driving attitude, driving norms, and perceived driving control.

Keywords: sustainability, wildlife conservation, wildlife roadkill, road safety

Introduction

One of the key objectives outlined in Sustainable Development Goal 15 is the preservation of biodiversity. This goal is geared towards halting the decline of biodiversity and averting the extinction of endangered species (Krauss, 2022). However, this goal faces challenges, such as habitat fragmentation, poaching, illegal trading, and land use change (Corlett, 2007; Siriwat & Nijman, 2020). In addition to these challenges, wildlife-vehicle collisions (WVCs) further threaten biodiversity, as expanding road networks increase the risk of wildlife roadkill incidents. Past studies have confirmed traffic volumes, land use and landscape types, road infrastructures, type of roads, and temporal factors to be important factors influencing WVCs (Pagany, 2020). Proximity to forests, cropland, and plantation areas, increases the likelihood of WVC, especially if both sides of a road have forest cover (Azhar et al., 2013; Chen & Wu, 2014). Precaution measures to mitigate WVCs have been suggested, focusing on improving road conditions and infrastructure, altering wildlife species behavior, and connecting natural habitats (e.g., Lester, 2015; Collinson et al., 2019).

Besides altering wildlife behaviors and habitat management, scholars have also suggested addressing human factors to mitigate WVCs (Lester, 2015). Pagany (2020) suggested that speeding reinforced WVCs and Langley et al. (2006) found that WVCs to have a significant fatality risk as 24% of drivers in the incident usually exceeding posted speed limits as compared to the drivers in general road collisions. Borza et al. (2023) even suggested that drivers may show passive involvement in mitigation measures of WVCs, despite having high concern of the incidents. One characteristic of WVCs is the nature of 'sudden events.' Drivers can hardly predict when they would encounter wildlife crossing or entering roadways, just as they cannot predict other drivers' errors in a possible vehicle crashing scenario. In both instances, speeding will reduce drivers' reaction time to any obstacle or possible accidents stimulus, hence substantially decreasing the probability of braking response time to avoid collisions (Ismail et al., 2024). The combination of high speeds and sudden animal crossings creates a dangerous situation that increases the likelihood of fatal accidents. Intention to drive slowly in possible WVC scenarios could mitigate this event. Moreover, intention to drive slowly was identified as a critical variable based on literatures on dangerous driving (Ulleberg & Rundmo, 2003; Shen et al., 2018). Therefore, understanding and identifying key determinants of driving intention are crucial for developing evidence-based management strategies. By using an online survey data among Malaysian drivers, the present paper aims to shed light on the impact of human dimensions of WVCs. Insights from this research can help inform decision-makers of the most effective mitigation measures.

Conceptual Framework

Social science research in wildlife conservation examines human-wildlife interactions, emphasizing the questions of how individuals or society respond to conservation initiatives, how behaviors are formed, or how to facilitate positive behavioral change to inform and formulate effective management decisions (Bennett et al., 2017). Such research is typically guided by established theories, such as the Theory of Planned Behavior (TPB), that propose relationships among concepts that represent different thought processes (Miller, 2017). The TPB emphasizes rational thinking, proposing that behaviors are compatible when they reflect target, action, context, and time components (Ajzen, 2005). For instance, "slowing down (action) a car (target) across forested areas (context) early in the morning (time)" exemplifies a behavior compatible for TPB analysis.

According to TPB, behavior is driven by intention, and intention is influenced by attitude, subjective norms, and perceived behavior control. Attitude is the positive–negative evaluation people make about subject, phenomenon, or events (Ajzen, 2005). Conceptually, attitude is central to the development of other concepts. Subjective norms pertain to the perceived social pressure dictating participation or abstention from a specific behavior, underscoring the notion of 'obligation' (Cao & Sakurai, 2025; Richards et al., 2024). Subjective norms can be divided into injunctive – belief about what is approved or disapproved by society, and descriptive norms – how most important others behave in a specific circumstance (Pang et al., 2023). Subjective norms can be measured through individual belief to meet others' expectation or particular group where the person feels belong. The perceived behavior control concerns the perceived ease or difficulty associated with performing a behavior (Cao & Sakurai, 2025; Richards et al., 2024). Ajzen went so far as to propose that perceived control could even act as a direct and influential proxy for shaping actual behavior, potentially outweighing behavior intention. In addition, perceived behavior control even found can moderate the influence of attitude and norms on attitude (Bosnjak et al., 2020). Specifically, a stronger perceived control enhances attitude importance in predicting intention while reducing norm influence. The three determinants of intention are independent predictors, hence not necessarily correlate to each other (Ajzen, 2020). Altogether, individual's behavior is formed by intention, guided by favorable attitude, supporting subjective norms, and a strong perceived behavior control.

TPB is grounded in the notion of causality and specificity (Ajzen, 2020). To explain, variables with similar correspondence (e.g., general attitude and general intention) are expected to have larger correlations in contrast to variables with different correspondence (e.g., specific attitude and general intention). The theory has been empirically proven in explaining wildlife-related behaviors, including hunting intentions and problem wildlife prevention practices (Hrubes et al., 2001; Amit & Jacobson, 2017), as well as general driving behaviors (Hai et al., 2024; Somoray et al., 2024). Yet, its use in the context of WVCs has been relatively limited, with researchers often adopting broader or alternative theoretical perspectives. To date, a handful of human dimensions research was conducted primarily focuses on values, attitude, and perception to explain driving intention and behaviors in WVCs. Studies generally find positive values and attitude toward wildlife/nature conservation associated with intention to drive responsibly (Ramp et al., 2016; Ayob et al., 2023; Borza et al., 2023). However, one study suggests attitude to wildlife do not always influencing driving intention (Pang et al., 2023), and intentional killing of wildlife on the road does exist (Secco et al., 2014) with some wildlife taxa received less sympathy from drivers in WVCs scenario (Crawford & Andrews, 2016). Theoretically, none of the studies completely adopted the TPB. Most studies address attitude as an independent concept and not integrated the whole TPB framework. To the authors' knowledge, the only study that mentions TPB is by Vanlaar et al. (2019). Vanlaar et al. suggest driving responses is part of intentions that influenced by perceived behavior control. However, the study did not explicitly adopt and measured the whole TPB framework in their study, rather using TPB to explain their findings. There is still an opportunity to empirically test how attitudes, subjective norms, and perceived behavior control influence driving responses as an extension from the study by Vanlaar et al. (2019).

To inform future management and education of driving impacts to wildlife, the present study aims to understand the extent of driving attitude, driving norm, and perceived driving control (reflecting perceived behavior control) predict intention to drive slowly across three possible WVC scenarios (Figure 1). Intention to drive slowly is characterized as a cautious and preventive driving approach. The dependent variable was chosen as this intention is integral in determining the likelihood and severity of WVCs and a very crucial aspect of safe driving. Additionally, the present study also examines patterns of factors that influence slow driving intention in WVCs scenarios.

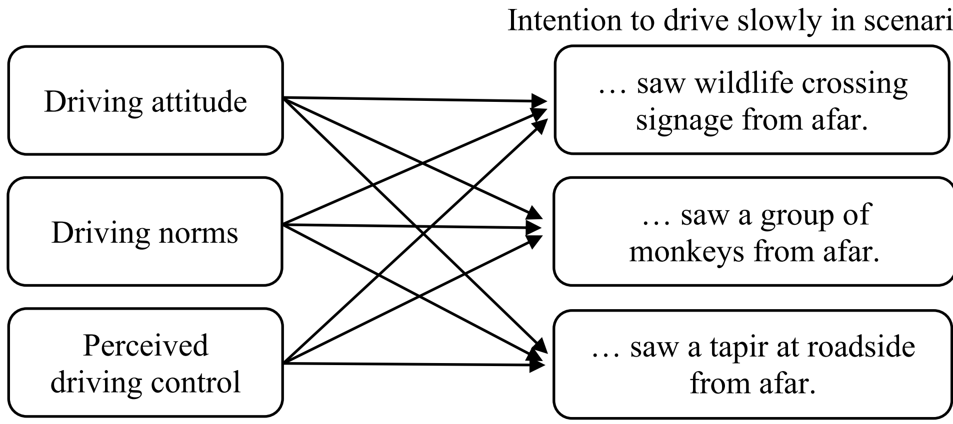

Figure 1. The conceptual model to understand intention to drive slowly based on the Theory of Planned Behavior.

Materials and methods

Survey method

A close-ended online questionnaire comprising of questions to measure driving attitude, driving norms, perceived driving control, driving intention, and year driving license was developed in Malay and English (on the same webpage). The survey was developed using QuestionPro free survey software. Initially, the Malay questions was translated into English and pretested among 30 respondents who have valid driving licenses. The pilot study respondents were interviewed to find out what they thought of the survey's concepts, wording, and layout, as well as to make suggestions for improvement. Open ended feedback and contextual relevance of the questionnaire were also collected from an employee of the Department of Wildlife and National Park of Peninsular Malaysia (DWNP). Minor adjustments to the questionnaire were made in response to their input, hence improving the face validity of the instrument.

The online survey was administered from September to October 2021. The survey was primarily disseminated through social media platforms – Facebook, Instagram, and WhatsApp. Specifically, the survey was shared through the personal accounts of the fourth and fifth authors and within two news and public media groups that have a high number of viewers and are frequently visited by Malaysian social media users. These groups were chosen to reach a broad cross-section of active drivers across different regions of Malaysia. No official accounts, such as those associated with universities, government agencies, or advocacy groups, were used to avoid institutional bias. The survey invitation included a brief introductory message about research on WVCs, targeting respondents who are (i) Malaysians, (ii) age 18 years and above, (iii) holding a valid driving license issued by the Road and Transport Department of Malaysia, and (iv) actively driving in the last five years. To maintain respondent anonymity, a general statement that informed of voluntary participation and assuring anonymity was also included. The strategy aligns with ethical practices for online surveys. Additionally, the DWNP granted approval to carry out the study (Ref. No.: B-00897-15-24). All questions were designed as "required" in the QuestionPro to avoid missing data. A total of 270 responses were collected at the end of the data collection period.

The online recruitment approach may limit the generalization of the current study. However, the strategy is perfect to collect data at that time due to the Covid-19 disease outbreak. The Malaysian government imposed a Movement Control Order at the time of the study period to contain the Covid-19 infection. The online strategy has ensured the safety of the researcher and any of the respondents to possible Covid-19 infection.

Research instrument

A total of 10 items were developed to assess driving attitude (4 items), driving norms (3 items), and perceived driving control (3 items) broadly based on the sample TPB questionnaire (Ajzen, 2019). For the attitudinal construct, respondents were asked how good or bad they evaluate driving intentions while crossing a forested area. The attitude items were coded on continuous 5-point scales ranging from -2 "bad" to +2 "good" with zero as neutral point. The normative statements included respondents' belief about approval and disapproval of family members, friends, and other drivers over his/her action of slowing down. The normative items were made slightly broader than what were suggested by Ajzen (2019) to suit the context of driving while on the road. Lastly, the perceived driving control covers the dimensions of easiness/difficulties while driving. The normative and perceived driving control items were coded on continuous 5-point scales ranging from -2 "strongly disagree" to +2 "strongly agree" with zero as the neutral point. Prior to answering the questions, a description of driving scenario was included. As an example, the description for attitudinal measure is "You are driving crossing a forested area. There is frequent sighting of wildlife crossing the road around the area/road. In your opinion, how good/bad it is if you…".

The dependent variable in this study was intention to drive slowly. Slowing down was operationalized as a preventive action intended to reduce the likelihood of collision and minimize the severity of impacts if a collision were to occur, hence can increase the likelihood of avoiding collisions due to increased reaction time. The dependent variable was responses in three different

WVCs scenarios (i.e., three questions) that are actual problem situations related to WVCs in Malaysia according to brief interview input from members of DWNP. The first scenario was seeing a wildlife crossing signage from afar. The second scenario was seeing a troop of monkeys at a roadside from afar while the third scenario was seeing a tapir at a roadside from afar. The intention to drive slowly was coded on a continuous 5-point scales ranging from –2 "definitely not" to +2 "absolutely yes" with 0 as "neutral".

Analysis

Principal component analysis (PCA) with Varimax rotation was conducted to identify the underlying factors for driving attitude, driving norm, and perceived driving control. Following the PCA, confirmatory factor analysis (CFA) with three latent constructs was conducted using 'lavaan' package (ver. 4.5.0) in R software to validate the factor structure. The overall fit of the model was assessed using χ^2, CFI, TLI, RMSEA, and SRMR. Then, reliability analyses (Cronbach's alpha) and composite reliability were performed to examine the consistency of the item. Cronbach alpha and corrected item-total correlations between items must exceed .65 and .400, respectively to ensure reliability (Vaske, 2008). Following the reliability analyses, descriptive analyses were performed to have an overview of each construct, and correlation analyses between driving attitude, driving norm, and perceived driving control were completed to examine the relationships between independent variables. Finally, three regression models were performed to make a prediction of intention to drive slowly in three scenarios. In addition, model tolerance, variance inflation factor, and condition index were inspected to assess multicollinearity issues.

Results

Measurement Model

The Kaiser-Meyer-Olkin measure of sampling adequacy was .75, and Bartlett's test of sphericity was significant, $\chi 2$ (45) = 725.09, $p < .001$, suggesting the data is suitable for dimensional reduction via PCA. A fixed three component solution was extracted, explaining 61% of the total variance. Items with factor loadings >.400 were retained for interpretation. Three items belong to the first component match with driving norms, accounting for 31.5% of variance. The second component (19.7%) comprised items measuring perceived driving control. The attitude component (10.1%) included all four items measuring attitude. However, one attitude item (i.e., How good/bad do you think to drive at 50km/hour in the forested area) loaded factor loading .475 in the driving norm component, indicating possible conceptual overlap.

The initial CFA on the TPB model tested four items on driving attitude, and three items each on driving norm and perceived driving control yet produced unacceptable goodness of fit. A second CFA for the model was performed after removing item four of driving attitude. This modification improved the goodness of fit within the acceptable range: χ^2/df=106.44, p<.001; CFI=.961, TLI=.941, and SRMR=.074 were all within acceptable/good range (Hooper et al., 2008). The RMSEA is poor but occurred due to the inflated effects of the index. In addition, other indices are meet the good/acceptable threshold. Every item significantly loaded on intended factors (driving attitude= .62–.77; driving norm= .57–.91; perceived driving control= .68–.85). Together, these CFA results verified three factors of TPB of the present study.

Reliability coefficients for driving norm and perceived driving control suggest acceptable reliability (Table 1), as Cronbach's alpha for the associated construct exceeded the generally accepted cut-off point of .65, except the items measuring attitude (α = .54). Inspection on the corrected item-total correlations found correlations of less than the acceptable threshold in item one (r = .354) and four (r = .214). Dropping item one from the construct will drastically lower Cronbach's alpha from .54 to .47. Removing item four, on the other hand, will improve the index from .54 to .58 because of its poor correlation and cross-loaded on both the attitude and norm components from the PCA. An additional composite reliability analysis in CFA revealed acceptable score across constructs (Table 1). Based on the assessment from PCA, CFA, and reliability analyses, item four was dropped from the attitudinal construct and excluded from subsequent analyses. Indices of driving attitude, driving norm, and perceived driving control were computed by calculating the average of the associated items.

Table 1. Results of descriptive and reliability analyses of driving attitude, driving norms, and perceived driving control in the study sample.

Variable	**Mean (SD)**	**Cronbach's alpha (>.65)**	**Composite reliability (>.70)**
Driving attitude[a]	1.35 (.59)	.58	.72
Driving norm[b]	1.07 (.59)	.76	.84
Perceived driving control[b]	–.62 (.88)	.75	.81
Intention to drive slowly[c] …			
.. saw wildlife crossing signage	1.29 (.85)		
.. saw monkey at roadside from afar	1.28 (.85)		
.. saw a tapir at roadside from afar	1.43 (.86)		

[a]Items were coded on 5-point scales ranging from –2 "bad" to +2 "good"
[b]Items were coded on 5-point scales ranging from –2 "strongly disagree" to +2 "strongly agree"

[c]Items were coded on a 5-point scales ranging from -2 “definitely not” to +2 “absolutely yes”

Preliminary analysis

On average, the respondents have positive driving attitudes and driving norms (Table 1). Correlation analyses using Pearson’s *r* showed that driving attitude, driving norm, and perceived driving control, were significantly correlated between each other. Respondents with more positive driving attitude are more likely to adhere to driving norm ($r = .254$, $p<.001$) but tend to perceive less in control while driving (–.478, $p<.001$). Driving norm had a negative relationship with perceived driving control (–.156, $p<.05$). Respondents tend to follow driving norms when they perceived themselves as having less control over their driving. Multicollinearity among predictors was not violated (Tolerance ≥ 0.739, Variance Inflation Factor ≤ 1.353, Condition index ≤ 6.83, Variance Proportions did not show high shared variance across multiple independent variables).

Influence of driving attitude, driving norms, and perceived driving control on driving intention

Overall, driving attitude, driving norms and perceived driving control predicted driving intention across three different scenarios (Table 2). The TPB fit the data adequately and predicted 34–42% of the variation of the intention measures, indicating typical relationship (Vaske, 2008). Between scenarios, the first scenario was better predicted by the TPB than the second and third scenarios.

Table 2. Results of multiple linear regression analyses with the driving intention in three scenarios as dependent variable.

Model variable	Drive slowly when …					
	… saw wildlife crossing signage from afar (Scenario 1)		… saw a group of monkeys from afar (Scenario 2)		… saw a tapir at the roadside from afar (Scenario 3)	
	β	Adj. R^2	β	Adj. R^2	β	Adj. R^2
		$.18^{**}$		$.16^{***}$		$.12^{***}$
Driving attitude	$.22^{**}$		$.24^{***}$		$.24^{***}$	
Driving norm	$.25^{***}$		$.16^{**}$		.11	
Perceived driving control	$–.12^{*}$		$–.15^{*}$		–.12	

Notes = * significant at $p < .05$, ** significant at $p < .01$, *** significant at $p < .001$

Across scenario, driving attitude was the only factor that significantly predicted intention to slow driving in all scenarios as opposed to driving norm and perceived driving control. In addition, driving attitude was consistently the superior factor that influenced driving intention relative to driving norm and perceived driving control, as indicated by the large β values. Driving attitude was only second-best factor to predict intention to drive slow in the first scenario. Perceived driving control did not influence intention to drive slow in the third scenario whereas driving norm was only statistically significant with driving slowly in two scenarios. The regression models clearly showed a clear pattern where respondents who held positive driving attitude to have a higher tendency to drive slowly. In scenario one and two, respondents who perceived themselves as having high control over their driving are less likely to not drive slowly. In contrast, respondents who tend to follow driving norms and are perceived to have less control over their driving are more prone to driving slowly when they saw wildlife crossing signage and encountered a monkey troop.

Discussion

The primary objective of this study was to examine the extent of driving attitude, driving norm, and perceived driving control predict intention to drive slowly across three possible WVC scenarios. By broadly based on the TPB, the research findings indicated that drivers' intentions were generally shaped by their attitude, adherence to social norms, and their perception of control over their behavior. The measurement of driving attitude was minimal, but the construct emerged as the dominant factor influencing these intentions, followed by driving norm and perceived driving control. These findings highlight the utility of TPB in predicting driving intention in WVCs in order to mitigate the incident and promote wildlife conservation.

From the measurement perspective, an alpha coefficient over .65 is mostly desirable for a set of items to be considered as a scale in social science. Despite the minimal reliability for the attitude scale, it was still retained for further analysis. Previous study suggested coefficients between .50 and .60 can also be considered as acceptable during preliminary investigations (Nunally, 1967; Gallagher et al., 2008; Peterson, 2013). Several studies have demonstrated that a scale with alpha coefficient less than .65 can still be used for further analyses (Sheena et al., 2014). However, improving this scale reliability in future research is highly suggested to minimize measurement error, hence improving model validity.

Our study reported effect sizes (Adj. R^2) ranging from 12 to 18%, reflect typical to substantial relationships (Vaske, 2008). While these values are comparatively lower than those typically observed in general road collision studies employing TPB (Hai et al., 2024; Somoray et al., 2024), they are align with the effect sizes reported in the aforementioned WVC studies (i.e., Crawford et al., 2015; Crawford & Andrews, 2016; Ramp et al., 2016; Pang et al., 2023; Borza et al., 2023).

While a direct comparison is challenging due to differences in study design and conceptual frameworks used in prior research, our findings reinforce the explanatory power of the TPB and its associated variables in predicting driving intentions in WVCs. In particular, the factor of driving attitude, driving norm, and perceived driving control provides a meaningful level of explanatory power for understanding driving intentions to WVCs scenarios.

The results further extended the current understanding of the importance of attitude in WVCs, and effectiveness of attitude in predicting behaviors. The present study evaluated 'driving attitude' as factors to examine driving intention in contrast to 'attitude towards wildlife' used in prior studies (Crawford et al., 2015; Ramp et al., 2016; Ayob et al., 2023; Borza et al., 2023; Pang et al., 2023). Both attitudinal measures were important factors for driving intention to explain WVCs. Either attitude towards wildlife or attitude towards driving is far superior cannot be explained based on the current data. As of now, we can conclude that attitude in the context of WVCs does have utilitarian – evaluation that guides action in maximizing results and minimizing harms, and value-expressive functions – evaluations that express personal values and fundamental beliefs (Manfredo, 2008). A single study that incorporates both types of attitudes is needed to determine the most important factor, thus explore the various level of importance between different attitude functions.

Our findings regarding the impact of driving norms on driving intentions in WVC scenarios represent a significant expansion of our current understanding of road safety, moving beyond the scope of general accidents. In general road collision study, normlessness proved to be an important factor to risky driving behavior (Ulleberg & Rundmo, 2003; Mallia et al., 2015). Normlessness (a personality trait that described socially unapproved behaviors required to achieve certain goals) positively and indirectly influenced risky driving behaviors. Normlessness also explained significant variation in negative attitude and risky driving behaviors. In the present study, driving norm proven to have influence on intention to drive slowly in WVCs and the second important factor after driving attitude. Although both current and personality-related studies conceptualized norms differently, the findings were consistent. Positive norms approved positive driving behaviors while negative norms approved negative driving behaviors.

Vanlaar et al. (2019) suggested driving behaviors as habitual. Our data based on TPB suggested driving intentions resulted from a deliberate decision-making process. Approaching the results from the neuroscientific perspective, we can conclude that driving intention and behaviors is manifested by both implicit (unconscious) and explicit (conscious) awareness. An implicit memory consists of memories that play no direct role in consciousness, usually shaped by repetition, but is very important in shaping behaviors (Miyashita, 2004). Implicit memory better reflect habitual actions. Explicit memory, on the other hand, requires a deliberate act of recollecting. Taken together, our findings and those of Vanlaar et al. (2019) suggest that minimizing WVCs may require both positive driving habit (implicit awareness) and conscious rational decision (explicit awareness).

We expected to see significant results in scenarios three (encountering Malayan Tapir from afar), as the scenario is comparable to scenario two (encountering monkey troop) except featuring different wildlife species. While previous study argues that WVCs involving a big mammal would be better explained by psychological factors (Crawford & Andrews, 2016), the results turned out to be surprisingly different. In fact, the scenario involving the Malayan tapir was the least explained by the regression models. In scenario three, neither the driving norm nor the perceived driving control have an impact on individuals' intention to drive slowly. The extent to which the same factors influenced an intention vary considerably according to context, in this case, the species–specific context.

Frequent sightings of WVCs can heighten awareness of the risks associated with WVCs (Borza et al., 2023). It is probable that frequent sightings of wildlife and wildlife crossing signage also increase safety belief that underlie norms and perceived driving control related to WVCs. In Malaysia, long-tailed macaques are widely distributed and frequently observed in many parts of the country, including in human-altered habitats such as temples, roadsides, agricultural areas, and human settlements (Hansen et al., 2022). Such high familiarity and exposure likely strengthen the normative beliefs that drivers should drive cautiously and the perception that they can effectively control their driving behavior when encountering the species. In contrast, the Malayan tapir is a lot less conspicuous than the long-tailed macaque, seldom encountered relative to long-tailed macaque, and not subject to active-hunting (Traeholt et al., 2016; Mohd Suri et al., 2022). Despite being recognized as one of Malaysia's 'big five' species, it has received limited public and conservation attention (Perak Academy, 2015). Consequently, the low level of familiarity and weak social representation surrounding the Malayan tapir reduce both perceived social pressure and control. This interpretation is consistent with previous studies that highlighted contextual influences of situation-specific (Liordos et al., 2017; Zainal Abidin, 2019) and species-specific (Crawford & Andrews, 2016) as important determinants of behavioral variation in wildlife-related contexts. Although descriptive results showed higher intention to slow down in the tapir scenario compared to others, the intention may be more reflective of species rarity or novelty rather than normative or control driven motivations.

Theoretically, our study provides useful information to understand driving behaviors in WVC scenarios. However, there are still various explanatory variables that could be very useful to further extend the current understanding of human dimensions of wildlife roadkill. The cognitive hierarchy framework is another valuable entry for future research, as it is central to examine abstract concepts such as values related to wildlife (Jacobs et al., 2018). In addition, it is important to recognize that individual driving habits, past experiences with wildlife on the road, and socio-demographic characteristics may also shape individual driving intentions. For instance, frequent driving through WVCs hotspot areas or prior encounters with WVCs could heighten risk awareness and influence driver's responses. Considering the TPB alongside the wildlife value constructs, past experiences, and socio-demographic measures in future research will improve the overall insight on WVCs and any moderating effects. The added factors for future research will also potentially improve the explained variance from the present study.

From the methodological perspective, the reliance on a self-reporting approach in collecting data stands as the major limitation of the present study. While this approach facilitated access to a broad audience and a safe data collection method during the global pandemic, it may have inadvertently led to sample bias, particularly an overrepresentation of younger, more technologically engaged individuals. The generalizability of the findings may be constrained to this limitation. Collaboration research with the Road Transport Department Malaysia and employing random sampling techniques in the recruitment process could enhance the representativeness of the findings. Additionally, the online survey approach is not immune to certain degree of social-desirability bias. Respondents may overestimate their responses to some of the survey questions. However, given the growing concern of WVC risks (Ayob et al., 2023), and education as well as awareness program in Malaysia, it is also plausible that the high proportion of respondents indicating a willingness to slow down reflects genuine responses rather than a response bias. Nevertheless, future studies could replicate the present study by conducting a hazard perception test or driving simulation, to better understand driving intentions and behaviors. In such study, video use should incorporate various possible WVC scenarios and contextual background (e.g., rainfall scenario, road type, visibility, time of day, vehicle type) to assess driving responses (D'Amico et al., 2015) in relation to driving attitude, driving norm, and perceived driving control. The findings from these responses can then be cross-referenced with self-reporting data for validation. As intention does not always translate into behavior, a different study that compares driving intention and observed driving behaviors on the field are recommended to reduce self-reporting bias.

The findings of this study offer several practical implications for policymakers and road safety managers to mitigate WVCs risks effectively. First, the significant influence of driving attitude and perceived driving control on slowing down suggests that dynamic wildlife warning systems could effectively encourage preventive behaviors. Policy makers could adopt a proactive safety approach by leveraging artificial intelligence technologies such as real-time wildlife detection and automated early warning systems. The system could help detecting wildlife presence close to roadside and display real-time alerts, enhance drivers' situational awareness and empower them to make safer driving decisions. By reinforcing drivers' positive driving attitude and perceived driving control over collision avoidance, these systems could reduce speeding and promote cautious driving in high-risk areas.

Second, the findings are very useful for improving driver education programs. Based on the significance of perceived driving control, future driver education programs could include virtual reality simulations or modules that allow drivers to practice slowing down or evasive maneuvers in WVCs possible scenarios. By increasing drivers' confidence in their ability to respond appropriately, these educational initiatives can reduce speeding behaviors. Third, targeted awareness and educational campaigns could leverage social norms and attitude through Communication, Education, Public Participation and Action (CEPA) strategies, using commercial advertisements to promote cautious driving, especially near wildlife crossing signs. This can be done through Public Service Announcement, exhibition, or series of social media posting. The strategy could increase social acceptability of cautious driving and positive driving attitude in wildlife-prone areas hence strengthen compliance with speed regulations. Future campaigns could also incorporate education on species familiarity to enhance driver responsiveness. Additionally, strengthening enforcement at identified wildlife crossing hotspots can be an effective measure, as drivers often neglected to reduce speed in these areas despite the presence of warning signage.

Conclusion

Our findings suggest driving intentions in WVC scenarios are shaped by driving attitude, driving norm, and perceived driving control. Driving attitude is the most important factor for driving intentions, whereas perceived driving control is the least important factor. The predictive power of the three factors depends on scenarios, as demonstrated by our analyses. Continued efforts are needed to minimize WVCs. An important strategy that will be useful to minimize WVCs is through the use of technology and artificial intelligence, the improvement of the current driving education and training, public awareness campaigns, and stricter enforcement. There is less emphasis given on WVC and its associated financial and physical impacts on drivers in the current driving education and license training scheme in Malaysia. The education and training modules could improve driving competency and driver's perceived driving control in unpredictable scenarios, while also instilling positive driving norms.

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