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RESEARCH ARTICLE

Incorporating passive use values in collision mitigation benefit-cost calculations: an application to deer and turtles in Minnesota

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Abstract
Passive use economic values for wildlife are a missing component in benefit-cost analyses informing decisions on the mitigation of wildlife-vehicle collisions through construction of wildlife crossing structures. The study describes a pilot mail survey of willingness to pay by Minnesota households for exclusionary fencing and passage structures to reduce vehicle/animal collisions in the state to protect deer and turtles. The discrete choice experiment study found strong support for fencing and passage structures, and statistically significant willingness to pay increased taxes to support their construction. A significant share of respondents had previously heard of collision avoidance structures as described in the survey (69%). A very large majority of respondents were supportive of the use of these types of structures to reduce animal/vehicle collisions (56% strongly favored and 28% favored). A large motivating factor in support for funding collision avoidance structures was concern for animal welfare.

Keywords Discrete choice · Wildlife collisions · Deer · Turtle · Willingness to pay

JEL Codes Q51 · Q57 · Q58

1 Introduction

Wildlife-vehicle collisions and the associated damage and economic costs that result impose a substantial cost on society (Huijser et al. 2009; State Farm Mutual Automobile Insurance Company 2021). Damage caused by collisions with large ungu-

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lates (deer, elk, and moose) represent substantial costs in terms of vehicle damage as well as human injury and death. In ongoing efforts to mitigate these collision-caused damages and costs, there has been significant research aimed at identifying and estimating the extent of these collision costs in recent years (see Huijser et al. 2009 for a review of this literature). In recent legislation, Congress found that in the U.S. there are more than 1,000,000 wildlife-vehicle collisions each year, costing over $8 billion. To address this challenge, Congress enacted the Wildlife Crossing Pilot Program (WCPP) with $350 million in funding to encourage design and construction of wildlife crossing structures[1]. Associated with understanding the scale and costs of the wildlife-collision problem has been research on the effectiveness, and specifically the cost-effectiveness of collision mitigation measures. While the costs of adopting or constructing collision mitigation structures is generally easily measured, estimating the benefits of successful mitigation measures is less so. Factors necessary to understand the benefits of collision mitigation include considerations of the type of animal(s) involved in collisions, average costs associated with vehicle damage, human injury and death, as well as any lost value of the animal killed. These benefit-cost estimations have been presented and discussed in generalized examples (Huijser et al. 2009), in relation to specific road sections and mitigation projects (Huijser et al. 2016), as well as presented in agency guidance on incorporating mitigation projects in new infrastructure (Ament et al. 2021).

In past studies the values associated with collision avoidance related to the injured/killed animals (as opposed to damage to vehicles or people) has been limited to easily identifiable direct use values of the animals, such as the value of the animal as hunted species. A second component of wildlife value heretofore omitted from the cost-benefit analysis of the cost-effectiveness of mitigation measures is passive use value for the animals.

There has been a proliferation of economic valuation studies of wildlife protection over the past 40 years (Martino and Kenter 2023). Specific to this study, Loomis and White (1996) provided the first aggregation of the literature on wildlife passive use values. They standardized and reported the economic value of threatened and endangered species to citizens of the U.S. based on 20 contingent valuation studies for 18 different wildlife species. Richardson and Loomis (2009) updated the earlier meta-analysis study to include studies conducted through 2001. A 2018 meta-analysis of the economic values associated with protection of threatened and endangered species expanded the set of passive use value estimates used by Richardson and Loomis (2009) by including estimates from the literature from after 2001, estimates from countries other than the U.S., and estimates including rare domestic livestock species (Amuakwa-Mensah et al. 2018). This analysis used 81 unique estimates and included U.S. and foreign studies, fish, reptiles, and terrestrial mammals.

In an extensive review of wildlife valuation studies, Martino and Kenter (2023) collected 150 studies of wildlife valuation estimated through stated and revealed

[1] "The Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act of 2021 (Pub. L. 117 – 58, November 15, 2021) authorized $350 million total in Federal-aid contract authority funding for Federal Fiscal Years (FY) 2022 through 2026 to be awarded by the U.S. Department of Transportation (DOT or the Department), through the Federal Highway Administration (FHWA), for the WCPP." https://highways.dot.gov/federal-lands/programs/wildlife-crossings.

preference methods. Of these 150 studies, 28 utilized discrete choice experiments (DCE) to estimate value. Recent examples of employing discrete choice experiments in the context of animal/ecosystem valuation include Brander et al. (2024) for valuing marine turtles, Petrolia et al. (2014) for valuing wetlands and wildlife habitat and, Phan and Chun-Hung (2022) for addressing human-elephant conflict.

A review of the current literature on the passive use value component appropriate for use in collision mitigation analyses was conducted by Duffield and Neher (2019). The prior studies of wildlife passive use value reviewed by Duffield and Neher were generally for endangered species such as wolves or threatened fish species. The authors found no prior studies where passive use values had been specifically estimated in the context of direct road mortality of wildlife. This current study takes the 2019 literature review as a starting point and develops and implements a pilot household survey designed to assess the appropriateness of utilizing DCE research to measure passive use values associated with preventing animal-vehicle collisions.

This research focuses on two specific species groups within the state of Minnesota: deer and turtles. Deer and turtles provide a potentially informative contrast in terms of passive use values. Deer-vehicle collisions cause both property damage and potentially morbidity or mortality to both deer and humans. By contrast, vehicle-turtle collisions are less likely to significantly impact cars and their drivers, but still incur morbidity/mortality for the turtles. Minnesota was identified as a state providing both widespread aquatic habitat and turtles, as well as being one of the states with the highest rates of damage from deer-vehicle collisions.

This paper expands the current economic literature by providing the first estimates of total economic loss to society (both direct and passive use losses) associated with vehicle collisions with deer and turtles in a U.S. state. In a funding environment where scarce highway construction dollars are allocated based on cost-benefit analyses, including the entire range of societal benefits associated with wildlife collision avoidance will help ensure the funding for and provision of avoidance structures are not undervalued and thus underfunded.

2 Materials and methods

Conservation and other advocacy organizations demonstrate that individuals attach an economic value to such things as preserving endangered species, open space, wild rivers, and wilderness areas. This economic value is demonstrated through the simple fact that individuals are willing to donate money to organizations working toward these goals. Some of this may be because people want the possibility of "using" the resources they are paying to help preserve through direct use activities such as hiking, hunting, or wildlife viewing. Some people, however, may never intend to make any direct use of a given resource, but still attach a value to the preservation of that resource. They may hold this value for a number of reasons: (1) they may want to preserve the resource for future generations (bequest value); (2) they may want to hold open the option to use the resource in some way in the future (option value); or (3) they may simply feel that preservation of a resource or species is the right thing to do, and thus attach a value to its existence or viability (existence value) (Krutilla

1967). The term passive use values as used in this paper includes any or all these possible motives. Direct use, conversely, includes recreational use of wildlife involving contact such as hunting or wildlife viewing.

People demonstrate their passive use value in the marketplace by contributing to organizations such as the Nature Conservancy, World Wildlife Federation, or Defenders of Wildlife. However, whether people hold existence values for resources is not contingent upon whether they donate money to support a cause. The fact that some people are willing to donate money is just the most obvious manifestation of these passive use values.

Given that passive use values exist, the problem facing economists is how to measure these values without collecting the monetary equivalent from the relevant human population. The primary technique used in the current analysis, contingent valuation, is the only direct method available to economists to measure passive use values. This method has been used in hundreds of applications in the last several decades (Carson 2012). Contingent valuation is recognized by governmental regulatory agencies such as the Department of the Interior, U.S. Fish and Wildlife Service, National Park Service, and National Oceanic and Atmospheric Administration as the appropriate tool for use in measuring passive use values (Carson et al. 2003). McFadden (1976) demonstrated how government investment actions can also be interpreted to represent welfare-maximizing choices for societal investments and thus revealing both direct and passive use values. Currently, large investments are being made in wildlife crossings in both North America and Europe demonstrating these societal priorities.[2]

2.1 Wildlife valuation concepts and methods

In the past several decades the concept of passive use value has played an ever-increasing role in decision-making on a broad range of public policy decisions and plans for use and operation of public infrastructure. Benefit-cost analysis as a field of economics was first developed in the context of water resource development. The Flood Control Act of 1916 was the first instance of a requirement that a proposed federal project must pass a benefit-cost test. In the 1950s recreation values were beginning to be utilized in benefit-cost decision making (Clawson 1959; Krutilla 1967). Passive use values began to be incorporated in this context in the early 1980s. Huijser et al. 2009 introduced the use of this tool to the application in road ecology.

Benefit-cost accounting is standard accounting framework which has its basis in applied welfare economics. In the context of incorporating direct use and passive use values associated with wildlife into the benefit cost analysis of wildlife collision mitigation spending, it is important to recognize that different species have different measures of economic value associated with their protection. Some species, such as ESA-listed small mammals, reptiles, or amphibians might have little to no identifiable direct use value but may nonetheless have passive use value associated with "existence" or "bequest" value to people living far removed from the species. Other

[2] For example, CALTRANS is currently constructing a very large crossing-the Wallis Annenberg Wildlife crossing-in California that is projected to cost $92 million. https://dot.ca.gov/caltrans-near-me/district-7/district-7-projects/d7-101-annenberg-wildlife-crossing.

species, such as game animals (deer, elk, etc.) may have direct use value as recreational prey species or in the context of direct use wildlife watching.

Incorporation of wildlife direct and passive use values within mitigation structure benefit-cost calculations requires a measure of wildlife value not generally measured and reported in the literature. Most studies of passive use values of wildlife denominate estimates of value in terms of dollars per household per year, or values aggregated over a given resident population associated with protecting a specific wildlife population. However, in terms of mitigation spending benefit-cost analysis, the most useful measure of wildlife value is in terms of per-animal, that is, per animal life saved by collision avoidance.

Value per household or total species valuation could be converted to value per individual animal through simple use of total species value divided by species population. The obvious result of this type of conversion is that species with very small populations, such as localized endangered species, could have very large per individual values while some species with widespread populations, such as deer or elk, might have comparatively small values. It is important to recognize that passive use values are not only found for existence of a given species but may also be associated with given populations. This parallels the recognition of "distinct population segments" in the Endangered Species Act. This is important for wildlife mitigation applications since a given road segment may have an impact on a local distinct population segment but a much more modest impact on the entire species.

While many different approaches can be used to estimate passive use values of a wildlife species (for example, benefit transfer or value meta-analysis), the most direct and targeted method is to design and undertake an original valuation study specific to the population or species of interest. These types of original passive use value studies have been conducted in the case of the Exxon Valdez oil spill (Carson et al. 2003), operation of Glen Canyon Dam (Duffield et al. 2016; Welsh et al. 1995), removal of dams on the Klamath river to restore salmon and steelhead runs and estimating national level losses due to the BP Deepwater Horizon oil spill (Bishop et al. 2017). The current study utilized this original targeted research method in an application of estimating passive use values for deer and turtles in MN.

2.2 Estimating household willingness-to-pay (WTP) to prevent vehicle/animal collisions

A discrete choice experiment (DCE) stated preference modeling question was included in the MN survey. The DCE model as used in this study has many advantages: (1) the payment vehicle used in the DCE questions (increased transportation taxes) are "incentive compatible" in that there is no clear incentive for the respondent to give a strategic (or false) response to the question, and (2) the question format also uses a "referendum style" presentation, asking whether people would "vote" for a program that would raise their taxes and give certain benefits. This type of structure was specifically recommended by the NOAA Blue Ribbon committee examining the validity of contingent valuation for passive use benefits (Arrow et al. 1993).

The primary question format in this study (discrete choice experiment) used stated preference (SP) data to estimate MN households' total value for potential outcomes associated with alternative collision avoidance programs. To analyze the data from the DCE questions, we applied a random utility modeling (RUM) framework, which is commonly used to model discrete choice decisions in SP studies. The RUM framework assumes that survey respondents implicitly assign utility to each choice option presented to them. This utility can be expressed as:

$$U_{ij} = V(X_{ij}, Z_i; \beta_i) + e_{ij}$$

- U_{ij} is individual i's utility for a choice option (i.e., restoration option) j.
- $V(\cdot)$ is the non-stochastic part of utility, a function of X_{ij}.
- X_{ij} represents a vector of attribute levels for the option j (including its cost) presented to the respondent.
- Z_i, a vector of personal characteristics.
- β_i, a vector of attribute-specific preference parameters.
- e_{ij} is a stochastic term, which captures elements of the choice option that affect individuals' utility but are not observable to the analyst.

On each choice occasion, respondents are assumed to select the option that provides the highest level of utility. By presenting respondents with a series of choice tasks and options with different values of X_{ij}, the resulting choices reveal information about how to identify preference combinations. There is a growing body of work that suggests that CV and choice experiments can yield valid measures of Willingness to Pay (see for example, Vossler et al. 2012 and Vossler and Evans 2009). The estimation of willingness to pay models was implemented using a maximum likelihood interval approach (Cameron and Huppert 1989; Welsh and Poe 1998).

2.2.1 Conditional logit estimation

To estimate the parameters of the DCE model, we used a standard conditional logit (CL) model (McFadden 1986), which assumes the disturbance term follows a Type I extreme-value error structure and uses maximum-likelihood methods to estimate the β_i attribute-specific preference parameters. The conditional logit is a computationally straightforward estimation approach that can provide useful insights into the general pattern of respondents' preference, trade-offs, and values. The parameter estimates from the CL model were then used to estimate the average marginal value of each non-cost attribute:

$$MWTP_k = -(\widehat{\beta}_{1k}/\widehat{\beta})$$

,where k refers to the kth element of the **X** and **β1** vectors.

3 Data collection and survey design

This study employed a random household repeat contact mail survey based on current guidance for survey research (Dillman et al. 2009), including initial cognitive interviews in the survey design phase, a pretest of the survey (200 households), and a main survey administration protocol.

In June 2021, potential respondents in a sample of 2,300 MN households drawn from a USPS address-based sample were sequentially mailed a series of survey items: (1) an initial postcard announcing the survey; (2) the full survey packet; (3) a reminder postcard to send back the survey, and (4) a final survey packet sent to non-respondents.

Based on previous household mail surveys in recent years (Duffield et al. 2016) it was anticipated that a repeat contact mail survey would yield in the range of 16% response rate. Overall, the response rate for the MN survey was 20.25%, suggesting that either MN respondents found the survey to be of greater interest than a typical household survey, or that MN households are more likely to complete mail surveys than typical US households. Perhaps a combination of these factors led to the better-than-expected response to the survey.

3.1 Survey design

The mail survey was organized into three general sections: introductory questions and information on wildlife collision avoidance structures; valuation questions; and demographic questions.

The major objective of this research was estimation of the total value (including passive use value) of deer and turtles protected from animal vehicle collisions. As noted, passive use values can only be estimated using contingent valuation survey methodology. In the case of the current research, the payment for protecting animals was framed as an annual increase in transportation taxes paid by the household. The outcomes were specific decreases in deer and turtle/vehicle collisions. The method for reducing these collisions was through funding construction of exclusionary fencing and animal over/underpasses to keep more animals off the roadways.

In terms of the goals of DCE survey design, this construction of the valuation question had many advantages. First, it uses a real program (wildlife passage and exclusion) as a method to achieve the outcomes. It also uses transportation taxes to fund those wildlife passages, which is a logical and commonplace funding source based on the “user pays” principle. In short, the valuation questions build on real life programs and funding sources to hypothesize the choice scenarios that are presented. This question construction is “incentive compatible”, or it induces the respondent to answer in a manner that is optimal in their own view. Further, it is “consequential” as there is a direct, real-life tie between costs and benefits.

The discrete choice question format asks respondents to make A/B choices between two competing scenarios. These scenarios differ in terms of “attribute levels” associated with them. For the MN survey, attributes chosen to be included were changes in deer/vehicle collisions, changes in common turtle/vehicle collisions, changes in rare or threatened turtle/vehicle collisions, and the cost associated with these changes.

Each respondent faced two choices between a status quo (no change) program and a program that had some combination of collision reductions and associated costs (Fig. 1).

The range of attribute levels included in the survey questions is shown in Table 1. Two design issues are overall sample size, and the share of the sample to allocate to each of the possible attribute level sets. Based on the number of attributes included in the discrete choice experiment questions (four) and the number of attribute levels, it was determined that an experimental design using six survey versions with two choice questions per version should adequately capture variation in response probability in a sample of 400 completed surveys. The STATA module **dcreate** was used to create an experimental design of the six survey versions. This module statistically determines the optimal sample allocation that makes the most efficient use of the overall sample and the number of attribute/attribute level combinations.

Q1. Each year in Minnesota, vehicles collide with about 40,000 deer and 100,000 turtles (including around 1,000 rare turtles). Please ask yourself whether the reduced deer and turtle collisions offered under Plan A (below) are worth the cost shown each year to your household in increased taxes for the next 10 years. Please check ONE box at the bottom of the table to indicate whether you prefer Plan A, or no expanded wildlife collision program.

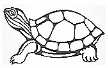
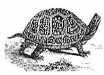
Resources impacted by plans	PLAN A Expanded Wildlife-vehicle collision reduction program	No Expanded Wildlife-vehicle collision reduction program
Change in Minnesota Deer-vehicle collisions 	50% decrease in collisions	No change
Change in vehicle collisions with COMMON TURTLE SPECIES 	10% decrease in collisions	No change
Change in vehicle collisions with RARE OR THREATENED TURTLE SPECIES 	10% decrease in collisions	No Change
Cost to your household in increased tax DOLLARS PER YEAR 	$60	$0
I would vote for (check only one ✓)	❑	❑

Fig. 1 Example discrete choice experiment question format

Table 1 Different attribute levels used in Experimental Design

Discrete Choice Experiment Question Attribute	Attribute Levels
Change in Deer-Vehicle Collisions	No change 10% decrease 50% decrease
Change in Common Turtle-Vehicle Collisions	No change 10% decrease 50% decrease
Change in Rare & Threatened Turtle-Vehicle Collisions	No change 10% decrease 50% decrease
Increase in Annual Household Transportation Taxes	$6 $20 $60 $120

4 Results

The core of the survey consisted of explanatory material and associated DCE valuation questions. The survey also asked attitude and reasoning questions to help understand the discrete choice responses. Finally, the survey asked standard demographic questions to help understand how representative the sample of respondents was compared to the overall MN population.

Survey respondents were initially asked a series of questions to gauge their level of experience both with driving and with previously having hit an animal while ether driving or riding in a car. The vast majority (96.72%) of respondents said that they personally drive a vehicle, with 74% saying they drive every day.

Significant percentages of respondents also reported being in a vehicle that had struck an animal. The largest percentage of respondents said they were in a vehicle that hit a deer (52%). The other species of particular concern to this study (turtles) showed 17% reporting hitting them with a vehicle. Other notable species reported to be frequently hit were birds (64%), raccoons (26%) and skunks (25%).

Regarding the 52% reporting being in a vehicle that hit a deer, it is of interest to look at other available data to determine if this sample overrepresents people who have been in a deer collision. Each year, State Farm Insurance reports annual probability of a driver hitting a deer (or other animals). In 2017 Minnesota drivers were estimated to have a 1 in 77 chance of hitting a deer. The average age of respondents to the current survey was 59.7. If we assume that the 1 in 77 chance of a deer collision has held steady over the past 40 years in MN, and assume the average driver in the respondent sample has been driving for 40 years (since they were 20) then the odds over those 40 years would be 1 in 1.93 or 52%--exactly the percent reporting being in a deer collision. Based on this average event, back-of-the-envelope calculation, it does not appear that the survey respondents have an "avidity bias" related to experience with vehicle/deer collisions.

The primary focus of the MN survey measured support for and specifically, willingness to pay for collision avoidance structures designed to reduce vehicle/ animal collisions. Three primary types of avoidance structures were described in the survey: overpasses, underpasses, and fencing and culverts (Fig. 2).

WAYS ROAD DESIGNERS TRY TO REDUCE THE NUMBER OF ANIMAL-VEHICLE COLLISIONS

Wildlife experts and road designers have found several methods that significantly reduce the number of wildlife-car collisions and that allow wildlife to safely get to the other side of the road. Below are three commonly used and effective methods.

OVERPASSES

Wildlife overpasses, with fencing to direct wildlife to the overpass, can provide a crossing that includes natural vegetation and is inviting to deer and other animals.

BRIDGE UNDERPASSES

Wildlife bridge underpasses with accessible shoreline when combined with fencing can be simpler and less expensive to build, but still provide very useful routes for animals to avoid crossing busy roads.

FENCING & CULVERTS

Road fencing which guides small animals such as turtles away from unsafe crossing locations and towards culverts can be cost-effective methods to reduce wildlife-vehicle collisions and provide passage across roadways.

Fig. 2 Survey descriptions of collision avoidance structures

Respondents were generally familiar with the described wildlife overpasses, underpasses, fencing and culverts, with 68.83% saying they had heard of these types of structures before, and with 53.44% saying they had seen or were aware of any of these types of structures in Minnesota. Respondents were strongly in favor of these types of structures, with 86% saying they either strongly favored or somewhat favored them.

4.1 Collision prevention program valuation modeling results

Much of the MN survey was dedicated to (1) describing the problem of vehicle/animal collisions in the state, (2) describing collision avoidance structures and their use, and (3) describing a potential program to fund and construct collision prevention structures such as exclusionary fencing, and road over and underpasses. These descriptions were followed by two DCE questions (Fig. 1). The data from the DCE question responses were analyzed and modeled using the STATA statistical module **clogit** (StataCorp 2017). The modeling results from the full set of responses are shown in Table 2.

The conditional logit modeling results show a generally well-fitting model of WTP with highly significant explanatory coefficients estimated for protecting deer, rare turtles, and for the cost variable. Additionally, all estimated coefficients had the expected signs. Protecting all three listed species had positive signs, indicating that protecting a higher percentage of the species from collisions was associated with a higher level of willingness to pay for collision prevention. Additionally, the cost variable had the expected negative sign, indicating that as the cost increased, the chances that the person would pay that cost decreased. This result indicates that the survey responses were consistent with economic theory.

Utilizing the estimated parameters from the conditional logit model (Table 2) to derive marginal WTP values is a straightforward calculation. The marginal value of preservation of any of the species in the model can be calculated as their estimated coefficient divided by the coefficient for cost times negative one, or $P_{species} = -(\widehat{\beta}_{species}/\widehat{\beta}_{cost})$.

The changes in vehicle/animal collisions were denominated in percentage reductions in collisions in the DCE questions. Therefore, the ratio of the estimated coefficients for deer (0.0198) divided by the coefficient for cost (-0.0049) results in a WTP value of $4.00 per household for a 1% reduction in deer/vehicle collisions in MN. Table 3 shows the estimated WTP values for a 1% reduction in collisions with deer, common turtles, and rare/

Table 2 Estimated conditional Logit Model of WTP for Animal/Vehicle collision avoidance

Choice	Coefficient	Robust Standard Error	z	*P*>|z|	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Deer	0.0198	0.0033	6.06	0.000	0.0134	0.0262
Common Turtles	0.0039	0.0033	1.21	0.225	-0.0024	0.0103
Rare orThreatened Turtles	0.0113	0.0033	3.44	0.001	0.0049	0.0177
Cost per household per year	-0.0049	0.0015	-3.28	0.001	-0.0079	-0.0020

N=1824, Wald chi^2(4)=69.59, Prob>chi^2=0.0000, Log pseudolikelihood = -585.45476, Pseudo R^2=0.0739

Table 3 Estimated WTP values for collision avoidance: by species

Impacted species	WTP per household for a 1% reduction in collisions	Standard Error[1]	WTP Lower 95% Confidence Interval	WTP Upper 95% Confidence Interval
Deer	$4.00	0.997***	$2.05	$5.96
Common Turtle	$0.80	0.63	$ 0	$2.04
Rare or Threatened Turtle	$2.29	0.951**	$0.42	$4.16

[1] ** indicates estimate is statistically significant at the 95% level of confidence; *** indicates 99% level of significance

threatened turtles. While the estimate for common turtles is not statistically significant, the point estimate ($0.80) is substantially less than the estimated value for rare/threatened turtles ($2.29). This is consistent with the concept of the marginal value associated with scarcity. It should be noted that while the estimates of $4.00 and $2.29 per household for a 1% reduction in deer and turtle collisions, respectively are highly statistically significant, a 2-tailed t-test shows that these means are not statistically different at a 95% level of confidence (p=0.215).

Additional permutations of the conditional logit model of WTP were estimated to test the robustness of the results and the consistency of values associated with subgroups. WTP values were estimated both for those respondents who had reported being in a vehicle that had hit an animal, and those who said they had not been in such a collision. These modeling results were consistent with expectations. Those who had been in animal/vehicle collisions valued preventing those collisions more highly than did those who had not been in an animal/vehicle collision.

An additional test was conducted to see if modeling results were significantly changed if those survey respondents who indicated they were “not at all certain” about their answers to the DC questions were excluded from the analysis. This exclusion did not substantially change the results.

Conversion of these results to “per household per animal” values entails dividing the per household value ($4.00 for a 1% decrease in collisions with deer) by the number of deer collisions avoided (1% of 40,000 annual collisions is 400 deer protected). Therefore, the value per deer protected per household implied by the DC model is $0.01 (Table 4).

Table 4 Estimated WTP values per animal, per household

Question format/Impacted Species	WTP	Number of animal collisions avoided	WTP per animal/ house-hold
WTP Estimates from Discrete Choice Experiment Model Responses			
DEER	$ 4.01	400	$ 0.010
TURTLES	$ 0.80	1,000	$ 0.001
RARE TURTLES	$ 2.29	10	$ 0.229
WEIGHTED COMBINED COMMON AND RARE TURTLES		1,010	$ 0.003

For common turtles this value is \$0.001, and for rare/threatened turtles \$0.229. The implied combined value for both common and rare/threatened turtles is \$0.003 per turtle per household.

4.2 Aggregating WTP across households

In theory, the process of aggregating estimated values per animal protected from a vehicle/animal collision to statewide (MN) values involves simply multiplying the estimated value per animal per household times the number of households in the state. This straight-ahead method assumes that those randomly selected households that did not respond to the survey have the same opinions and values as those who did complete and return the survey. One way to test the plausibility of this assumption is to compare selected information collected from the sample respondents to information for the entire state as collected by the US Census in their Annual Community Survey.

These comparisons showed some clear differences between the survey respondents and the entire MN statewide population. The survey sample is more male (55.9% vs. 49.3% for the US Census), significantly more Caucasian (96.5% vs. 63.8% for the US Census), and more highly educated (56% with a college degree or above vs. 35% for the US Census) than is the average Minnesota resident.

In terms of income levels, the current survey respondents have generally higher incomes on average than the average MN household (38.8% vs. 27.8% for the US Census reporting household incomes over \$100K).

One method of adjusting or correcting for these differences in the survey sample and the entire MN population would be to reweight the survey observations to align with their proportions in the population (for example, place higher weights on non-white respondents, or lower weights on high income individuals). This method was explored for the sample, but very small numbers of respondents in some underrepresented groups made the re-estimation of weighted models unstable, and unreliable.

As an alternative, a robust and extremely conservative adjustment is to make the assumption that those not returning a survey place a zero value on the collision avoidance program (Haefele et al. 2016). Thus, total statewide estimated values per animal protected were multiplied by 0.2024 (our response rate) and assumed zero benefits for the 79% of households who chose not to respond to the survey after multiple mailings. It should be noted there is no evidence non-respondents to the survey truly have a "zero" value for collision avoidance programs. Therefore, use of the assumption of a zero value for non-respondents in the current study provides a very conservative estimate of total value.

Based on this study of total value associated with preventing deer and turtle deaths through collision avoidance structures in MN, the estimated conservative value of an avoided deer collision is \$4,135, and the estimated value of an avoided turtle/vehicle collision is \$1,260.

4.3 Attitudinal question responses

Following the DCE valuation questions, several survey questions probed respondents' motivations for the way they answered the DCE questions. Immediately following the second DCE question respondents were asked "how certain do you feel about your choices in Q7 and Q8 above?" This "certainty" question is often asked to test whether the responses of those who were less certain in their responses significantly bias the survey results. As noted, excluding those who responded that they were "not at all certain" about their responses had no substantial impact on the DC modeling results. This is as expected from the observed distribution of responses to this question, where 94% of respondents said they were either "very certain" (53%) or "somewhat certain" (41%).

Additional attitude questions probed reasons for either supporting or opposing the collision mitigation programs in the DC questions. Among those who voted "not to expand" the wildlife-vehicle collision reduction program in either of the DC questions, 64% said they did so "because I believe my taxes are already too high."

A question for those who voted to support the expanded wildlife-vehicle collision reduction program in either of the two DC questions asked for their level of agreement with two statements regarding motivations (Fig. 3). Interestingly, a higher percentage of respondents indicated they were more motivated to support the program due to concern for animals (81% either agreed or strongly agreed) than due to concern for protecting themselves or their families from collisions (72% either agreed or strongly agreed).

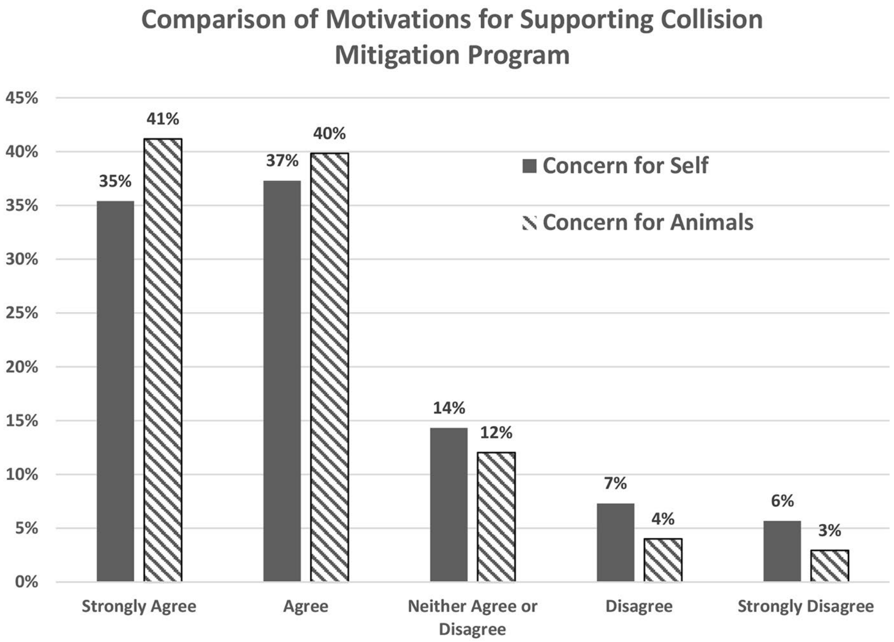


Fig. 3 Comparison of motivations for supporting collision mitigation program

In responding to a set of four statements on wildlife and wildlife protection, overall, respondents expressed a strong level of agreement with motives concerning protection of wildlife and concern about wildlife being hit in road collisions. This is consistent with the substantial values estimated for protecting deer and turtles in MN from collisions.

4.4 Passive use values in the context of mitigation analysis

Huijser et al. 2009 provide a detailed description of the analytic framework needed to utilize estimated costs and benefits within a breakeven analysis intended to provide a decision framework for choosing and funding potential collision mitigation measures/structures. The Huijser article also provides data and estimates on the benefits (avoided costs) associated with avoided direct collision costs. They estimated the average deer/vehicle collision had a direct cost in 2007 dollars of $6,617 associated with vehicle damage, injury/death, and loss/removal of the animal. In our survey year dollars (June 2021) this inflation-adjusted estimate is $8,546 per deer collision.

The direct collision costs estimated and reported by Huijser of $8,546 (2021 $) notably exclude any nonuse or passive-use values for deer. The primary motivation for the current research was to provide an empirically based estimate for this missing benefit component associated with prevention of animal/vehicle collisions.

Estimates for passive use protection value per MN deer was $4,135 for the DCE valuation model. This is a generally separate category of value from the collision costs by Huijser et al. and is to a large degree additive to their estimates. An exception to this additivity might be the argument that the hunting value per animal is included in the passive use value estimate, or that the collision costs weighted by the very low probability of a deer/vehicle collision might be duplicative. However, these costs would likely represent a very small share of direct collision costs.

This result is also consistent with statistics showing that the odds of a driver in MN hitting a deer in a given year are in the range of around 1:77 or 1.3%. Based on this, and given the uncertainty associated with the passive use estimates, we conclude that there is very little overlap between the direct cost and passive cost estimates. Therefore, a preliminary estimate of the complete benefits (direct collision costs plus passive use costs) of an avoided deer/vehicle collision in MN is $8,546 + $4,135 = $12,681. For this estimate, direct collision costs account for 68% of the loss of a deer collision and passive use values account for 32%.

In the case of vehicle/turtle collisions, direct costs are generally low to zero. Therefore, the estimate of passive use values from this study ($1,260) represents the loss to MN from such collisions.

5 Discussion and conclusions

Overall, the current pilot study was successful in estimating a heretofore missing component of value associated with prevention of wildlife-vehicle collisions–passive use values associated with protecting species from collisions. Previous cost-benefit analyses of potential construction of collision avoidance structures that lacked consideration of these passive use values of animal protection likely under-valued the benefits of avoidance structures. While this research was successful in reaching the goals of the study design, like any study, there remain limitations to the interpretation and broad application of the study results. One limitation concerns the possibility of non-response bias in the survey results. As noted, to compensate for potential bias, the analysis adopted the very conservative assumption that all nonrespondents had a zero WTP to fund collision avoidance structures.

The discrete choice experiment model questions in the survey included attributes for both common turtles and rare/threatened turtles. While the rare/threatened turtle estimated coefficient was statistically significant and was larger than the not-significant coefficient for common turtles (as expected), the lack of a significant estimate for protecting common turtles raises questions. It may be the case that the design of the range of attribute levels for common turtle protection (10% reduction to 50% reduction) did not sufficiently capture the economic tradeoffs households are willing to make to protect these species. However, it also may be that inclusion of two groups of turtle species in the same question format posed a difficult cognitive burden on respondents to parse their concern for the two groups. In any event, any reliance on WTP estimate for common turtles from the DCE model should recognize the lack of statistical significance of those estimates.

While the survey and associated analysis was largely successful in developing and implementing procedures appropriate for estimating individual animal values which can be used as an input to benefit-cost decision-making in prioritizing collision avoidance structure funding, one clear improvement on this research would be to include a follow up non-response survey which would allow weighting of responses and the use of a less conservative approach to non-response bias correction than that used in the current analysis. Additionally, a larger sample size than employed in the current study could result in more precise WTP estimates. Another benefit of a larger sample would be the higher likelihood that more complex models which account for respondent heterogeneity could be successfully estimated to further explore value differences across individuals or groups.[3]

Another conservative aspect of the deer and turtle estimates is related to the nature of collision avoidance structures. An overpass or underpass/culvert with associated exclusionary fencing is agnostic to which species use it. In addition to deer or turtles, numerous other species likely would make use of the structures and consequently have a lower likelihood of being involved in a vehicle collision. Since the valuation questions only explicitly valued deer and turtles, these values are likely underestimates of the passive values associated with protection of all species who benefit from the structures.

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[3] Both mixed logit specifications and latent class discrete choice models were explored but failed to converge given the available sample sizes of this pilot study. However, the conditional logit specification provides average parameters that while obscuring preference heterogeneity across respondents, is appropriate for the stated purpose of estimating average passive use values for the population.

ity Task 1 – Cost Effective Solutions Transportation Pooled-Fund Project TPF-5(358) (Administered by: Nevada Department of Transportation).

Data availability The underlying survey data was gathered from randomly chosen human subjects.

Declarations

Ethics approval These participants were informed that completion of the survey and any questions within it was entirely on a voluntary basis.

Conflict of interest The authors declare they have no actual or potential conflicts of interest related to this research.

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