Safety Impact of Concrete and Cable Barriers on Rural Interstates

Presented by

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Primary Sources

- Villwock, N.M., Blond, N., Tarko, A. (2008). *Risk Assessment of Various Median Treatments of Rural Interstates*, Joint Transportation Research Program, SPR-2950. (http://rebar.ecn.purdue.edu/JTRP/)
- Tarko, A.P., Villwock, N.M., Blond, N. (2008). The Effect of Median Design on Rural Freeway Safety – Flush Medians with Concrete Barriers with Depressed Medians. *Transportation Research Record*, No. 2060, pp.29-37.
- Villwock, N.M, N. Blond, and A. Tarko (2010). Cable Barriers and Traffic Safety on Rural Interstates. *ASCE Journal of Transportation Engineering* (under review).

Background

Median barriers are considered effective safety countermeasures that eliminate head-on collisions.

Concrete barriers are traditionally used in narrow medians and low-tension cable barriers in wider medians.

High-tension cable barriers are an emerging new type of protection.

Many USA rural freeways require or will require soon widening. Utilizing part of the medians for new lanes will increase the use of median barriers.

Or rather expensive widening the right-of-way should be preferred to avoid narrowing medians?

The overall safety effect of various median treatments is largely unknown, thus a benefit-cost based selection of median solutions is not possible today.

Project Objectives

- Estimate the relationships between various median designs and the collision frequency/severity

- Gain more knowledge on safety impacts of selected median treatments

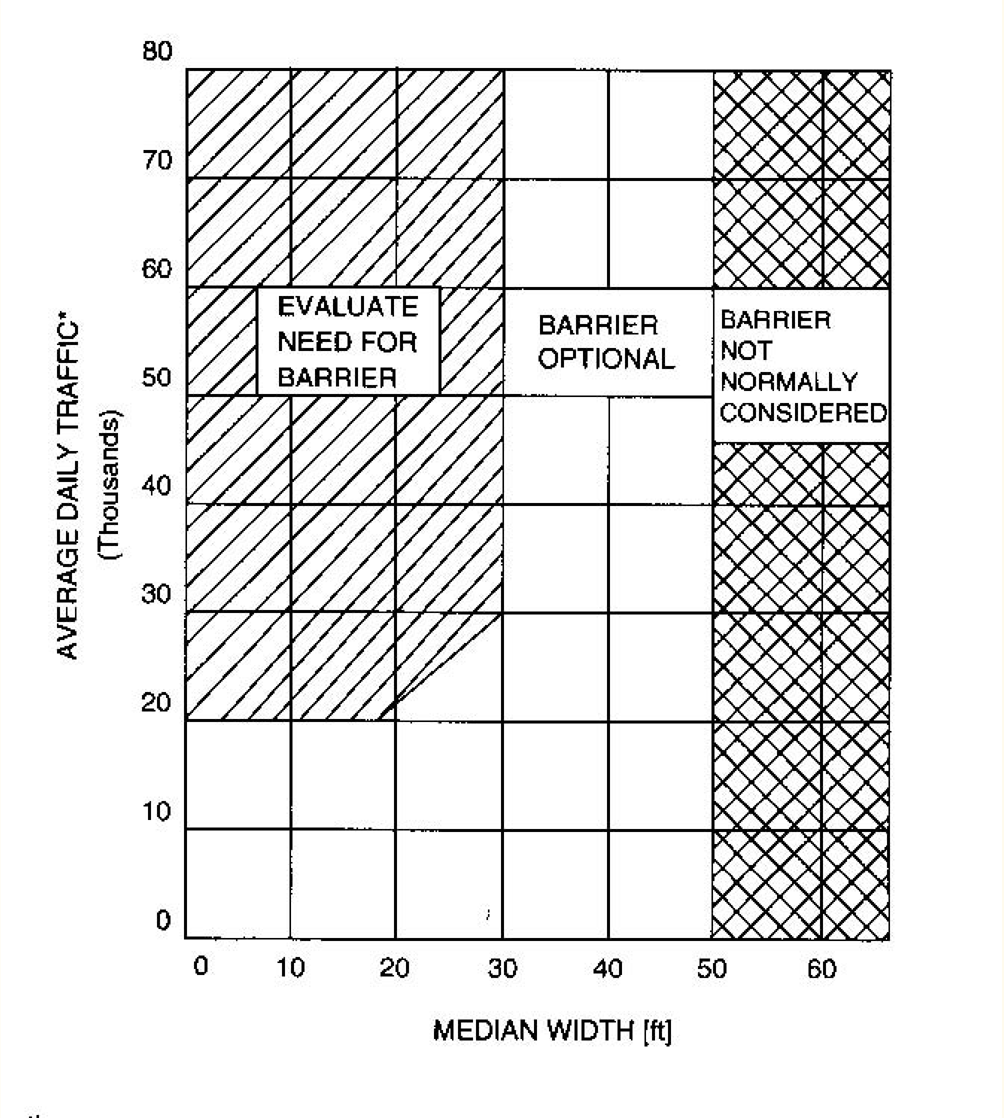
- Develop tools useful for planner and designers who consider alternative solutions for existing and modernized rural interstates

Literature Study Conclusions

- Wider medians (no barriers) reduce cross-over crashes but this reduction is rather weak
- Barriers almost eliminate cross-over crashes
- Barriers increase total number of crashes by reduce severity
- Cable barriers need to be installed carefully (under-riding and over-riding)

AASHTO Guidelines

(AASHTO, 2002)



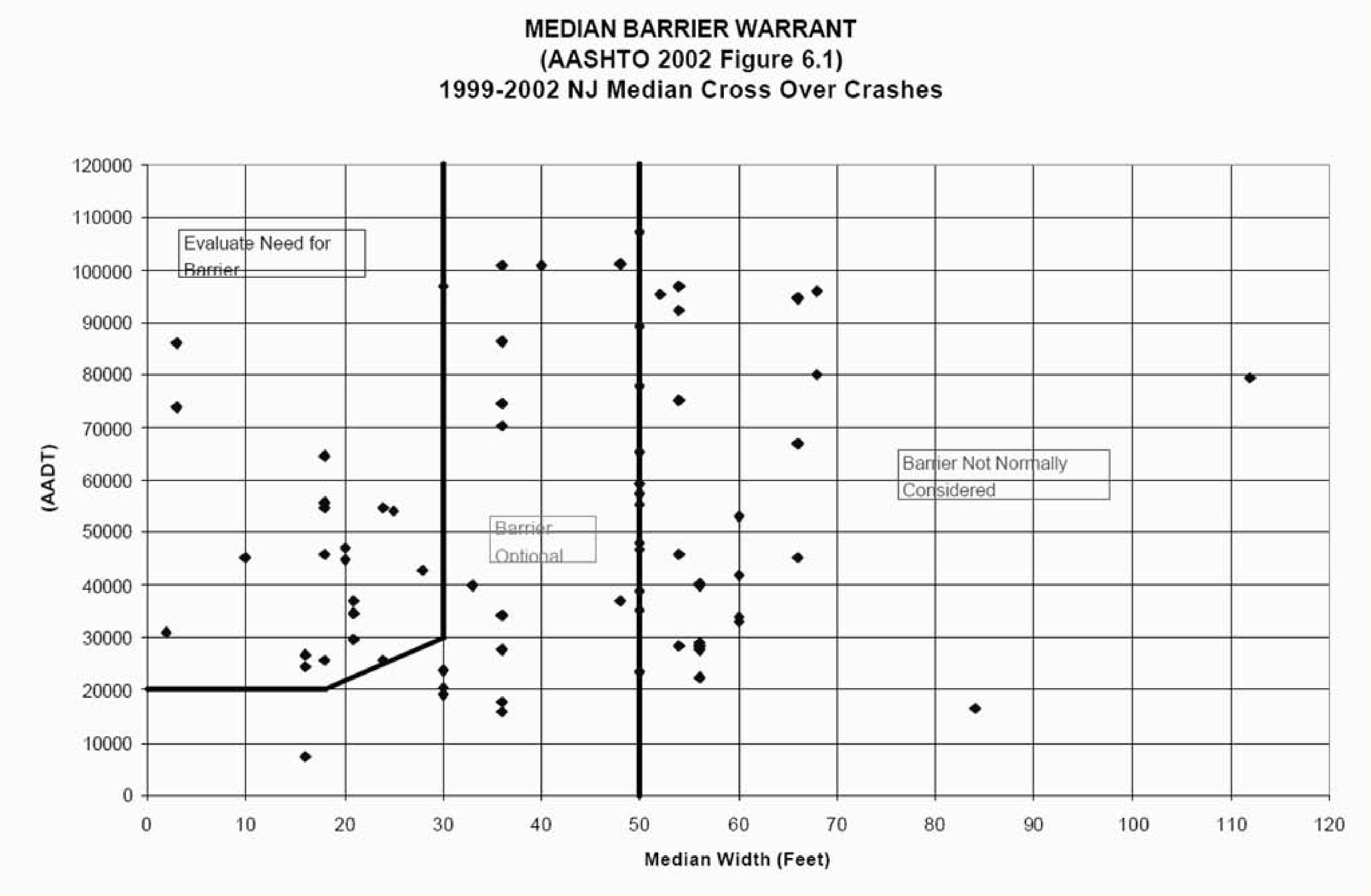
Barrier Test Levels

There are six tests levels (TLs) for longitudinal barriers.

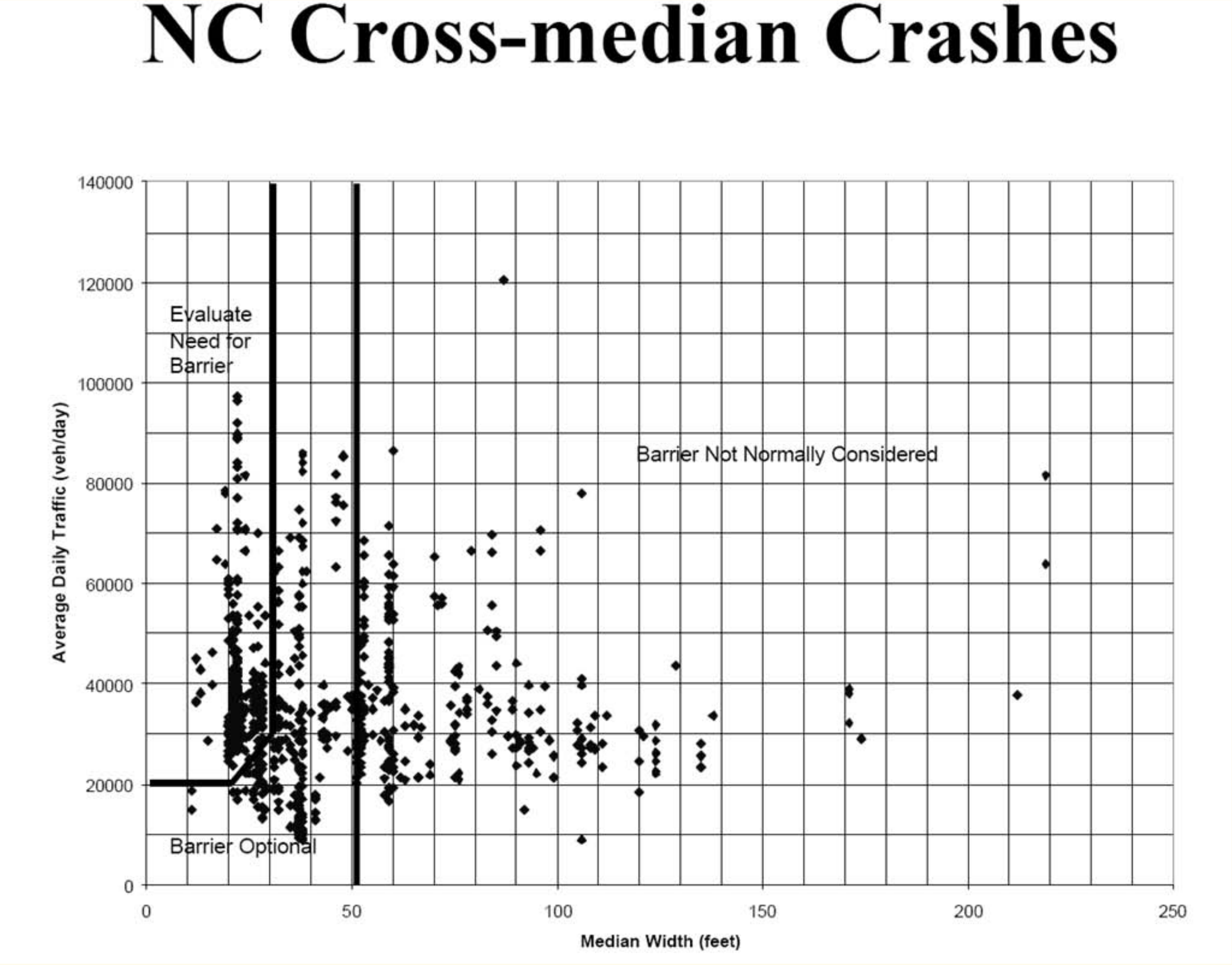
- For TL-1, TL-2 and TL-3: The barrier must successfully pass the test of an 820 kg car impacting a barrier at an angle of 20 degrees and a 2,000 kg pickup truck impacting a barrier at an angle of 25 degrees, at speeds of 50 km/h (TL1), 70 km/h (TL2), and 100 km/h (TL3).
- For TL-4: In addition to the TL-3 tests, the barrier must also pass the test of an 8,000 kg single-unit truck at an impact angle of 15 degrees and 80 km/h.
- For TL-5 and TL-6: The single-unit truck used for TL-4 is substituted by a 36,000 kg tractor trailer (van) for TL5 and by a 36,000 kg tractor trailer (tanker) for TL-6.

Barrier Type	Description	Test Level	Deflection (in)
Low-tensioned Cable	Three Steel Cables	TL-3	138
High-tensioned Cable	***3 or 4 Steel Cables***	***TL-3, TL-4***	***94-112***
Weak-Post, W-Beam	Two Steel W sections	TL-2	84
Weak-Post, Box-Beam	Steel Tube	TL-3	66
Strong-Post, Blocked-Out W-Beam	Two Steel W sections	TL-3	24
Strong-Post, Thrie-Beam	***Two Thrie-Beams***	***TL-3, TL-4***	***20***
Concrete Safety Shape	***No***	***TL-4, TL-5***	***0***

Median Width Effect



Median Width Effect



Research Methodology

- Collected data for more than 30,000 crashes on 1,127 miles of interstates in eight US states
- Crash frequency analysis
  - Negative Binomial regression
  - Empirical Bayesian before-and-after study
- Crash severity analysis - discrete choice models

Research Methodology
Crash Classification

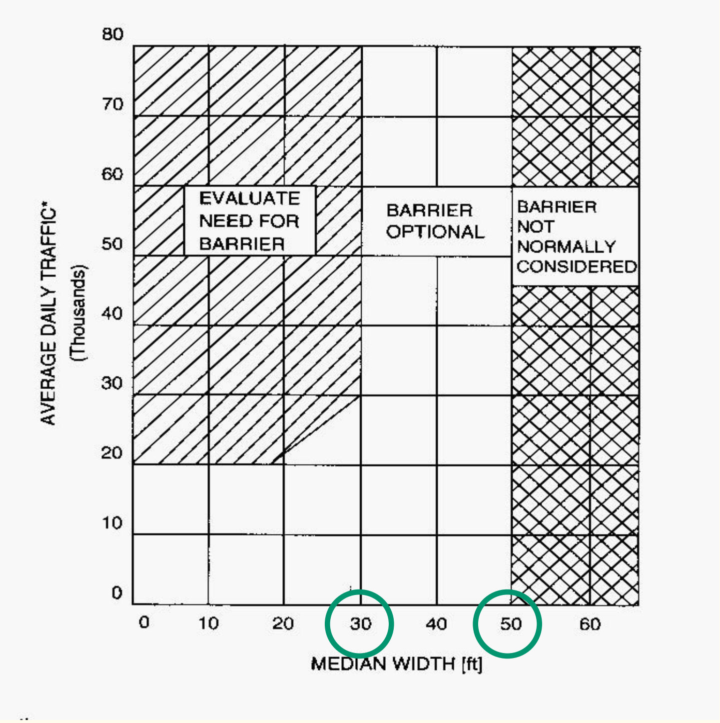
Single Vehicle (SV)

Multiple Vehicle – Same Direction (SD)

Multiple Vehicle – Opposite Direction (OD)

Research Methodology

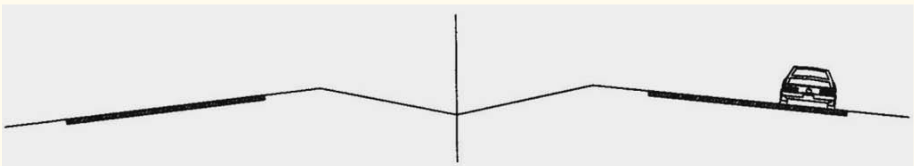
Median Classification



Median Design	Abbreviation
Depressed median, no barrier, width < 30 ft.	D1N
Depressed median, no barrier, 30 ft. ≤ width ≤ 50 ft.	D2N
Depressed median, no barrier, width > 50 ft.	D3N
Depressed median, high-tensioned cable barrier, 30 ft. ≤ width ≤ 50 ft.	D2H
Depressed median, high-tensioned cable barrier, > 50 ft.	D3H
Depressed median, low-tensioned cable barrier, 30 ft. ≤ width ≤ 50 ft.	D2L
Depressed median, low-tensioned cable barrier, > 50 ft.	D3L
Depressed w/berms, no barrier, width > 50 ft.	C3N
Berm median, no barrier, width > 50 ft.	B3N
Flush median, concrete barrier, width < 30 ft.	F1C
Flush median, concrete barrier, 30 ft. ≤ width ≤ 50 ft.	F2C
Sloped median, no barrier, width > 50 ft.	S3N

Median Designs

Cross-Section of a Depressed Median



Example Crash Frequency Models

D3N – depressed, wide, no barrier, Indiana

$$SV = YL\left(AADT\right)^{0.338}\exp\left(-2.202 - 0.027\left(HF\right)\right)$$

$$MVSD = YL\left(AADT\right)^{1.240}\exp\left(-12.249 + 0.033\left(RAL\right)\right)$$

$$MVOD = YL\left(AADT\right)^{0.465}\exp\begin{pmatrix}-4.433 + 0.016\left(PSL\right) - 0.036\left(ISW\right) + \\ 0.060\left(HR\right) + 0.027\left(RON\right)\end{pmatrix}$$

SV = expected number of single vehicle crashes,
MVSD = expected number of multiple-vehicle same-direction crashes,
MVOD = expected number of multiple-vehicle opposite-direction crashes,
Y = number of years,
L = segment length (mi),
AADT = annual average daily traffic, veh/day,
HF = frequency of horizontal curves, 1/mi,
RAL = frequency of ramps, 1/mi,
PSL = posted speed limit, mi/h,
ISW = inside should width, ft,
HR = average horizontal curvature, 1/mi,
RON = frequency of on-ramps, 1/mi.

Example Crash Severity Models

D3N – depressed, wide, no barrier, Indiana

$$P\left(FAT-INJ\right)=\frac{1}{1+\exp\left(1.543+0.019\left(ROF\right)+0.033\left(RON\right)-0.161\left(PHC\right)\right)}$$

$$P\left(FAT-INJ\right)=\frac{1}{1+\exp\left(\begin{array}{l}0.565-0.054\left(LNS\right)+0.00000243\left(AADT\right)+\\0.013\left(PSL\right)+0.403\left(PT\right)-0.049\left(BRG\right)+\\0.026\left(ROF\right)-0.107\left(PVC\right)+0.115\left(PHC\right)\end{array}\right)}$$

$$P\left(FAT-INJ\right)=\frac{1}{1+\exp\left(0.669-0.184\left(LNS\right)-0.00000679\left(AADT\right)-0.335\left(PVC\right)\right)}$$

ROF = frequency of off-ramps, RON = frequency of on-ramps, 1/mi, veh/day, PHC – presence of a horizontal curve , LNS – total number of lanes, AADT = annual average daily traffic, PSL = posted speed limit, mi/h, PT – proportion of trucks, BRG – frequency of bridges, 1/mi, PVC – presence of a vertical curve.

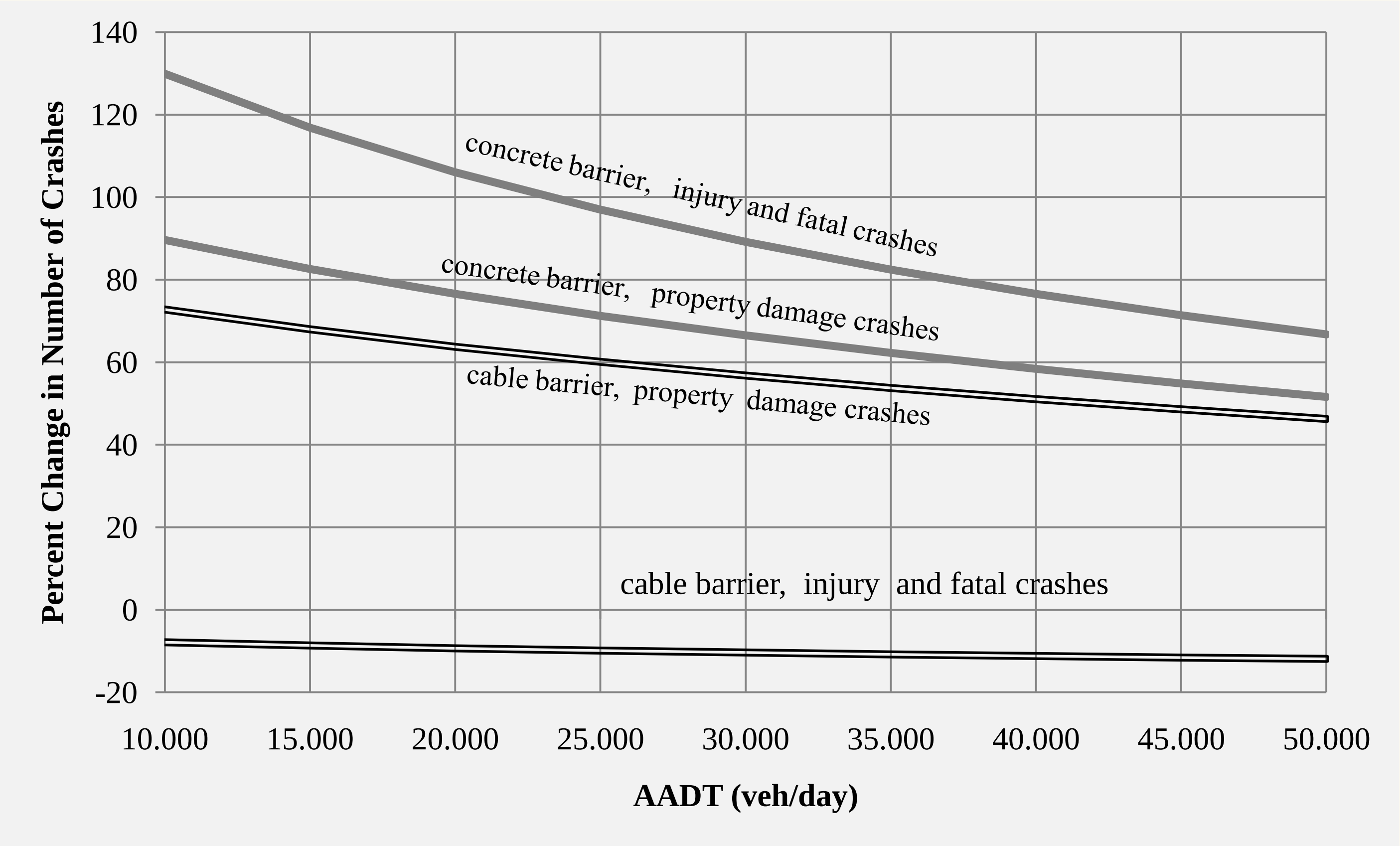
Crash Modification Factors

Treatment		SV	SD	OD
Before	After			
D3N 4 lanes	D3H 4 lanes	1.7	1	0.06
D2N 4 lanes	F1C 6 lanes	2.2	0.8	0

Computational Procedure

1. Estimate the *before* number of SV, MVSD, and MVOD crashes
2. Estimate the *before* proportions of severe SV, MVSD, and MVOD crashes
3. Calculate the *before* number of severe and property damage SV, MVSD, and MVOD crashes
4. Estimate the *after* number of SV, MVSD, and MVOD crashes with Crash Modification Factors
5. Estimate the *after* proportions of severe SV, MVSD, and MVOD crashes
6. Calculate the *after* number of severe and property damage SV, MVSD, and MVOD crashes
7. Aggregate the number of crashes within the *before* and *after* periods and compare the results

Safety Impact



Cost of Rural Freeway Crashes

(2003-2008, Indiana)

Crash Type	Number of Crashes	Vehicles Damaged	Persons Injured			
			K	A	B	C
MV-OD INJ	275	612	71	66	362	76
MV-OD PDO	670	1418	0	0	0	0
MV-SD INJ	1911	4341	104	238	2307	1036
MV-SD PDO	10404	21806	0	0	0	0
SV INJ	3775	3775	163	427	4031	1071
SV PDO	20395	20395	0	0	0	0

Cost of Rural Freeway Crashes

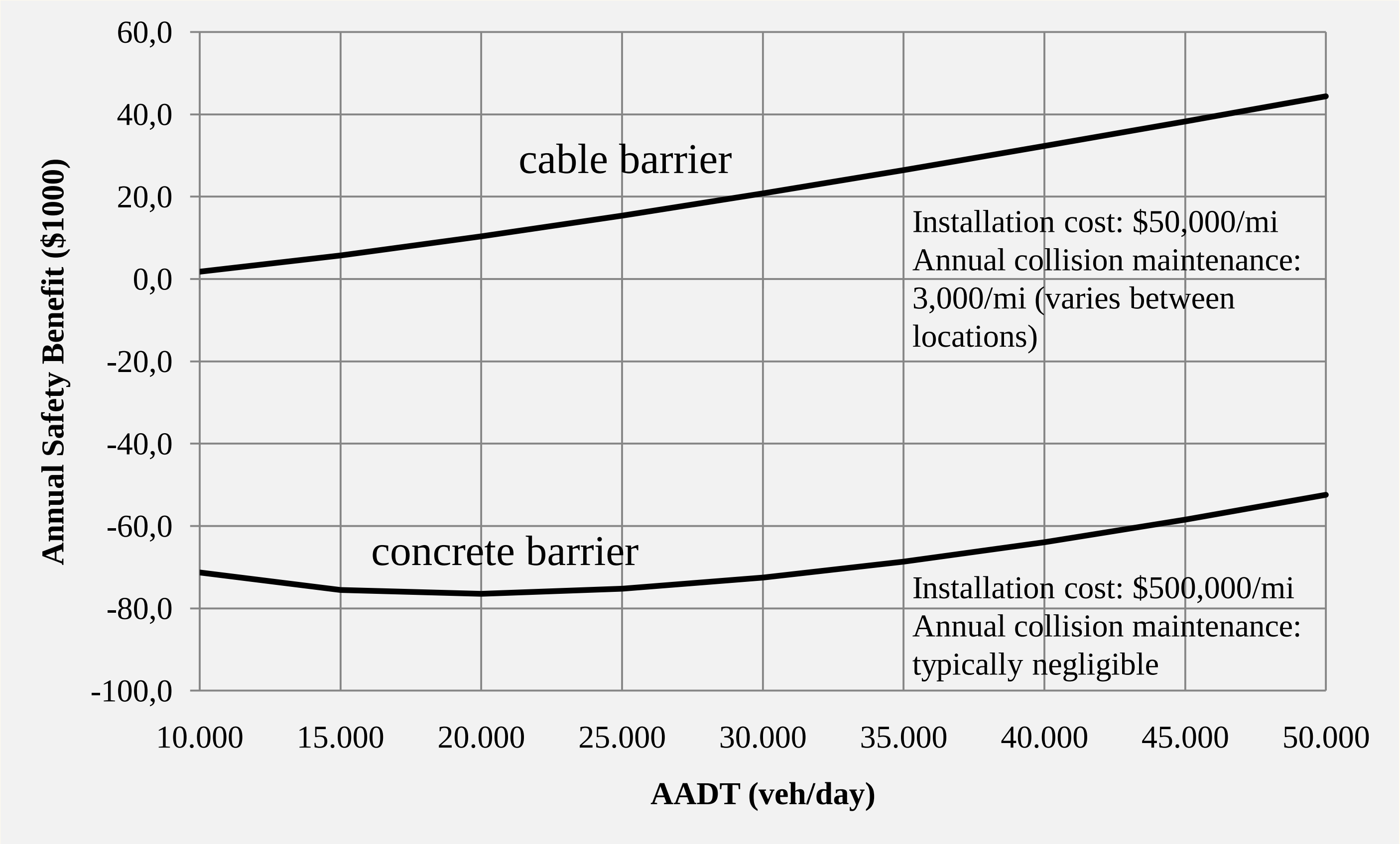
(2003-2008, Indiana)

Crash Type	Average Vehicles Damaged	Average Persons Injured				Average Cost (2008$)
		K	A	B	C	
MV-OD INJ	2.23	0.258	0.240	1.316	0.276	392,762
MV-OD PDO	2.12	0.000	0.000	0.000	0.000	8,466
MV-SD INJ	2.27	0.054	0.125	1.207	0.542	121,189
MV-SD PDO	2.10	0.000	0.000	0.000	0.000	8,384
SV INJ	1.00	0.043	0.113	1.068	0.284	94,502
SV PDO	1.00	0.000	0.000	0.000	0.000	4,000

Average Economic Cost by Injury Severity, 2008 at http://www.nsc.org/news_resources/injury_and_death_statistics/Pages/EstimatingtheCostsofUnintentionalInjuries.aspx
Death $1,300,000; Incapacitating injury (A) $67,200; Non-incapacitating evident injury (B) $21,800; Possible injury (C) $12,300

Damaged vehicle $4,000 (stipulated based on Indiana 2002 data)

Annual Safety Benefit



Truck overrode cable barriers

http://glasgowdailytimes.com/local/x552025916/Truck-overrode-cable-barriers

March 30, 2010
By SUSAN TEBBEN For the Daily Times

GLASGOW — Investigators on the scene of the wreck that killed 11 people on Interstate 65 near Munfordville Friday morning are checking the cable barriers that the tractor-trailer passed over to enter oncoming traffic.

The investigation is now being taken up by the National Transportation Safety Board, who dispatched a "Go Team" to investigate. "**The truck overrode the cable barrier**, but the cables were not compromised," said Knudson.

The NTSB will also investigate the cable barriers that run along the side of the road. These barriers, which began to be installed in 2006, were put in place to reduce the number of cross-over crashes, according to Keirsten Jaggers, public information officer for the Kentucky Transportation Cabinet.

"The state has chosen to use cable barriers rated higher than what is required by the Federal Highway Administration. The cable barriers are designed to withstand impacts of passenger cars, pickup trucks and single unit box trucks, but are not designed to withstand the impact of tractor-trailers," Jaggers said, adding that the cabinet believes the cables have helped save lives, despite not preventing every crash.

"It's important to understand that one [barrier] is not a substitute for another, they are used in different situations," Hecox said. "The thought was years ago that the grass in the median would be enough to stop vehicles from going into oncoming traffic, but the cable barriers would provide an additional means of stopping."

Friday's crash was the deadliest single collision in Kentucky since a 1988 …

http://www.gsihighway.com/nucor/research/chapter6powers/CableSlope2.mpg

Other Considerations

- Existing warrants and manuals
- Liability risk (USA)
- Impact ratings (heavy trucks)
- Median cross-section
- Right of way cost

Conclusions

- Cross-over crashes are the main concern to road agencies and majority of past research focused on these crashes
- Concrete medians confirmed to be the most effective “eliminator” of cross-over crashes
- Cable barriers reduce the cross-over crashes to 6% (penetration by heavy vehicles, over-ridings and under-ridings)

Conclusions

- Barriers increase the number of single-vehicle crashes: concrete barriers by 120% and cable barriers by 70%.
- Concrete barriers increase while cable barriers reduce the overall severity of crashes.
- In general, barriers slightly reduce or do not affect the multiple vehicle same direction crashes

Conclusions

- Cable barriers are beneficial and this safety benefit is growing with traffic. At considerable traffic (50,000 veh/day or more) the investment may pay off in one year.
- Concrete barriers maybe justified where the risk of penetration of cable barriers by heavy trucks is considerable.

Thank you.
Questions?