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## IDENTIFICATION OF LOCATION OF ANIMAL-VEHICLE COLLISION AND PRINCIPALS OF ITS MITIGATION ON THE ROADS

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***Purpose***. The animal–vehicle collisions (AVC) are serious risk of danger for animals, motorists and passengers on the roads and there are various methods of study of AVCs on the highways. ***Methodology***. The study reviewed of the article includes theoretical and empirical result about of identification location AVC on the such directions of research: 1.)The speed limit and traffic volume; 2.) Temporal patterns; 3.) Spatial patterns; 4.) Effective mesh size; 5.) The correlation and regression analysis; 6.) Mitigation measure. ***Results.*** For example we found out that more study shown the next directions of research: spatial patterns, the correlation and regression analysis and mitigation measure. As a result the analysis has shown that variations in landscape scale habitat composition of area were correlated with variations in wildlife crossing rates at the landscape scale. The hot spots of AVC generally were associated with topographic features that directed animals towards highways, the presence of habitat adjacent to highways, or food resources that attracted animals. ***Practical value***. There are correlations between the number and spatial distribution of AVC and recorded wildlife measuring the distributions and populations of wildlife species. We found out some the unexplored the directions for our research in this field. *References 53, no tables, no figures.*

**Key word:** mitigation of animal–vehicle collisions, regression.

## ВИЗНАЧЕННЯ МІСЦЬ ЗІТКНЕННЯ ТРАНСПОРТНИХ ЗАСОБІВ З ТВАРИНАМИ І ПРИНЦИПИ ЇХ ЗНИЖЕННЯ НА ДОРОГАХ

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***Мета***.Зіткнення тварин з автомобілем або дорожньо-транспортні пригоді з наїздом на тварин (ДТП НТ) є серйозним ризиком небезпеки для тварин, автомобілістів і пасажирів на дорогах. ***Методологія.*** Ми розглянули дослідження, які використовують різні методи для вивчення (ДТП НТ) на дорогах. Наша стаття включає в себе теоретичний і емпіричний результат про ідентифікаційного місцезнаходження ДТП НТ, який розділений за напрямках досліджень: 1.) Обмеження швидкості та обсягу трафіку; 2.) Тимчасові структури; 3.) Просторові структури; 4.) Ефективний розмір сітки; 5.) Кореляційний і регресійний аналіз; 6.) Пом'якшувальні заходи. ***Результати.***Ми виявили, що найбільш широко представлені дослідження для наступних напрямків ДТП НТ: просторові структури, кореляція і регресійний аналіз, і пом'якшувальні заходи. Аналіз показав, що відмінності в масштабі ландшафту місць проживання тварин корелювали зі змінами переходів тварин через автодорогу в масштабі ландшафту. Гарячі точки ризику ДТП НТ зазвичай були пов'язані з топографічними особливостями, які, направляють тварин до автодороги, наявність проживання, прилеглої до шосе, або харчових ресурсів, які залучають тварин. ***Практична цінність.***Є кореляції між кількістю і просторового розподілу ДТП НТ і розподілом і населенням видів тварин.

**Ключові слова:** пом'якшення зіткнень тварин транспортних засобів, регресія.

PROBLEM STATEMENT. The animal–vehicle collisions (AVC) are serious risk of danger for animals, motorists and passengers on the roads. The term AVC are covers any animal: domestics and wildlife that has other abbreviation: elk-vehicle collision (EVC), wildlife –vehicle collisions (WVC), deer –vehicle collisions (DVC), wildlife–vehicle accidents (WVA). In the United States, the total number of annual deer–vehicle collisions was estimated at more than 1 million in the early 1990s [1]. These collisions were estimated to cause 155–211 human fatalities, 13,713–29,000 human injuries, and more than U.S. $1 billion in property damage a year [2]. In 2000, Canada experienced more than 30,000 collisions with animals resulting in 23 human fatalities, 1,887 human injuries, and more than U.S. $60 million in property damage [3]. Similar figures are available from Europe, where the annual number of collisions with ungulates was estimated at 507,000, causing 300 human fatalities, 30,000 human injuries, and more than $1 billion dollars in material damage [4]. In several regions in the United States and Canada these numbers have increased even further over the last decade [2,3,5,6,]. These AVCs have caused significant damage to human safety, property, and wildlife in the past decades. These AVCs have caused significant damage to human safety, property, and wildlife in the past decades. These collisions caused about 200 human fatalities, and 20,000 human injuries annually in the United States [7]. In Ukraine, according to the Interior Ministry of State Traffic Inspectorate, in the period 2007-2014 occurred 15 671 numbers of AVC which resulted to 28 human fatalities and 396 human injuries [53]. In this situation is needed to prepare the mitigation action for decrease of amount AVC on the roads. For prepare of this article we reviewed 53 studies about identification of location of AVCs and mitigation action on the roads. Our analysis had been formed on the groups of researches: 1.) The speed limit and traffic volume; 2.) Temporal patterns; 3.) Spatial patterns; 4.) Effective

mesh size; 5.) The correlation and regression analyses; 6.) Mitigation measures. For prepare of this had been reviewed studies about identification of location of AVC and its mitigation measures.

EXPERIMENTAL PART AND RESULTS OBTAINED.

1.THE SPEED LIMIT AND TRAFFIC VOLUME. The speed limit, rural versus urban, and presence of white-tailed deer habitat have an increasing effect on AVC risks [9]. For evaluation of characteristics of fatal animal-vehicle collisions from 1995–2004 by using the Fatality Accident Reporting System database of the National Highway Traffic Safety Administration as the main manager for reducing the risk of AVC [10]. The evaluation of vehicle speed and traffic volume on deer–vehicle collision rates are used to measure these variables [11]. The influence of vehicle speed and traffic volume on deer–vehicle collision (DVC) rates showed no relationship between annual average daily traffic flow (AADT) and posted speed limit (PSL) typically are used to measure these variables. The authors to propose three explanations for results: a.) no causal relationship exists; b.) AADT and PSL, as measured, actually explain little of the variation; and c.) data quality problems exist [12].

2. TEMPORAL PATTERNS. The study of the AVC on the parameter "date": by day of week, by the day of month, by the months of year, by the years, by the hour of day and season of the year by use of chart of the distribution of accidents with collisions on animals with date and time, and a graph comparing the values of the number of accidents from collisions with animals and the average linear deviation [8]. The temporal pattern of AVC by used clusters analysis of seasonal data shown the differences and variations are related to habitat and traffic characteristics [13]. The identification of areas of AVC by used the relationships between species and factors associated with accident levels such as the time of year or day, road characteristics, and the intensity of traffic levels [14]. Analyses the temporal and spatial patterns AVC are involving wild boar and roe deer using geographic information systems (GIS) and spatial statistics [15].

3. SPATIAL PATTERNS. The developing a modelling approach for presence and presence/absence data collected from the Snowy Mountain Highway in southern New South Wales, Australia, to compare the effectiveness of this approach for five species/groups of species. The authors observed that models of species killed in a clumped fashion were effective at identifying hotspots, while for species where fatalities were distributed evenly along the road the models were less effective. The actual data of spatial clustering is the preferred method of hotspots identification and predictive models of presence/absence date should be constructed if the intention is to extrapolate to additional areas [16]. The evaluation of relationships between the traffic and abundance of wildlife on the probabilities of WVCs using the total number of reported WVCs [17].

Landscape models and roadside habitats based on roadside characteristics that can be an effective way to reduce AVC [18]. The AVC with wild boar cross roads has connected with habitats and results for its mitigation is involve changes in behavioural patterns of drivers and changes in farming practices near of the AVC place of roads [19]. Using the such predictions attributes of AVC as: reducing speed limits around greenbelt areas, brighter vehicle headlights, placement of street lights in known moose areas, underpasses for wildlife at known crossings, and snow removal to reduce barrier height in areas of high animal concentrations [20].

The identified roadway and non-roadway factors could be useful for identifying locations by used the relationship between AVC and deer density near roads [21]. The spatially predictive models that use the habitat variables assessed included road-related variables as traffic volume and land cover characteristics as mean patch area of the landscape [16]. The analysis relation between animal road-crossings and AVC data from police that indicate different spatiotemporal risk zones [22].

The analyses was indicated that variations in landscape scale habitat composition of area were correlated with variations in wildlife crossing rates at the landscape scale and different species also showed different affinities for the roadside [23]. The hot spots of AVC generally were associated with topographic features that directed animals towards highways, the presence of habitat adjacent to highways, or food resources that attracted animals [24]. To estimate of compare and combine on the state level AVC data collected by representatives from the Department of Transportation and Natural Resources from each five states were surveyed and used to collect the data of and collected the date of police-reported DVCs, deer-carcass numbers and deer-population estimates in period 10 years [25]. The mid-size and large-sized mammals crossing activity at specific locations that are correlated with the surrounding habitat and the roadway the following: (1) use habitat suitability as the primary indicator of crossing activity; (2) consider how landscape structure interacts with habitat suitability to either increase or decrease the level of use an area of suitable habitat receives by a particular species; (3) consider how the design of the existing highway interacts with habitat suitability and landscape structure to influence behavior of crossing; (4) synthesize this information by mapping the landscape and roadway features/conditions likely to be associated with crossing or that are attractive/repellant to the species present [26]. Identify roadway, habitat, and moose population features that correlated with the reported number of moose-vehicle collisions (MVCs) and propose measures to reduce risks to motorists [27]. Evaluation of the spatial error associated with reported wildlife-vehicle collisions (WVCs) and look at the demographic and temporal patterns of elk and wildlife-vehicle collisions on different road-types [28].

The results obtained by the analysis of 7,759 records on roe deer road-killed are as follows: (a) Frequency of roe deer-vehicle collisions that expressed by the average number of roe deer killed annually on roads for every 1,000 ha of the surface, is the highest in sub-Alpine and sub-Panonic regions. (b) The risk of

collision with roe deer varies over the year – the majority of crashes occur in April and May; however, the risk is high during the summer and autumn as well. (c) The daily pattern of roe deer-vehicle collisions has a pronounced bimodal distribution with peaks at dawn (5 a.m. – 7 a.m.) and dusk (6 p.m. – 10 p.m.). (d) The risk for collision with roe deer is higher in a fragmented landscape, where the forest edge is very long [29]. The road sections with high collision rates, or vertebrate-mortality hotspots (VMH), by detecting clusters of animal collision locations and analysis was conducted by comparing the spatial pattern of road kills with that expected in a random situation. In such a condition, the likelihood of collisions for each road section would show a Poisson distribution. Differences of variables between hotspots and low-mortality sections were evaluated with the Mann-Whitney U-test [30].

The spatial, temporal and spatial-temporal techniques to investigate patterns of AVCs in Western Australia between 1999 and 2008, at different levels of scale and use the graphs were adapted to identify temporal patterns of vehicle crashes at two different levels of scales: daily and weekly with respect to their causes. The spatial structures of vehicle crashes were analyzed using Kernel density estimation analysis at three different scales: national, city and local level. [31]. During the period between 2003-2011 has observed an annual increase of WVC for wild boar and red deer, this increase was significantly correlated with hunting statistics, used as an index of population density. The temporal analysis demonstrated an increase of WVC during night time with peak of accidents at dusk and dawn. Monthly distribution revealed the role of breeding, dispersal and hunting data in shaping temporal patterns of accidents. Spatial analysis, focusing on wild boar, roe deer and red fox demonstrated clustering of accidents for all these species, until scale between 20 to 70 km and mapping of accidents via Kernel density analysis permitted us to highlight areas with high risk of WVC [32].

The mammals crossing activity is locations that are correlated with habitat on both sides of a highway and its placement in the landscape. There are no single set of variables identifies all preferred crossing locations because every landscape and every highway is unique, identifying the best location for each mitigation project for safety of animal must be approached individually. There are results of study: a.) use habitat suitability as the primary indicator of crossing activity; b.) consider how landscape structure interacts with habitat suitability to either increase or decrease the level of use an area of suitable habitat receives by a particular species; c.) consider how the design of the existing highway interacts with habitat suitability and landscape structure to influence crossing behavior; d.) synthesize this information by mapping the landscape and roadway conditions likely to be associated with crossing or that are attractive to the species present that to identify the most likely crossing locations [32].

4. EFFECTIVE MESH SIZE. Habitat fragmentation due to transport infrastructure and other human development poses a threat for many wildlife species. This threat may differ depending on the species and types of fragmenting elements: landscape division, splitting index, and effective mesh size. There is a need to quantify the level of habitat fragmentation and the impact of habitat fragmentation on different wildlife species for use in transportation planning. Such measures would be useful in assessing the cumulative impact of multiple road projects on wildlife connectivity and habitat suitability, for long-range wildlife impact mitigation planning for transportation projects, and as an indicator for the environmental monitoring of habitat fragmentation due to roads. Effective mesh size (meff) is a biologically relevant landscape metric that quantifies the degree of landscape fragmentation. The definition of the effective mesh size is based on the probability that two randomly chosen points in a region will be located in the same non-fragmented area of land. The authors calculated effective mesh size to assess the level of landscape fragmentation in the State of California, USA, based on four fragmentation geometries defined by a combination of highways, minor roads, urbanized areas, agricultural areas, and natural fragmenting features (e.g., rivers, lakes, and alpine areas). The effective mesh size for these four fragmenting geometries were calculated for the entire State of California using eight sets of planning units: 1) transportation planning districts, 2) municipal county boundaries, and 3) six levels of watersheds. To demonstrate the methodology, we examined how effective mesh size may impact for two species important to transportation planning in California: mule deer (Odocoileus hemionus) and mountain lion (Puma concolor). The calculated effective mesh sizes were compared with the home range sizes and daily movement distances of the selected focal species to determine the potential impact of habitat fragmentation and to identify areas where transportation projects will potentially impact these focal species. Based on the results of this analysis, was been suggest that integrating an effective mesh size-based tool into transportation planning frameworks would be valuable to improve identification of potential landscape level impacts early in the planning process. The calculation of effective mesh size will give transportation planners a way to analyze the cumulative impacts of roads in districts, counties, and watersheds and can be used as an environmental indicator for ecological assessment of transportation system impacts [34,35,36,37, 38]. The estimation of table with 19 variations of the models that will be of various sizes of fragmentation varies accordingly the parameters of fragmentation: effective mesh size, the effective density of the mesh, the degree of landscape distribution for local road [39].

The presentation of transportation corridors for wildlife and give examples of how wildlife mitigation measures can be incorporated into long range plans and in routine everyday actions of state departments. The authors has presents of results include data from a continent-wide telephone survey conducted over a two-year period to learn of accomplishments in wildlife passage and how wildlife and ecosystem needs to have

been incorporated into the transportation planning process.

5. THE CORRELATION AND REGRESSION ANALYSIS. The correlation and regression analysis between some parameters of AVC use in next articles [40,41,42]. To identify the conditions of the roadways, and their surrounding landscape, which lead to a higher probability of moose and deer-vehicle accidents. Identifying the influencing environmental and habitat variables helps, in turn, to identify which areas should be the focus of mitigating procedures for existing highways and provides a valuable component and enhancement to the highway planning and design process for proposed highways [40]. The evaluation of traffic characteristics, vegetative and topographic features associated with mule deer kills on three highways in northeastern Utah in period October 1991 to October 1993 that had been accounted 397 deer roadkills. Spotlight density of deer and deer mortality were strongly correlated from summer 1992 through summer 1993 ($r = 0.94$). Traffic conditions, topographic features, and vegetative characteristics is causes of mortality levels in those highway [41].

The analysis revealed dangerous roads, most of which were situated in the eastern part of the country and number and spatial distribution of wildlife–vehicle accidents (WVA) in Lithuania in 2002–2007, as registered by the Lithuanian Police Traffic Supervision Service. The observed correlations between the number and spatial distribution of WVA and recorded wildlife inventory data strongly suggest that WVA can be used for indirectly measuring the distributions and populations of wildlife species [42].

Use of Global Positioning System (GPS) telemetry to assess spatial and temporal patterns of elk highway crossings and its compare by used method of correlations between number of elk crossed the highway with biotops, which are located around and also before and after reconstruction on the highway of Arizona where had been reconstructed for safety: 11 wildlife underpasses, six bridges, and associates its ungulate proof fencing [43]. The methods for AVC research is diagonal inflated bivariate Poisson model regression demonstrates its capability of fitting two data from: reported AVC data and carcass removal data that show the impact of traffic elements, geometric design and geographic characteristics of AVC and carcass removal data [44]. The spatial relationship of AVCs by using chi-square test of independence, and a landscape metric as the percentage of adjacency and habitat type and structure may play an important role in the identification of location AVC [45].

6. MITIGATION MEASURES. The developing and planning of model design of mitigation strategies of AVC on roads [46]. Evaluation of performance of fencing and passage construction by using some species of animal for developing spatial model for predictions of AVC [47]. Telephone interviews were conducted with transportation and ecology professionals in every state and province and based on research data is needed to make that greater efforts in long term transportation plans and everyday retrofits are necessary to provide for wildlife and ecosystems needs [48].The use of surveys transportation professionals in the United States and Canada that answered questions by telephone concerning wildlife crossings, planning for wildlife and ecosystems, animal-vehicle collision information, and research activities related to roads and wildlife [49].

The useful example of wildlife conservation and transportation planning and development in the State of Vermont have become part of a collaborative efforts between the Vermont Fish and Wildlife Department and the Vermont Agency of Transportation. The both states departments have become increasingly sophisticated and more broadly applied throughout the state to understand of conflicts and strategies for improving wildlife movement, reducing wildlife mortality, and improving the safety of the motorist and traveling public. For it is necessary to identify potentially signify wildlife habitat throughout the state. Such information would allow for these agencies to make informed decisions regarding the conservation of important wildlife habitat and investments for mitigation of impacts associated with transportation such as underpasses, land conservation, and other measures. Geographic Information System (GIS)-based models have been developed in other states and in Canada to identify potentially significant wildlife habitat [50].

Long-term and year-round monitoring of wildlife crossing structures by using of temporal and spatial variability in performance studies is important reason for developing of mitigation programs of AVC and implemented monitoring programs of sufficient experimental design into period before and after construction wildlife crossing structures. There are two problems: a.)The results obtained from most studies remain as only passive observations; 2.) Studies that collected data was not suitable for wildlife habituation to such large-scale landscape change. Such habituation periods can take several years depending on the species as they experience, learn and adjust their own behaviours to the wildlife structure. The brief monitoring periods frequently incorporated are simply insufficient to draw on reliable conclusions [51]. For define of locations where wildlife movement and highway operation conflict is an essential first step in making highways safer for motorists and animals by using an expert-opinion approach have been identified 86 conflict areas (hotspots) for wildlife along roads in the Oregon state and most of these hotspots were locations with frequent deer-vehicle collisions. For evaluation of AVC to use the opinion of expert that assessing many miles of highway for the presence of wildlife hotspots [52].

CONCLUSIONS. In review is shown that no single set of variables identifies all preferred crossing locations because every landscape, every biotope for animals and every highway is unique, identifying the best location for each mitigation project for AVC must be approached individually. For vehicle speed and traffic volume on deer–vehicle collision (DVC) rates showed no relationship between annual average daily traffic flow (AADT) and posted speed limit (PSL) or relationship is very small. For temporal patterns that

sometimes used in conjunction with the spatial patterns, or sometimes as a separate pattern have been conducted theoretical and empirical study that enough. But these results can be individual not only for individual countries but also for its territorial units too. For spatial patterns had been conducted out theoretical study that enough and for empirical study is needed to consider of spatially predictive models that use the habitat variables and landscape models with roadside habitats based on roadside characteristics. The effective mesh size have been conducted theoretical study that enough and for empirical study that not enough. For the correlation and regression analysis had been conducted theoretical study that enough and for empirical study that not enough because there are individual characteristics of landscape and biotops around of roads. For mitigation measures have been conducted theoretical that enough and empirical study that enough for implementation in the USA, Canada and European Union, but not enough for implementation in other countries. We propose to use above studies for implementation of mitigation measures of AVC on the roads in Ukraine.

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## ОПРЕДЕЛЕНИЕ МЕСТ СТОЛКНОВЕНИЯ ТРАНСПОРТНОГО СРЕДСТВА С ЖИВОТНЫМИ И ПРИНЦИПЫ ИХ СНИЖЕНИЯ НА ДОРОГАХ

(обзорная статья)

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***Ціль.*** Столкновения животных с автомобилем или дорожно-транспортные происшествие с наездом на животных- (ДТП НЖ) являются серьезным риском опасности для животных, автомобилистов и пассажиров на дорогах. Мы рассмотрели исследования, которые используют различные методы для изучения (ДТП НЖ) на дорогах. ***Методология.*** Наша статья включает в себя теоретический и эмпирический результат о идентификационного местонахождения ДТП НЖ, который разделен на такие направлениях исследований: 1.) Ограничение скорости и объема трафика; 2.) Временные структуры; 3.) Пространственные структуры; 4.) Эффективный размер сетки; 5.) Корреляционный и регрессионный анализ; 6.) Смягчающие меры. ***Результати.***Мы обнаружили, что наиболее широко представлены исследований для следующих направлений ДТП НЖ: пространственные структуры, корреляция и регрессионный анализ, и смягчающие меры. Анализ показал, что различия в масштабе ландшафта мест обитания животных коррелировали с изменениями переходов животных через автодорогу в масштабе ландшафта. Горячие точки риска ДТП НЖ обычно были связаны с топографическими особенностями, которые, направляют животных к автодороге, наличие обитания, прилегающей к шоссе, или пищевых ресурсов, которые привлекают животных. ***Практическая ценность***. Есть корреляции между количеством и пространственного распределения ДТП НЖ и распределением и популяцией видов животных.

**Ключевые слова:** смягчение столкновений животных транспортных средств, регрессия.