VILNIUS TECH
Vilnius Gediminas Technical University

Proceedings of the 13th International Scientific Conference

ENVIRONMENTAL ENGINEERING

April 23–24, 2026, Vilnius, LITHUANIA

eISSN 2029-7092
eISBN 978-609-476-444-8
Article ID: enviro.2026.2453
https://doi.org/10.3846/enviro.2026.2453



# DO METEOROLOGICAL AND ROAD CONDITIONS INFLUENCE ANIMAL-VEHICLE COLLISIONS?

Gytautas IGNATAVIČIUS, Alius ULEVIČIUS, Vaidotas VALSKYS, Lina MATAČINA*

*Institute of Biosciences, Life Sciences Center, Vilnius University, 10257 Vilnius, Lithuania*

Received 11 February 2026; revised 24 February 2026; accepted 26 February 2026

**Abstract**. Significant uncertainty remains regarding the relationship between meteorological conditions and Animal-Vehicle Collisions (AVCs). This study aimed to evaluate the influence of meteorological and related road conditions on AVC occurrence in Lithuania. Meteorological data and collision records from 56 automatic weather stations were linked with 1,632 AVCs reported between 2018 and 2022. Principal Component Analysis (PCA) revealed that meteorological variables form two statistically significant groups with contrasting associations with AVC occurrence. The first group – characterized by higher air and road surface temperatures, greater visibility, and a higher road adhesion coefficient – was positively associated with AVC occurrence. In contrast, the second group, defined by snow and ice cover, rain intensity, and the presence of water on the road surface, showed a negative association with AVC occurrence. These findings suggest that AVC risk increases under favourable driving conditions, likely due to changes in driver behaviour, whereas adverse weather conditions may reduce collision risk as drivers tend to exercise greater caution. Overall, the results provide new insights into the role of meteorological and road conditions in AVC dynamics and highlight the importance of considering human behavioural responses when developing AVC mitigation strategies.

**Keywords:** human-wildlife conflict, meteorological conditions, traffic safety.

## 1. Introduction

Economic development is influenced by roads, which also provide important mobility benefits and support social and cultural development. Globally, the total length of roads is estimated to increase by 25 million kilometre by 2050 (Strano et al., 2017). Despite the many advantages of roads, their environmental impact cannot be neglected. Roads have both direct and indirect effects on the environment. The indirect impact includes ecosystem degradation, habitat fragmentation, water and air pollution, and lighting conditions (Madadi et al., 2017; Kourchi et al., 2025). The most noticeable direct negative effect of roads is Animal-Vehicle Collisions (AVCs) (Bennett 2017; Silva et al., 2019). Around one million AVCs occur annually in the United States, and they result in human harm or human fatalities, financial loss, or millions of animal deaths (Roy & Ksaibati, 2021).

Over the past decades, researchers have sought to determine various factors that influence the occurrence of AVCs. These factors include characteristics of roads (Bíl et al., 2019; Pagany, 2020; Su et al., 2023), vehicle speed or traffic volume (Jaroszweski & McNamara, 2014; Abraham & Mumma 2021), spatial-temporal factors (Lagos et al., 2012; Neumann et al., 2012; Morelle et al., 2013). Others have highlighted the importance of species-specific factors (Garrah et al., 2015; Laliberté & St-Laurent 2020; Ortega et al., 2023). Knowledge of these factors' influence can provide a basis for mitigation measures. Nevertheless, considerable uncertainty remains regarding meteorological variables and AVCs.

Among all potential AVCs factors, studies of meteorological conditions were typically conducted outside of the context of animal-related accidents. Previous research on traffic safety has highlighted the influence of meteorological conditions, examining variables such as rainfall, temperature, humidity, snow cover, and fog (Lio et al., 2019; Pińskwar et al., 2023). Nevertheless, the results of these studies may depend on the methods used and various local conditions (Ramp & Roger 2008; Rolandsen et al., 2011; Stevens et al., 2019; Pińskwar et al., 2023). Also, the effects of adverse meteorological conditions on driver behaviour were discussed in relevant studies (Kilpeläinen & Summala 2007; Pavlou et al., 2023). To spot the potential hazards on the road, drivers reduce their driving speed (Yan et al., 2014). Heavy rain was also found to significantly increase driver lane-keeping behaviour (variance of lane position) (Ahmed et al., 2018). Zou et al. (2020) reported that, compared with clear days, the risk of vehicle collisions significantly

* Corresponding author. E-mail: *lina.matacina@gmc.vu.lt*

increases on rainy days. Other studies have found that extremely low or high temperatures significantly influence the risk of road traffic accidents due to driver concentration (Zou et al., 2020). During a heat wave, traffic accidents increase by 4.7% (Park et al., 2021). Studies in Europe have shown that fog, mist, and smoke are the main causes of road crash fatalities, followed by rain and snow (Pavlou et al., 2023). In addition, higher wind speeds have a crucial effect on road traffic accidents (Backer et al., 2022; Wang et al., 2024). Even though the number of traffic accidents caused by gale wind is small compared to the total number of traffic accidents, another study (Backer et al., 2022) found that high-speed winds accounted for only 0.3 to 0.5% of traffic accidents. One possible explanation is that higher wind gust results in vehicle spins and rollovers, mainly on bridges and viaducts. In general, current studies have found that icy roads and extreme rainfall significantly increase the occurrence of traffic accidents (Seeherman & Liu 2015; Call & Flynt 2021; Wang et al., 2024).

Despite the large body of literature covering various aspects of AVCs, there is limited research on the role of meteorological conditions (Shao et al., 2010; Kazemi et al., 2016; Pagany, 2020; Roy & Ksaibati 2021; Su et al., 2023). A significant barrier to this is the challenge of data collection and the complexity of weather impacts (Lamptey et al., 2024). Nonetheless, research has shown that unfavourable meteorological conditions can influence behavioural changes in wild ungulates. Research revealed that high daytime temperatures may extend ungulate nocturnal activity, increasing the probability of AVC occurrence (Carvalho et al., 2017; Brivio et al., 2024). For example, more vehicle collisions with moose occur during time with high temperatures (Dussault et al., 2006). Due to their high sensitivity to heat, moose seek habitats that act as thermal refuges, leading to more frequent road crossings (Ditmer et al., 2018). Kazemi et al. (2016) note that the number of AVCs increases under extreme meteorological conditions, such as mist, fog, heavy precipitation. Poor visibility may affect driver behaviour by reducing vehicle speed. By contrast, there are only a few studies on the relation between meteorological variables and AVCs. Nevertheless, the conclusions are inconsistent (Dussault et al., 2006; Rolandsen et al. 2011). These rather contradictory results may be attributed to species-specific responses to extreme meteorological conditions and to regional variations in responses to different environmental factors (responses in one region may differ from those in another). This topic remains largely unstudied despite the importance of meteorological influence in traffic safety and AVCs.

Despite previous studies examining AVCs in various regions, there is limited evidence on how meteorological conditions influence AVCs in Lithuania. Our study highlights a research gap in understanding the influence of meteorological conditions on AVCs. This study aimed to evaluate the impact of meteorological and related road conditions on the occurrence of AVCs. By linking meteorological conditions to AVC occurrences, the goal is to identify patterns that can be used to improve road safety strategies in Lithuania.

## 2. Materials and methods

From 2018 to 2022, a total of 38.093 road traffic accidents were recorded in Lithuania, of which 23.554 involved collisions with animals, accounting for 61.83% of all registered accidents. It should be noted that more recent collision data were not used due to limitations in data accessibility and obtaining official statistics for the most current years. In Lithuania, it is required to call the police if an accident with an animal occurs. Consequently, data on AVCs represent only those incidents that have been officially reported to the Lithuanian Police. Incidents that were not officially reported are not included in this analysis.

The Road Weather Information System (RWIS), which is based on weather stations on country roads, was first developed in Lithuania in 1999 (Laurinavičius & Juknevičiūtė-Žilinskienė, 2011). Road surface conditions and meteorological data are collected remotely via automatic weather stations. In Lithuania, weather stations provide real-time data at 15-minute intervals. For this study, the National access point database, maintained by Via Lietuva, is the main source of all meteorological data used for further analysis (National Access Point, n.d.). By the end of 2024, a total of 167 weather stations were put into operation on the roads of Lithuania (Road Weather Conditions, 2025). Of these, 99 meteorological stations are located on highways. For further analysis, we first selected stations located only on the highways. However, newly installed meteorological stations whose data could not be linked to the analysed period were excluded from further analysis. Meteorological stations that overlapped within the applied 5 km buffer were also removed. Finally, a total of 56 weather stations (Figure 1) were used for further analysis.

Data about air, road surface temperatures (°C), relative air humidity (%), wind speed (m/s), snow, ice, water cover (mm), visibility (meters), and adhesion coefficient (μ) were taken from each WS Table 1.

Table 1. Meteorological road parameters

| Meteorological variables | Units |
|---|---|
| Road surface temperature | °C |
| Air temperature | °C |
| Adhesion coefficient | μ |
| Ice thickness | mm |
| Snow thickness | mm |
| Water thickness | mm |
| Visibility | meters |
| Relative humidity | (%) |
| Wind speed | *m/s* |

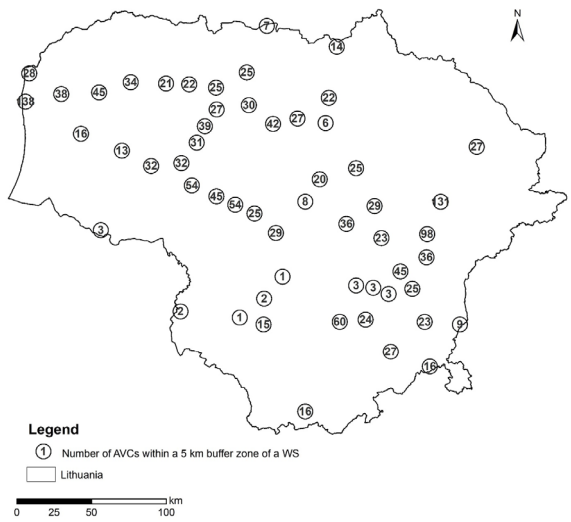


Figure 1. Distribution of AVCs within buffer zone of WS during 2018–2022

A buffer zone in this evaluation is defined as an area within 5 km of radius from the WS. The AVCs that fell into the buffer zone of WS during the period 2018–2022 (Figure 1) were selected for further analysis. Data about AVCs were taken from the Lithuanian Road Police Database. Totally, the 1632 AVCs were linked to precise meteorological data. The data indicate that roe deer (*Capreolus capreolus*) account for 65.75% of all recorded cases (Table 2). This finding suggests that this ungulate is the most frequently detected species within the study area, likely reflecting its high population density, spatial distribution, and ability to adapt to changing environments. XLSTAT and Principal Component Analysis (PCA) with a Spearman correlation matrix were used to analyze the statistical significance of meteorological factors on AVCs.

Table 2. Main species involved in AVCs within 5 km buffer zone in Lithuania between 2018 and 2022.

| Species | Percentage of accidents (%) |
|---|---|
| Roe deer (*Capreolus capreolus*) | 65.75 |
| Moose (*Alces alces*) | 9.07 |
| Unidentified | 9.99 |
| Wild boar (*Sus scrofa*) | 4.41 |
| Red deer (*Cervus elaphus*) | 3.25 |
| Fox (*Vulpes vulpes*) | 1.90 |
| Dog (*Canis familiaris*) | 1.53 |
| Others * | 4.11 |

*Note*: *Includes 11 species of wild and domestic animals that comprise < than 5% of total accidents.

## 3. Results

The results of analyzes of distribution of AVCs between day and night also did not distinguish the factor that would be statistically significant. The only difference is that the higher numbers of AVCs occur at night.

Barlett's sphericity test (Chi-square (observed value) – 1422.1; Chi-square (critical value) – 61.7; *DF* – 45, *p*-value < 0.0001) showed that the correlations between the variables is significantly different from 0. Together, PC1 and PC2 capture 52.16% of the total variability in the dataset.

Results of PCA showed that the most important factors to occur AVC are higher air and road temperature (0.97, $p < 0.05$) together with less significance of visibility and adhesion coefficient (0.42, $p < 0.05$) (Figure 2b). On the contrary poor weather conditions like ice cover (–0.61, $p < 0.05$), snow cover (–0.62, $p < 0.05$), rain intensity (–0.53, $p < 0.05$) and water cover (–0.68, $p < 0.05$) formed the second group of factors (Figure 2a).

PCA showed that meteorological variables distributed into two main groups: a) significant for less possibility of occurrence of AVCs and b) significant for occurrence of AVCs. Wind speed and relative humidity did not show any significant correlation between meteorological factors.

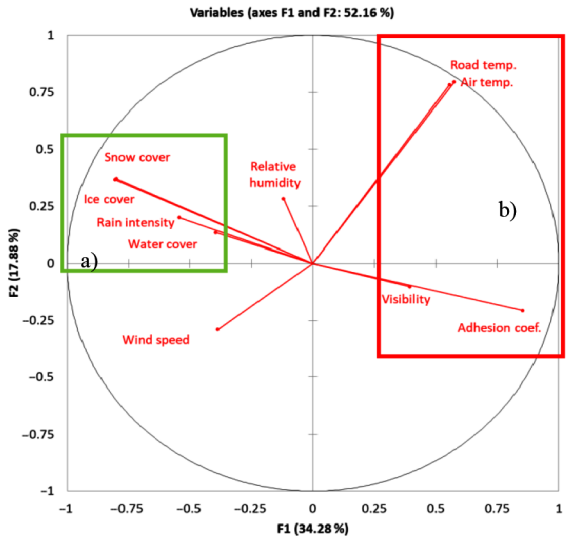


Figure 2. Principal component analyzes (PCA) of meteorological variables of AVCs: a) significant for less possibility of occurrence of AVCs; b) significant for occurrence of AVCs

## 4. Discussion

In this study, we analyzed the distribution of animal-vehicle collisions on Lithuanian highways in relation to meteorological variables. Our findings demonstrate that AVCs increase significantly during the nighttime. The results presented in this study align with previous research showing higher rates of ungulate collisions during periods of low visibility, as animals tend to be more active during dark hours (Su et al., 2023; Torres et al., 2025). On the other hand, drivers may improve their attention

and adjust their driving behavior to the road conditions. For instance, low visibility can result in reduced vehicle speed (Kioko et al., 2015). Other studies have demonstrated that low visibility and driving in fog can reduce speed by up to 10% compared with clear weather (Khan et al., 2018).

It has already been shown that unfavorable weather conditions can strongly influence the total accident risk (Van Langevelde & Jaarsma, 2005; Barrientos & Bolonio, 2009; Laliberté & St-Laurent, 2020). While the influence of wind on rollover and sideslip accidents has been widely studied, its effects on AVCs remain relatively underexplored (Eltemasi & Behtooiey, 2024). Nonetheless, some indirect assumptions on wind effects on AVCs can be drawn from previous findings. For instance, Baur et al. (2021) described the influence of high wind velocity on ungulate harvest success. This may support the assumption that ungulates reduce their activity at high wind speeds. Higher wind speeds lead to higher noise levels; for example, for ungulates such as roe deer, it is more difficult to identify potential risks, which increases vigilance and the use of safe environments (Baur et al., 2021).

The potential influence of relative humidity on AVC occurrence has not yet been examined in previous studies. The relationship between relative humidity and animal-vehicle collisions is complex. Environmental factors, such as humidity, can influence animal movement patterns and specific behaviours. On the contrary, an increase in relative humidity has been negatively correlated with road mortality among birds (Raymond et al., 2021).

Road surface and air temperature are environmental factors beyond human control. Additionally, air temperature can strongly affect animal behaviour (Attias et al., 2018; Zhou et al., 2022). It was found that in cold weather, ungulates seek shelter in forested environments, thereby minimizing their exposure to adverse meteorological conditions (Rivrud et al., 2014). Dussault et al. (2006) found that more moose-vehicle collisions occur on days with high atmospheric pressure and temperatures. Researchers think the reason may be increased nocturnal activity or seeking cover to avoid biting insects. High temperatures can also significantly affect harvest rates. Rivrud et al. (2014) found that the probability of being harvested decreased with increasing temperature.

The slipperiness of a road surface varies with environmental factors. Our findings indicated that most AVCs occurred on high-adhesion-coefficient roads. Road adhesion conditions play a crucial role in traffic safety, as poor adhesion can impair drivers' ability to assess road conditions and substantially increase the risk of skidding or crashing (Li et al., 2023). Conversely, Meng et al. (2020) noted that the safe driving speed in inclement weather conditions is linearly related to the road adhesion coefficient. As the adhesion coefficient decreases, the safe driving speed decreases accordingly.

Seasonal variation in ice, snow, and water cover significantly alters animal movement behavior, often forcing wildlife to seek alternative routes that intersect with roads, thereby increasing the risk of AVCs (Cunningham et al., 2022). Our findings indicated that the majority of AVCs occurred when the road surface was dry, especially during nighttime. The effects of snow cover and ice thickness are not statistically significant, likely because most AVCs occur when there is no snow cover on roads. Conversely, Garrett and Conway (1999) reported a slightly higher number of car accidents when the roads are wet and slushy.

The aim of AVC research is to develop dynamic and effective approaches to minimize collision risks for both wildlife and humans. By integrating AVC datasets with environmental, spatiotemporal, or meteorological analyses, it becomes possible to identify and model spatial and temporal risk patterns more accurately. Such risk assessments should enable the projection of collision risks into future periods and their application to regions lacking comprehensive analysis. Nevertheless, challenges related to temporal forecasting, data quality, spatial transferability, and the integration of detailed meteorological variables remain key limitations that must be addressed to improve the reliability and applicability of AVC risk modelling.

## 5. Conclusions

The analysis of AVCs data around 56 meteorological stations in Lithuania led to the following conclusions:

No meteorological factor demonstrated statistically significant differences in the distribution of AVCs between day and night, although a consistently higher number of AVCs occurred during the night, suggesting a general but not statistically significant temporal tendency.

Overall, the study demonstrates that by using Principal Component Analysis, higher air and road temperatures are the most influential factors associated with increased AVC occurrence, while visibility and road adhesion showed weaker but still significant contributions. Together, the first two principal components explained 52.16% of the total variance, confirming the relevance of temperature-related variables in shaping AVC patterns. Adverse weather conditions – including ice cover, snow cover, rain intensity, and water cover – were associated with a reduced likelihood of AVC occurrence and formed a distinct group of negatively correlated variables. This may support the hypothesis that increased driver attentiveness under such circumstances plays a more critical role than changes in animal movement patterns.

This study also shows that wind speed and relative humidity did not demonstrate significant relationships with AVC occurrence, indicating limited influence within the analyzed meteorological framework.

## References


Abraham, J. O., & Mumma, M. A. (2021). Elevated wildlife-vehicle collision rates during the COVID-19 pandemic. *Scientific Reports*, *11*, Article 20391. https://doi.org/10.1038/s41598-021-99233-9

Ahmed, M., Ghasemzadeh, A., Hammit, B. E., Khan, M. N., Das, A., Ali, E., Young, R. K., & Eldeeb, H. (2018). *Driver performance and behavior in adverse weather conditions*: *An investigation using the SHRP2 naturalistic driving study data – Phase 2* (Final Report No. WY-18/05F). U.S. Department of Transportation. https://rosap.ntl.bts.gov/view/dot/35664

Attias, N., Oliveira-Santos, L. G. R., Fagan, F. W., & Mourão, G. (2018). Effects of air temperature on habitat selection and activity patterns of two tropical imperfect homeotherms. *Animal Behaviour*, *140*, 129–140. https://doi.org/10.1016/j.anbehav.2018.04.011

Backer, N., Rust, H. W., & Ulbrich, U. (2022). Weather impacts on various types of road crashes: A quantitative analysis using generalized additive models. *European Transport Research Review*, *14*, Article 37. https://doi.org/10.1186/s12544-022-00561-2

Barrientos, R., & Bolonio, L. (2009). The presence of rabbits adjacent to roads increases polecat road mortality. *Biodiversity and Conservation*, *18*, 405–418. https://doi.org/10.1007/s10531-008-9499-9

Baur, S., Peters, W., Oettenheym, A., & Menzel, A. (2021). Weather conditions during hunting season affect the number of harvested roe deer (*Capreolus capreolus*). *Ecology and Evolution*, *11*(*15*), 10178–10191. https://doi.org/10.1002/ece3.7825

Bennett, V. J. (2017). Effects of road density and pattern on the conservation of species and biodiversity. *Current Landscape Ecology Reports*, *2*, 1–11. https://doi.org/10.1007/s40823-017-0020-6

Bíl, M., Andrášik, R., Duľa, M., & Sedoník, J. (2019). On reliable identification of factors influencing wildlife-vehicle collisions along roads. *Journal of Environmental Management*, *237*, 297–304. https://doi.org/10.1016/j.jenvman.2019.02.076

Brivio, F., Apollonio, M., Anderwald, P., Filli, F., Bassano, B., Bertolucci, C., & Grignolio, S. (2024). Seeking temporal refugia to heat stress: Increasing nocturnal activity despite predation risk. *Proceedings of the Royal Society B*: *Biological Sciences*, *291*(2015), Article 20231587. https://doi.org/10.1098/rspb.2023.1587

Call, A. D., & Flynt, G. A. (2022). The impact of snowfall on crashes, traffic volume, and revenue on the New York State Thruway. *Weather*, *Climate*, *and Society*, *14*(*1*), 131–141. https://doi.org/10.1175/WCAS-D-21-0074.1

Carvalho, C. F., Custódio, A. E. I., & Marçal-Júnior, O. (2017). Influence of climate variables on roadkill rates of wild vertebrates in the Cerrado biome, Brazil. *Journal of Biosciences*, *33*, 1632–1641. https://doi.org/10.14393/BJ-v33n6a2017-39538

Cunningham, C. X., Nuñez, T. A., Hentati, Y., Sullender, B., Breen, C., Ganz, T. R., Kreling, S. E. S., Shively, K. A., Reese, E., Miles, J., & Prugh, L. R. (2022). Permanent daylight saving time would reduce deer-vehicle collisions. *Current Biology*, *32*(*22*), 4982–4988. https://doi.org/10.1016/j.cub.2022.10.007

Ditmer, M., Moen, R., Windels, S., Forester, J., Ness, T. E., & Harris, T. R. (2018). Moose at their bioclimatic edge alter their behavior based on weather, landscape, and predators. *Current Zoology*, *64*(*4*), 547. https://doi.org/10.1093/cz/zox051

Dussault, C., Poulin, M., Courtois, R., & Ouellet, J.-P. (2006). Temporal and spatial distribution of moose-vehicle accidents in the Laurentides Wildlife Reserve, Quebec, Canada. *Wildlife Biology*, *12*(*4*), 415–442. https://doi.org/10.2981/0909-6396(2006)12[415:TASDOM]2.0.CO;2

Eltemasi, M., & Behtooiey, H. (2024). Examining the relationship between wind speed, climatic conditions, and road accidents in Iran. *Heliyon*, *10*(*13*), Article e33228. https://doi.org/10.1016/j.heliyon.2024.e33228

Garrah, E., Danby, R. K., Eberhardt, E., Cunnington, G. M., & Mitchell, S. (2015). Hot spots and hot times: Wildlife road mortality in a regional conservation corridor. *Environmental Management*, *56*, 874–889. https://doi.org/10.1007/s00267-015-0566-1

Garrett, L. C., & Conway, G. A. (1999). Characteristics of moose-vehicle collisions in Anchorage, Alaska, 1991–1995. *Journal of Safety Research*, *30*(*4*), 219–223. https://doi.org/10.1016/S0022-4375(99)00017-1

Jaroszweski, D., & McNamara, T. (2014). The influence of rainfall on road accidents in urban areas: A weather radar approach. *Travel Behaviour and Society*, *1*, 15–21. https://doi.org/10.1016/j.tbs.2013.10.005

Kourchi, Y. E., Santos ,X., Fahd, S., Chergui, B. (2025). Occupancy analysis uncovers environmental factors contributing to road mortality of amphibians. *European Journal of Wildlife Research*, *71*, Article 53. https://doi.org/10.1007/s10344-025-01932-5

Kazemi, V. D., Jafari, H., & Yavari, A. (2016). Spatio-temporal patterns of wildlife road mortality in Golestan National Park, North East of Iran. *Open Journal of Ecology*, *6*(*6*), 312–324. https://doi.org/10.4236/oje.2016.66031

Khan, M. N., Ghasemzadeh, A., & Ahmed, M. M. (2018). Investigating the impact of fog on freeway speed selection using the SHRP2 naturalistic driving study data. *Transportation Research Record*, *2672*(*16*), 282–291. https://doi.org/10.1177/0361198118774748

Kioko, J., Kiffner, C., Phillips, P. M., Patterson-Abrolat, C., Collinson, W., & Katers, S. (2015). Driver knowledge and attitudes on animal vehicle collisions in northern Tanzania. *Tropical Conservation Science*, *8*(*2*), 352–366. https://doi.org/10.1177/194008291500800206

Kilpeläinen, M., & Summala, H. (2007). Effects of weather and weather forecasts on driver behavior. *Transportation Research Part F*: *Traffic Psychology and Behaviour*, *10*(*4*), 288–299. https://doi.org/10.1016/j.trf.2006.11.002

Laliberté, L., & St-Laurent, M. H. (2020). In the wrong place at the wrong time: Moose and deer movement patterns influence wildlife-vehicle collision risk. *Accident Analysis & Prevention*, *135*, Article 105365. https://doi.org/10.1016/j.aap.2019.105365

Lamptey, B., Sahabi, A. S., Gudoshava, M., Mutemi, J., Bopape, M. J., Adefisan, E. A., Igri, M. P., Seidou, S., Ndiaye, O., Parker, D. J., Dougill, A. J., Fink, A. H., Knippertz, P., Woolnough, S., & Kolstad, E. W. (2024). Challenges and ways forward for sustainable weather and climate services in Africa. *Nature Communications*, *15*, Article 2664. https://doi.org/10.1038/s41467-024-46742-6

Lagos, L., Picos, J., & Valero, E. (2012). Temporal pattern of wild ungulate-related traffic accidents in northwest Spain. *European Journal of Wildlife Research*, *58*, 661–668. https://doi.org/10.1007/s10344-012-0614-6

Laurinavičius, A., & Juknevičiūtė-Žilinskienė, L. (2011, May 19–20). Eleven years of RWIS operation in Lithuania: Possibilities for the use of the data collected. In *Proceedings of the 8th International Conference on Environmental Engineering* (pp. 1108–1112). Vilnius, Lithuania.

Li, C., Liu, P., Xie, Z., Li, Z., & Huan, H. (2023). Road adhesion coefficient estimation based on vehicle-road coordination and deep learning. *Journal of Advanced Transportation*, Article 3633058. https://doi.org/10.1155/2023/3633058

Lio, C.-F., Cheong, H.-H., Un, C.-H., Lo, I.-L, & Tsai, S.-Y. (2019). The association between meteorological variables and road traffic injuries: A study from Macao. *PeerJ*. https://peerj.com/articles/6438/

Madadi, H., Moradi, H., Soffianian, A., Salmanmahiny, A., Senn, J., & Geneletti, D. (2017). Degradation of natural habitats by roads: Comparing land-take and noise effect zone. *Environmental Impact Assessment Review*, *65*, 147–155. https://doi.org/10.1016/j.eiar.2017.05.003

Meng, E., Wang, B., Wei, J., Liu, H., Zhao, K., & Hu, Z. (2020). Test and analysis of characteristics of safe driving speed on typical ice-snow road. *Journal of Physics*: *Conference Series*, *1575*, Article 012197. https://doi.org/10.1088/1742-6596/1575/1/012197

Morelle, K., Lehaire, F., & Lejeune, P. (2013). Spatio-temporal patterns of wildlife-vehicle collisions in a region with a high-density road network. *Nature Conservation*, *5*, 53–73. https://doi.org/10.3897/natureconservation.5.4634

National Access Point. (n.d.). *Kelių oro sąlygų stotelių duomenys*. https://maps.eismoinfo.lt/portal/apps/sites/#/npp/pages/weather

Neumann, W., Ericsson, G., Dettki, H., Bunnefeld, N., Keuler, N. S., Helmers, D. P., & Radeloff, V. C. (2012). Difference in spatiotemporal patterns of wildlife road-crossings and wildlife-vehicle collisions. *Biological Conservation*, *145*, 70–78. https://doi.org/10.1016/j.biocon.2011.10.011

Ortega, A. C., Aikens, E. O., Merkle, J. A., Monteith, K. L., & Kauffman, M. J. (2023). Migrating mule deer compensate en route for phenological mismatches. *Nature Communications*, *14*, Article 2008. https://doi.org/10.1038/s41467-023-37750-z

Pagany, R. (2020). Wildlife-vehicle collisions – Influencing factors, data collection, and research methods. *Biological Conservation*, *251*, Article 108758. https://doi.org/10.1016/j.biocon.2020.108758

Park, J., Choi, Y., & Chae, Y. (2021). Heatwave impacts on traffic accidents by time-of-day and age of casualties in five urban areas in South Korea. *Urban Climate*, *39*, Article 100917. https://doi.org/10.1016/j.uclim.2021.100917

Pavlou, D., Christodoulou, G., & Yannis, G. (2023). The impact of weather conditions and driver characteristics on road safety on rural roads. *Transportation Research Procedia*, *72*, 4081–4088. https://doi.org/10.1016/j.trpro.2023.11.369

Pińskwar, I., Choryńsk, A., & Graczyk, D. (2023). Good weather for a ride (or not?): How weather conditions impact road accidents – A case study from Wielkopolska (Poland). *International Journal of Biometeorology*, *68*, 317–331. https://doi.org/10.1007/s00484-023-02592-3

Raymond, S., Schwartz, A. L W., Thomas, R. J., Chadwick, E., & Perkins, S. E. (2021). Temporal patterns of wildlife roadkill in the UK. *PloS ONE*, *16*(10), Article e0258083. https://doi.org/10.1371/journal.pone.0258083

Ramp, D., & Roger, E. (2008). Frequency of animal-vehicle collisions in NSW. In D. Lunney, A. Munn, & W. Meikle (Eds.), *Too close for comfort*: *Contentious issues in human-wildlife encounters* (pp. 118–126). Royal Zoological Society of New South Wales.

Rivrud, I. M., Meisingset, L. E., Loe, L. E., & Mysterud, A. (2014). Interaction effects between weather and space use on harvesting effort and patterns in red deer. *Ecology* & *Evolution*, *4*(*24*), 4786–4797. https://doi.org/10.1002/ece3.1318

Road weather conditions. (n.d.). https://eismoinfo.lt/#!/

Rolandsen, C. M., Solberg, E. J., Herfindal, I., Van Moorter, B., & Sæther, B.-E. (2011). Large-scale spatiotemporal variation in road mortality of moose: Is it all about population density? *Ecosphere*, *2*(*10*), 1–12. https://doi.org/10.1890/ES11-00169.1

Roy, U., & Ksaibati, K. (2021). Investigating trends and characteristics of animal-vehicle crashes in Wyoming. *Journal of Sustainable Development of Transport and Logistics*, *6*(*2*), 1–18. https://doi.org/10.14254/jsdtl.2021.6-2.2

Seeherman, J., & Liu, Y. (2015). Effects of extraordinary snowfall on traffic safety. *Accident Analysis* & *Prevention*, *81*, 194–203. https://doi.org/10.1016/j.aap.2015.04.029

Shao, C., Yi, P., & Alhomidan, A. (2010). High and low deer-vehicle collision roadway sections – what makes them different? *Open Transportation Journal*, *4*, 87–92.

Silva, C., Simões, M. P., Mira, A., & Santos, S. M. (2019). Factors influencing predator roadkills: The availability of prey in road verges. *Journal of Environmental Management*, *247*, 644–650. https://doi.org/10.1016/j.jenvman.2019.06.083

Stevens, S. E., Schreck, C. J., Saha, S., Bell, J. E., & Kunkel, K. E. (2019). Precipitation and fatal motor vehicle crashes. *Bulletin of the American Meteorological Society*, *100*(*8*), 1453–1461. https://doi.org/10.1175/BAMS-D-18-0001.1

Strano, E., Giometto, A., Shai, S., Bertuzzo, E., Mucha, P. J., & Rinaldo, A. (2017). The scaling structure of the global road network. *Royal Society Open Science*, *4*(*10*), Article 170590. https://doi.org/10.1098/rsos.170590

Su, H., Wang, Y., Yang, Y., Tao, S., & Kong, Y. (2023). An Analytical framework of the factors affecting wildlife–vehicle collisions and barriers to movement. *Sustainability*, *15*(14), Article 11181. https://doi.org/10.3390/su151411181

Torres, R. T., Neves, T., Grilo, C., Leite, P., Rossa, M., & Carvalho, J. (2025). Wrong place at the wrong time: Patterns explaining ungulate-vehicle collisions in Portugal. *Mammalian Biology*, *105*, 387–401. https://doi.org/10.1007/s42991-025-00487-x

Van Langevelde, F., & Jaarsma, C. F. (2005). Using traffic flow theory to model traffic mortality in mammals. *Landscape Ecology*, *19*, 895–907. https://doi.org/10.1007/s10980-005-0464-7

Wang, Q., Zhao, Y., Li, L., Kong, L., & Si, W. (2024). Influence of snowy and icy weather on vehicle sideslip and rollover: A simulation approach. *Sustainability*, *16*(*2*), Article 888. https://doi.org/10.3390/su16020888

Yan, X., Li, X., Liu, Y., & Zhao, J. (2014). Effects of foggy conditions on drivers' speed control behaviors at different risk levels. *Safety Science*, *68*, 275–287. https://doi.org/10.1016/j.ssci.2014.04.013

Zhou, W., Wang, M., Gao, K., Gao, H., Wei, F., & Nie, Y. (2022). Behavioural thermoregulation by montane ungulates under climate warming. *Diversity and Distributions*, *28*(*10*), 2229–2238. https://doi.org/10.1111/ddi.13626

Zou, Y., Zhang, Y., & Cheng, K. (2020). Exploring the impact of climate and extreme weather on fatal traffic accidents. *Sustainability*, *13*(*1*), Article 390. https://doi.org/10.3390/su13010390