Update and expansion of the WVC mitigation measures and their cost-benefit model.

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Costs mitigation measures

Expensive!?

Balance costs vs. benefits!!!

Cost-benefit analyses

- Costs:

  Equipment, installation, construction, operation, maintenance, removal

- Benefits:

  Reduced costs collisions

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Research, part of a Special Feature on Effects of Roads and Traffic on Wildlife Populations and Landscape Function

Cost–Benefit Analyses of Mitigation Measures Aimed at Reducing Collisions with Large Ungulates in the United States and Canada: a Decision Support Tool

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ABSTRACT. Wildlife–vehicle collisions, especially with deer (*Odocoileus* spp.), elk (*Cervus elaphus*), and moose (*Alces alces*) are numerous and have shown an increasing trend over the last several decades in the United States and Canada. We calculated the costs associated with the average deer–, elk–, and moose–vehicle collision, including vehicle repair costs, human injuries and fatalities, towing, accident attendance and investigation, monetary value to hunters of the animal killed in the collision, and cost of disposal of the animal carcass. In addition, we reviewed the effectiveness and costs of 13 mitigation measures considered effective in reducing collisions with large ungulates. We conducted cost–benefit analyses over a 75-year period using discount rates of 1%, 3%, and 7% to identify the threshold values (in 2007 U.S. dollars) above which individual mitigation measures start generating benefits in excess of costs. These threshold values were translated into the number of deer–, elk–, or moose–vehicle collisions that need to occur per kilometer per year for a mitigation measure to start generating economic benefits in excess of costs. In addition, we calculated the costs associated with large ungulate–vehicle collisions on 10 road sections throughout the United States and Canada and compared these to the threshold values. Finally, we conducted a more detailed cost analysis for one of these road sections to illustrate that even though the average costs for large ungulate–vehicle collisions per kilometer per year may not meet the thresholds of many of the mitigation measures, specific locations on a road section can still exceed thresholds. We believe the cost–benefit model presented in this paper can be a valuable decision support tool for determining mitigation measures to reduce ungulate–vehicle collisions.

Key Words: *animal–vehicle collisions; cost–benefit analysis; deer; economic; effectiveness; elk; human injuries and fatalities; mitigation measures; moose; roadkill; ungulate; vehicle repair cost; wildlife–vehicle collision*

INTRODUCTION

Wildlife–vehicle collisions affect human safety, property and wildlife. The total number of large mammal–vehicle collisions has been estimated at one to two million in the United States and at 45 000 in Canada annually (Conover et al. 1995, Tardif and Associates Inc. 2003, Huijser et al. 2007b). These numbers have increased even further over the last decade (Tardif and Associates Inc. 2003, Huijser et al. 2007b). In the United States, these collisions were estimated to cause 211 human fatalities, 29 000 human injuries and over one billion US dollars in property damage annually (Conover et al. 1995). In most cases, the animals die immediately or shortly after the collision (Allen and McCullough 1976). In some cases, it is not just the individual animals that suffer. Road mortality may also affect some species on the population level (e. g., van der Zee et al. 1992, Huijser and Bergers 2000), and some species may even be faced with a serious reduction in population survival probability as a result of road mortality, habitat fragmentation, and other negative effects associated with roads and traffic (Proctor 2003, Huijser et al. 2007b). In addition, some species also represent a monetary value that is lost once an individual animal dies (Romin and Bissonette 1996, Conover 1997).

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Huijser et al., 2009, Ecology & Society

Benefits: Costs of collisions (in 2007 US$)

Description	Deer	Elk	Moose
Vehicle repair costs per collision	$2,622	$4,550	$5,600
Human injuries per collision	$2,702	$5,403	$10,807
Human fatalities per collision	$1,002	$6,683	$13,366
Towing, accident attendance and investigation	$125	$375	$500
Hunting value animal per collision	$116	$397	$387
Carcass removal and disposal per collision	$50	$75	$100
Total	$6,617	$17,483	$30,760

Huijser et al., 2009, Ecology & Society

Costs mitigation measures

Table 1. The estimated effectiveness, present value costs (in 2007 US$, 3% discount rate), and costs per percent reduction of mitigation measures aimed at reducing collisions with large ungulates over a 75-year time period. The measures are ordered based on their estimated effectiveness. If a measure is estimated to be 86% effective, it means that ungulate–vehicle collisions are estimated to reduce by 86% as a result of the implementation of that mitigation measure (e.g., a reduction from 100 collisions to 14 collisions).

Mitigation measure	Effectiveness	Crossing opportunity?	Source	Present value costs (US$)	Costs per percent reduction (US$)
Seasonal wildlife warning sign	26%	Yes	Sullivan et al. (2004): 51%; Rogers (2004): 0%	$3728	$143
Vegetation removal	38%	Yes	Jaren et al. (1991): 56%; Lavsund and Sandegren (1991): 20%	$16 272	$428
Fence, gap, crosswalk	40%	Yes	Lehnert and Bissonette (1997): 42%, 37%	$300 468	$7512
Population culling	50%	Yes	Review in Huijser et al. (2007a)	$94 809	$1896
Relocation	50%	Yes	Review in Huijser et al. (2007a)	$391 870	$7837
Anti-fertility treatment	50%	Yes	Review in Huijser et al. (2007a)	$2 183 207	$43 664
Fence (incl. dig barrier)	86%	No	Reed et al. (1982) 79%; Ward (1982): 90% Woods (1990): 94%–97%; Clevenger et al. (2001): 80%; Dodd et al. (2007): 87%	$187 246	$2177
Fence, underpass, jump-out	86%	Yes	Reed et al. (1982) 79%; Ward (1982): 90% Woods (1990): 94%–97%; Clevenger et al. (2001): 80%; Dodd et al. (2007): 87%	$538 273	$6259
Fence, under- and overpass, jump-out	86%	Yes	Reed et al. (1982) 79%; Ward (1982): 90% Woods (1990): 94%–97%; Clevenger et al. (2001): 80%; Dodd et al. (2007): 87%	$719 667	$8368
Animal detection system (ADS)	87%	Yes	Mosler-Berger and Romer (2003): 82%; Dodd and Gagnon (2008): 91%	$1 099 370	$12 636
Fence, gap, ADS	87%	Yes	Mosler-Berger and Romer (2003): 82%; Dodd and Gagnon (2008): 91%	$836 113	$9610
Elevated roadway	100%	Yes	Review in Huijser et al. (2007a)	$92 355 498	$923 555
Road tunnel	100%	Yes	Review in Huijser et al. (2007a)	$147 954 696	$1 479 547

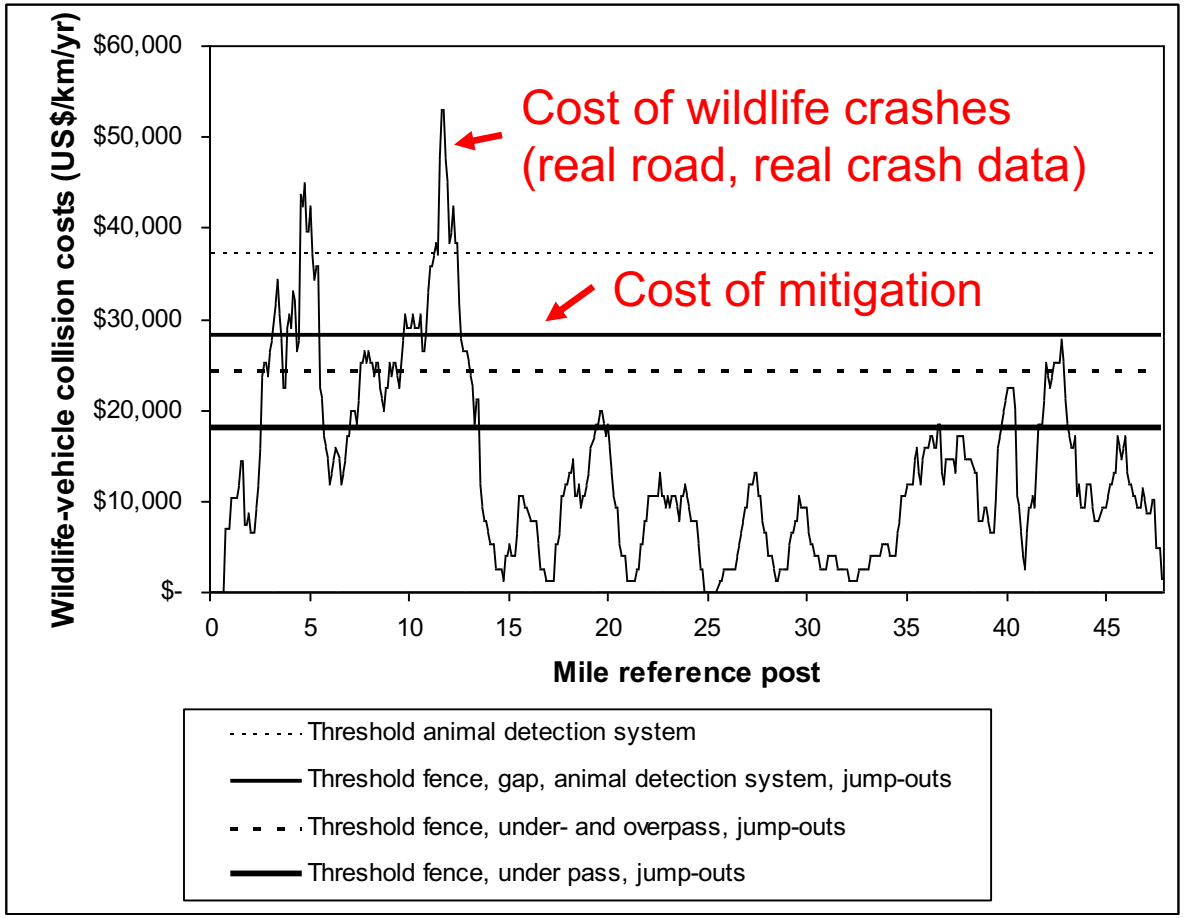
Huijser et al., 2009, Ecology & Society

Cost-benefit analyses

- 75 year long period
- Discount rate:

  1%, 3%, 7%

Example road section
MT Hwy 83, Seeley-Swan Montana



Not (yet) included:
Costs and benefits
Biological Conservation

Huijser et al., 2009, Ecology & Society

Update (in 2020 US$)

Table 5: Total costs associated with large wild ungulate-vehicle collisions (in 2020 US$).

	Costs per collision							
Cost category	Deer	Elk	Moose	Gray wolf	Grizzly bear	Cattle	Horse	Burro
Direct costs								
Vehicle repair	$4,418	$7,666	$9,435	$4,418	$4,418	$9,435	$9,435	$7,666
Human injuries	$6,116	$14,579	$26,811	$6,116	$6,116	$26,811	$26,811	$14,579
Human fatalities	$3,480	$23,200	$46,400	$3,480	$3,480	$46,400	$46,400	$23,200
Sub total	$14,014	$45,445	$82,646	$14,014	$14,014	$82,646	$82,646	$45,445
Passive use value	$5,075	$27,751	$27,751	$40,342	$4,235,770	?	?	?
Total	$19,089	$73,196	$110,397	$54,356	$4,249,784	$82,646	$82,646	$45,445

$6,617 in 2007

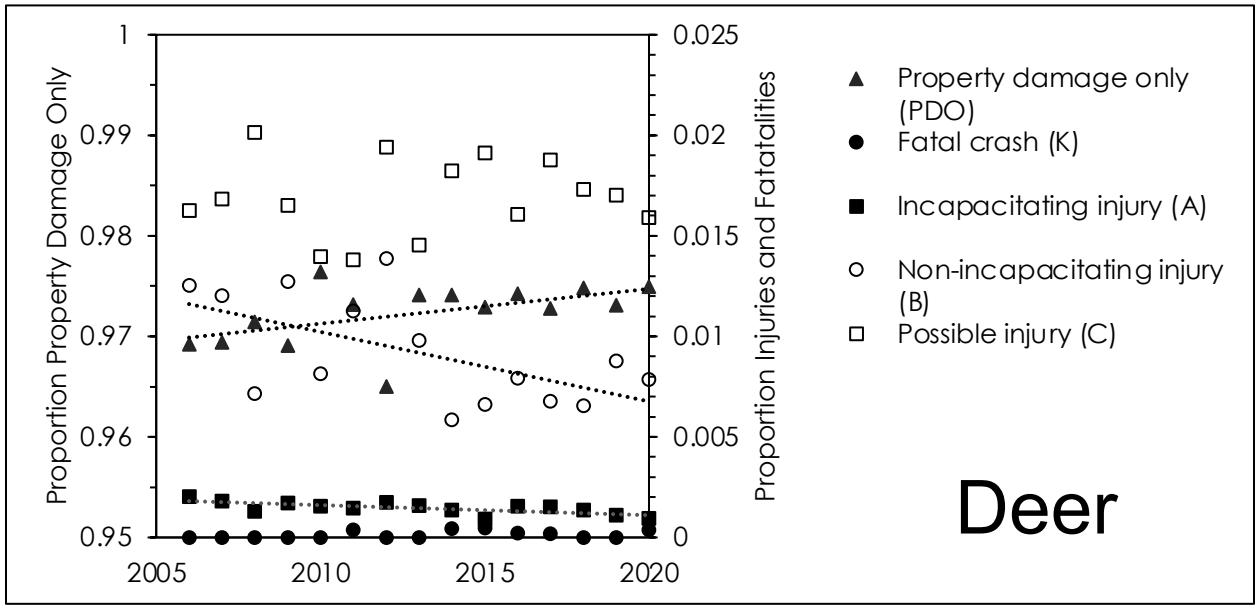
The direct costs associated with vehicle repair, human injuries and human fatalities increased by a factor 2.12 (for deer), 2.60 (for elk) and 2.69 (for moose), compared to the 2007 values (Huijser et al. 2009). When the passive use values are included, these factors increase to 2.88 (for deer), 4.19 (for elk) and 3.59 (for moose), compared to the 2007 values (Huijser et al. 2009).

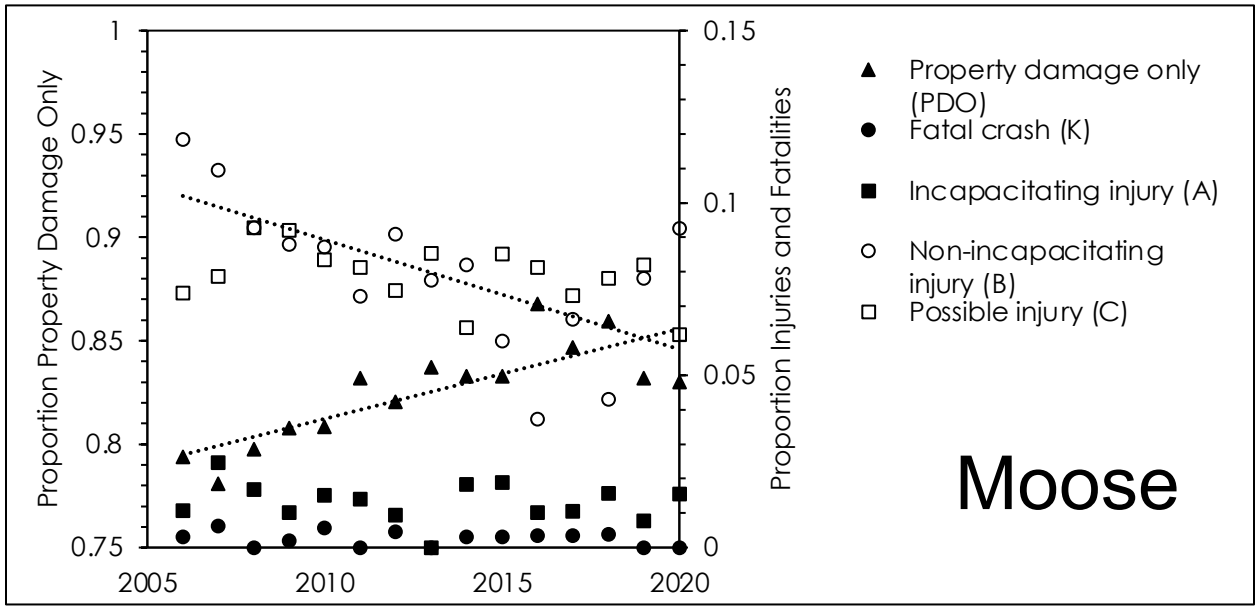
Getting safer?

Proportion

- Human injuries decrease
- Property damage only increase

- It is getting significantly safer!
- But in very small proportions (not substantial)





Cost of Fences and Crossing Structures (in 2020 US$)

Table 7: Estimated construction costs for large mammal fences and different types and dimensions of wildlife crossing structures (in US$ 2020). Bissonette & Hammer 2000; Huijser et al. 2009; 2016a; Arizona Daily Star 2015; Clevenger & Huijser 2021; Pers. com. Pat Basting and Joe Weigand, Montana Department of Transportation; Jeff Gagnon, Arizona Game and Fish Department; Terry McGuire, McGuire Consulting; Greg Schonert, North Dakota Department of Transportation; Nova Simpson, Nevada Department of Transportation. The dimensions are from the animal's perspective, e.g. width = the road length covered by the structure, height = the height between the ground and the ceiling of an underpass, length = the distance that animals travel through or on top of the structure to reach the other side of the road (i.e. the width of the road).

Structure type	Mean	SD	Median	Minimum	Maximum	N
Fence, 2.4-2.7 m tall, no apron, for 1 km on both sides rd	$91,064	$20,651	$98,869	$67,648	$106,675	3
Fence, 2.4-2.7 m tall, with apron, for 1 km on both sides rd	$169,667	$25,334	$170,231	$139,792	$198,415	4
Jump-out	$10,124	$5,946	$8,130	$5,432	$16,811	3
Metal culvert, width 1.8-2.4 m, height 1.2-2.4 m, length 29-40 m	$134,862	$41,401	$125,670	$96,753	$191,355	4
Box culvert, width 1.2-2.4 m, height 1.2-2.4 m	$102,895	$22,651	$102,824	$75,942	$139,879	6
Box culvert, width 3.6 m, height 2.4 m, length 24-52 m	$485,105	$109,586	$461,192	$389,451	$604,673	3
Box culvert, width 6.1 m, height 4.0 m, length 30 m	$1,067,257	$45,894	$1,040,760	$1,040,760	$1,120,250	3
Underpass, width 7.0-8.5 m, 3.7-5.6 m high, length 15-52 m	$485,444	$159,899	$474,021	$253,679	$983,875	24
Bridge, width 14-30 m, length 14-40 m	$1,403,804	$1,174,429	$953,324	$181,402	$3,074,610	7
Bridge, width 100-120 m, length 12-17 m	$3,092,367	$904,394	$3,092,367	$2,452,864	$3,731,870	2
Overpass, 15-30 m wide, length about 70 m	$1,740,852	$327,960	$1,904,832	$1,248,912	$1,904,832	4
Overpass, 50-60 m wide, length 63-123 m	$4,273,104	$1,577,583	$4,973,694	$2,243,730	$6,559,168	8

Thresholds

Much lower than in 2007!

3.2 in 2007

Very low threshold

Table 9: Threshold values for the 4 different types and combinations of mitigation measures (costs in 2020 US$).

Threshold values	Discount rate	Fence (no apron)	Fence (apron)	Fence (apron), underpass, jump-outs	Fence (apron), under- and overpass, jump-outs
US$/km/yr	1%	$6,230	$9,470	$18,499	$21,834
US$/km/yr	3%	$7,460	$11,558	$25,388	$32,030
US$/km/yr	7%	$10,496	$16,620	$43,009	$56,900
Deer/km/yr	1%	0.379	0.577	1.127	1.330
Deer/km/yr	3%	0.454	0.704	1.546	1.951
Deer/km/yr	7%	0.639	1.012	2.620	3.466
Elk/km/yr	1%	0.099	0.150	0.294	0.347
Elk/km/yr	3%	0.119	0.184	0.403	0.509
Elk/km/yr	7%	0.167	0.264	0.683	0.904
Moose/km/yr	1%	0.066	0.100	0.195	0.230
Moose/km/yr	3%	0.079	0.122	0.267	0.337
Moose/km/yr	7%	0.111	0.175	0.453	0.599
Grizzly bear/km/yr	1%	0.002	0.003	0.005	0.006
Grizzly bear/km/yr	3%	0.002	0.003	0.007	0.009
Grizzly bear/km/yr	7%	0.003	0.005	0.012	0.016

Grizzly bear US Hwy 93 N

- About 22 km road length St. Ignatius - Ronan
- Grizzly bear mortality 0-2, extreme 6
- Assume: 1 grizzly bear hit / year
- 0.045 grizzly bear hit / km / year
- 5 times higher than the 0.009 threshold!!!

… which suggests that multiple large wildlife crossing structures (e.g. bridges and overpasses) are economically defensible based on not hitting grizzly bears alone

Opportunity & Optimism

Human safety

Economic sense

Biological conservation

Adapting for Climate change

Recreation

Physical and mental health