



# Performance-Based Highway Design

What the heck is it?

We all have a stake in **A**  **B**



# National Research Scene

Topic (SORTED BY TOTAL VOTES)	AASHTO Votes (22)	TRB Votes (34)	Total Votes
Median Design and Barrier Issues in Urban and Rural Environments (1.1)/Median: Types and Design (Crossover Crashes) (2.1)	13	15	<u>28</u>
Performance-based Geometric Design Analysis (1.3)	7	17	<u>24</u>
Multimodal Highway Design for "Complete Streets" (1.2)/Determine the primary and secondary users for various functional classes. (2.3)	6	17	<u>23</u>
Investigation of Alternative Geometric Highway Design Processes (Design Decision Support) (1.3)	8	12	<u>20</u>
Horizontal Curve Design Philosophy (Should it be for driver	4	14	<u>18</u>

TRB research needs workshop – 2004



# National Research Scene

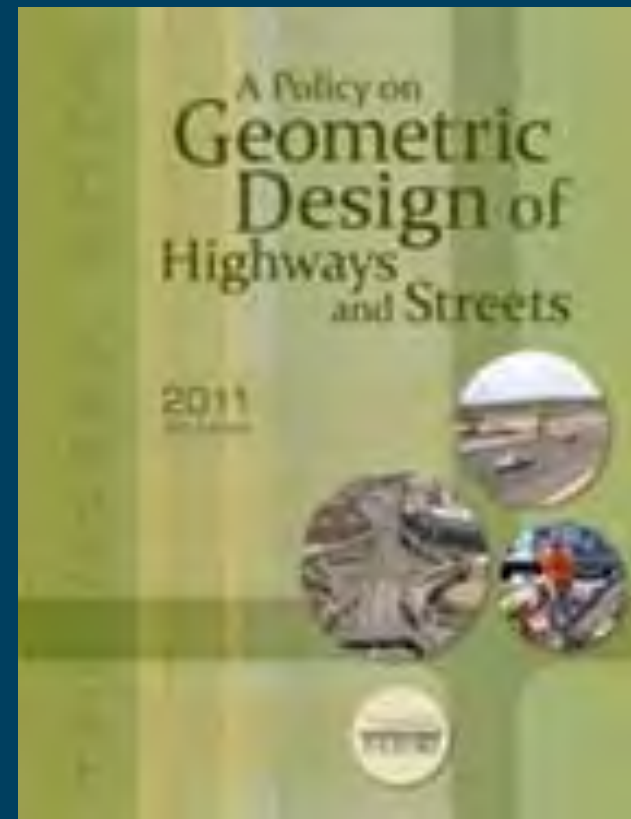
**TABLE 4 Proposed Research Program Sequence**  
(Corresponding Numbers for Problem Statements in Part III Shown in Parenthesis)

Research Categories	Research Sequence			
	A	B	C	D
Methodology	Performance-based Geometric Design Analysis (2)	Investigation of Alternative Geometric Highway Design Processes (4)	Continued	Continued
Criteria	Superelevation Criteria for Steep Grades on Horizontal Curves (13)	Horizontal Curve Design Philosophy (5)		
Highways	Median Design and Barrier Considerations in Urban and Rural Environments (1)	Transition Zone Design (8)	Accommodating Bicyclists on Rural Highways (21)	

TRB: *Geometric Design Strategic Research – 2007*



# “Code-based” road design



# Code-based road design

Design Speed (km/h)	METRIC					Rounded Radius (m)	Design Speed (mph)	US Customary					Rounded Radius (ft)
	Maximum e (%)	Maximum r	Total (e/100 + r)	Calculated Radius (m)	Calculated Radius (ft)			Maximum e (%)	Maximum r	Total (e/100 + r)	Calculated Radius (ft)		
15	4.0	0.40	0.44	4.0	4	4.0	10	0.38	0.42	10	15.9	16	
20	4.0	0.35	0.39	8.1	8	8.1	15	4.0	0.32	0.36	41.7	42	
30	4.0	0.28	0.32	22.1	22	22.1	40	4.0	0.27	0.31	86.0	86	
40	4.0	0.23	0.27	46.7	47	46.7	50	4.0	0.23	0.27	152.9	154	
50	4.0	0.19	0.23	85.6	86	85.6	60	4.0	0.20	0.24	250.0	250	
60	4.0	0.17	0.21	136.0	136	136.0	70	4.0	0.19	0.22	371.2	371	
70	4.0	0.15	0.19	203.1	203	203.1	80	4.0	0.18	0.20	533.3	533	
80	4.0	0.14	0.18	299.0	300	299.0	90	4.0	0.17	0.19	770.2	771	
90	4.0	0.13	0.17	437.2	438	437.2	100	4.0	0.16	0.18	1098.0	1098	
100	4.0	0.12	0.16	624.2	625	624.2	110	4.0	0.15	0.17	1500.0	1500	

Metric	US Customary
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EN-EN OR EX-EX		EX-EN		TURNING ROADWAYS		EN-EX (WEAVING)			
FULL FREEWAY		FULL FREEWAY		SYSTEM INTER-CHANGE		SYSTEM TO SERVICE INTERCHANGE		SERVICE TO SERVICE INTERCHANGE	
CDR OR FDR		CDR OR FDR		SERVICE INTER-CHANGE		FULL FWY.		CDR OR FDR	
MINIMUM LENGTHS MEASURED BETWEEN SUCCESSIVE RAMP TERMINALS									
300 m [1000 ft]	240 m [800 ft]	150 m [500 ft]	120 m [400 ft]	240 m [800 ft]	180 m [600 ft]	600 m [2000 ft]	480 m [1600 ft]	480 m [1600 ft]	300 m [1000 ft]

10.0	0.38	0.44	15.2	15
10.0	0.32	0.38	39.5	39
10.0	0.27	0.33	89.8	81
10.0	0.23	0.29	143.6	144
10.0	0.20	0.26	230.8	231
10.0	0.18	0.24	340.3	340
10.0	0.16	0.22	464.3	465
10.0	0.15	0.21	642.9	643
10.0	0.14	0.20	833.3	833
10.0	0.13	0.19	1061.4	1060
10.0	0.12	0.18	1333.3	1330
10.0	0.11	0.17	1659.9	1660
10.0	0.10	0.16	2041.7	2040
10.0	0.09	0.15	2500.0	2500
10.0	0.08	0.14	3041.6	3040
8.0	0.38	0.46	14.5	14
8.0	0.32	0.40	37.5	38
8.0	0.27	0.35	76.2	76
8.0	0.23	0.30	134.4	134
8.0	0.20	0.28	214.3	214
8.0	0.18	0.26	314.1	314
8.0	0.16	0.24	444.4	444
8.0	0.15	0.23	587.0	587
8.0	0.14	0.22	757.6	758
8.0	0.13	0.21	960.3	960
8.0	0.12	0.20	1200.0	1200
8.0	0.11	0.19	1482.9	1480
8.0	0.10	0.18	1818.2	1810
8.0	0.09	0.17	2205.9	2210
8.0	0.08	0.16	2656.7	2670
10.0	0.38	0.48	13.9	14
10.0	0.32	0.32	35.7	36
10.0	0.27	0.27	72.1	72
10.0	0.23	0.23	120.0	120
10.0	0.20	0.20	200.0	200
10.0	0.18	0.18	281.7	282
10.0	0.16	0.16	375.0	375
10.0	0.14	0.14	470.0	470
10.0	0.13	0.13	569.4	569
10.0	0.12	0.12	672.7	673
10.0	0.11	0.11	781.3	781
10.0	0.10	0.10	894.7	895
10.0	0.09	0.09	1013.3	1010
10.0	0.08	0.08	1137.3	1130
12.0	0.38	0.38	13.3	13
12.0	0.32	0.32	34.1	34
12.0	0.27	0.27	68.4	68
12.0	0.23	0.23	119.0	119
12.0	0.20	0.20	178.6	179
12.0	0.18	0.18	252.2	252
12.0	0.16	0.16	340.0	340
12.0	0.14	0.14	442.9	443
12.0	0.13	0.13	560.7	561
12.0	0.12	0.12	694.3	694
12.0	0.11	0.11	843.3	843
12.0	0.10	0.10	1008.0	1008
12.0	0.09	0.09	1188.9	1189
12.0	0.08	0.08	1386.0	1386
12.0	0.08	0.20	2133.3	2130

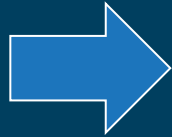
b Usable shoulders on arterial section is needed to reduce 0.6 m [2 ft].

110	55.0	73.4	129.0	110	12.0	0.11	0.23	414.2	414	80.0	80		
90	62.6	92.9	155.5	120	12.0	0.09	0.21	539.9	540	85.0	85		
100	69.5	114.7	184.2	130	12.0	0.08	0.20	685.4	685	90.0	90		
110	76.5	138.8	215.3										
120	83.4	165.2	248.6					220	60	220.5	345.5	566.0	570
130	90.4	193.8	284.2					250	65	238.9	405.5	644.4	645
								285	70	257.3	470.3	727.6	730
									75	275.6	539.9	815.5	820
									80	294.0	614.3	908.3	910

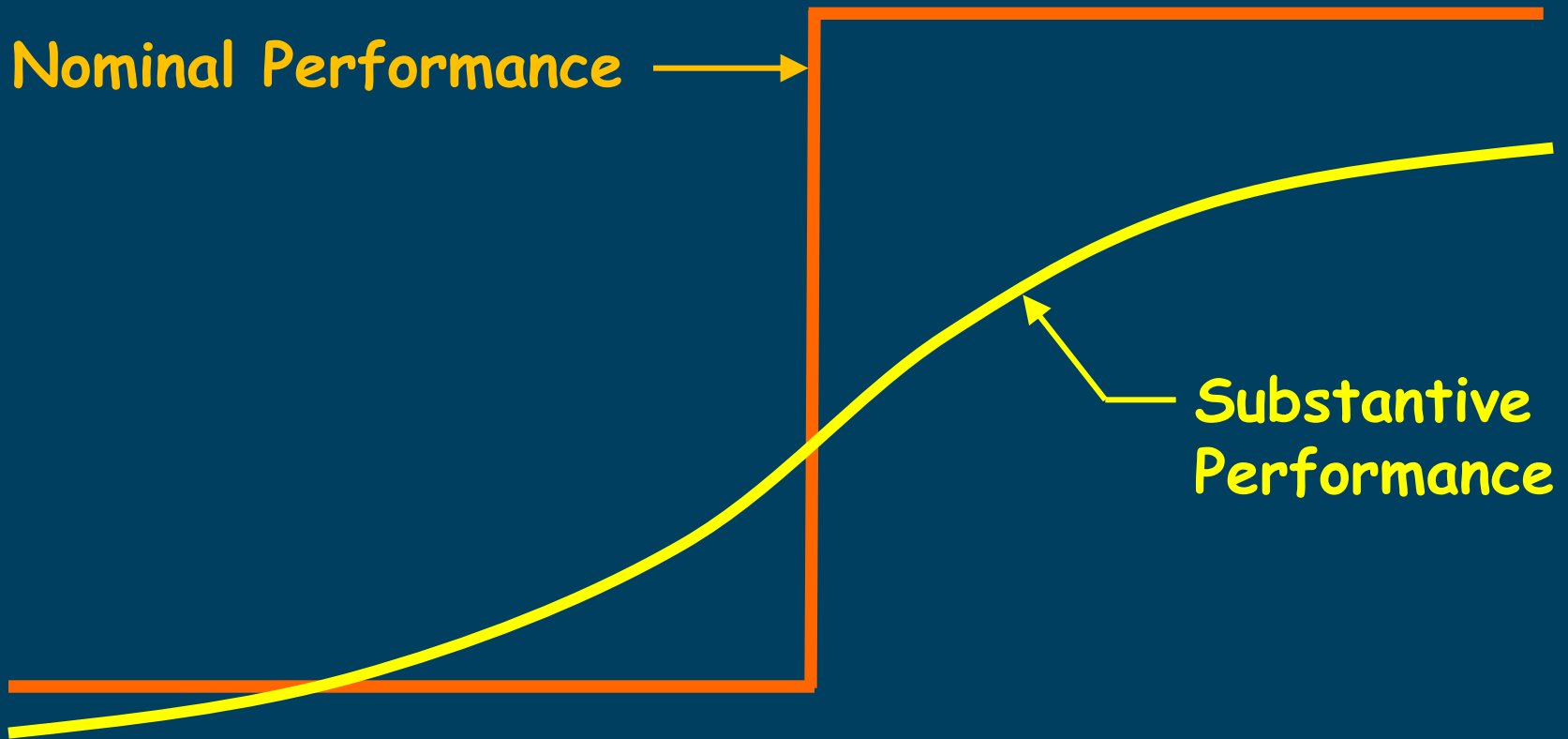
Note: In recognition of safety considerations, use of  $e_{max} = 4.0\%$  should be limited to urban conditions.



# The traditional design process



# Performance basis



# Performance basis

Metric					US Customary				
Design speed (km/h)	Minimum width of traveled way (m) <sup>a</sup> for specified design volume (veh/day)				Design speed (mph)	Minimum width of traveled way (ft) <sup>a</sup> for specified design volume (veh/day)			
	under 400	400 to 1500	1500 to 2000	over 2000		under 400	400 to 1500	1500 to 2000	over 2000
60	6.6	6.6	6.6	7.2	40	22	22	22	24
70	6.6	6.6	6.6	7.2	45	22	22	22	24
80	6.6	6.6	7.2	7.2	50	22	22	24	24
90	6.6	6.6	7.2	7.2	55	22	22	24	24
100	7.2	7.2	7.2	7.2	60	24	24	24	24
110	7.2	7.2	7.2	7.2	65	24	24	24	24
120	7.2	7.2	7.2	7.2	70	24	24	24	24
130	7.2	7.2	7.2	7.2	75	24	24	24	24
All speeds	Width of usable shoulder (m) <sup>b</sup>				All speeds	Width of usable shoulder (ft) <sup>b</sup>			
	1.2	1.8	1.8	2.4		4	6	6	8

<sup>a</sup> On roadways to be reconstructed, an existing 6.6-m [22-ft] traveled way may be retained where alignment and safety records are satisfactory.

<sup>b</sup> Usable shoulders on arterials should be paved; however, where volumes are low or a narrow section is needed to reduce construction impacts, the paved shoulder may be reduced to 0.6 m [2 ft].





# Ongoing research

## NCHRP Project 15-47 “An Improved Geometric Design Process”

- ▶ Some AASHTO criteria are based on outdated and/or overly simplistic models lacking scientific basis
- ▶ Dimensional design criteria should be based only on measurable performance effects



# “measurable performance effects”

## Prediction of the Expected Safety Performance of Rural Two-Lane Highways

PUBLICATION NO. FHWA-RD-99-207

DECEMBER 2000



US Department of Transportation  
Federal Highway Administration

Research, Development, and Technology  
Turner-Fairbank Highway Research Center  
6300 Georgetown Pike  
McLean, VA 22101-2298



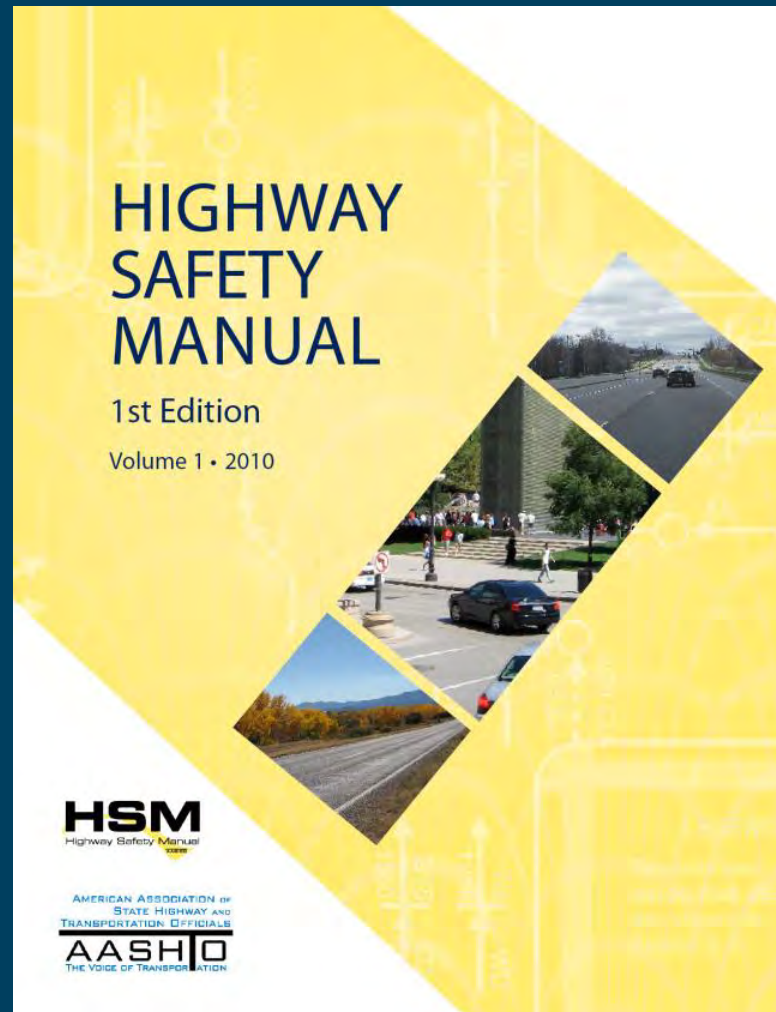
# Knowledge!



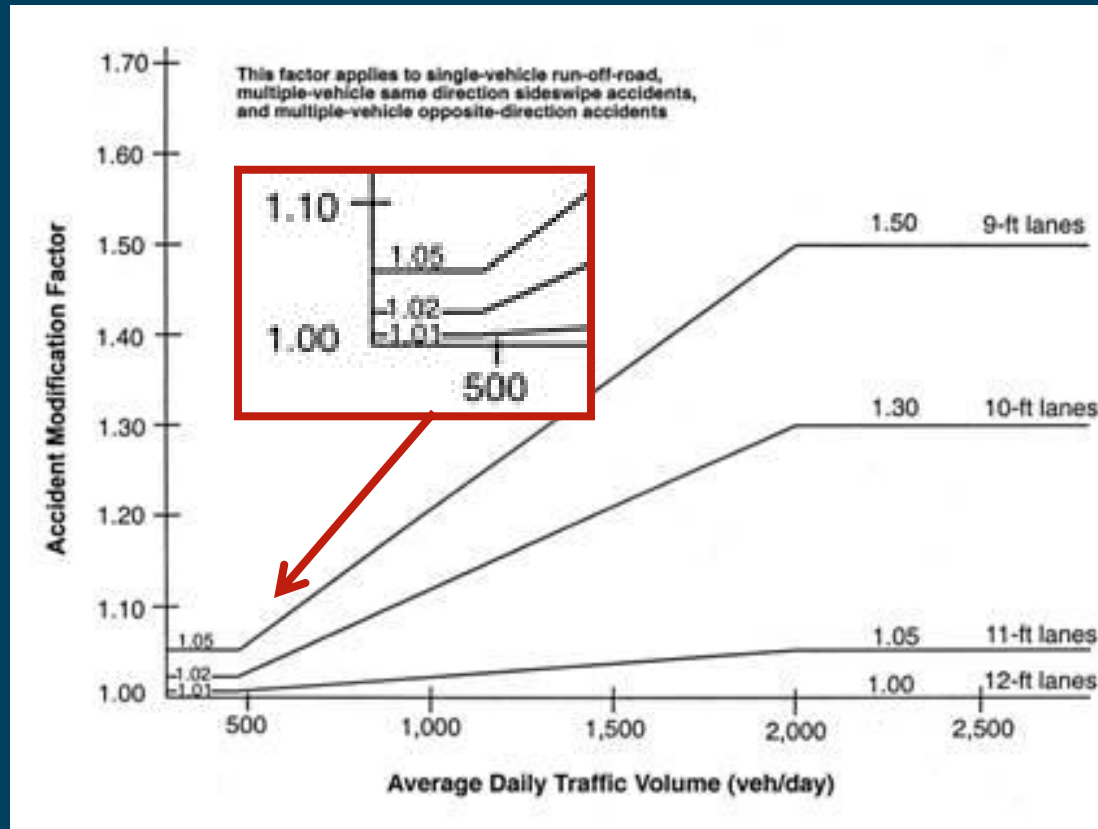
# Unintended consequences



# “measurable performance effects”



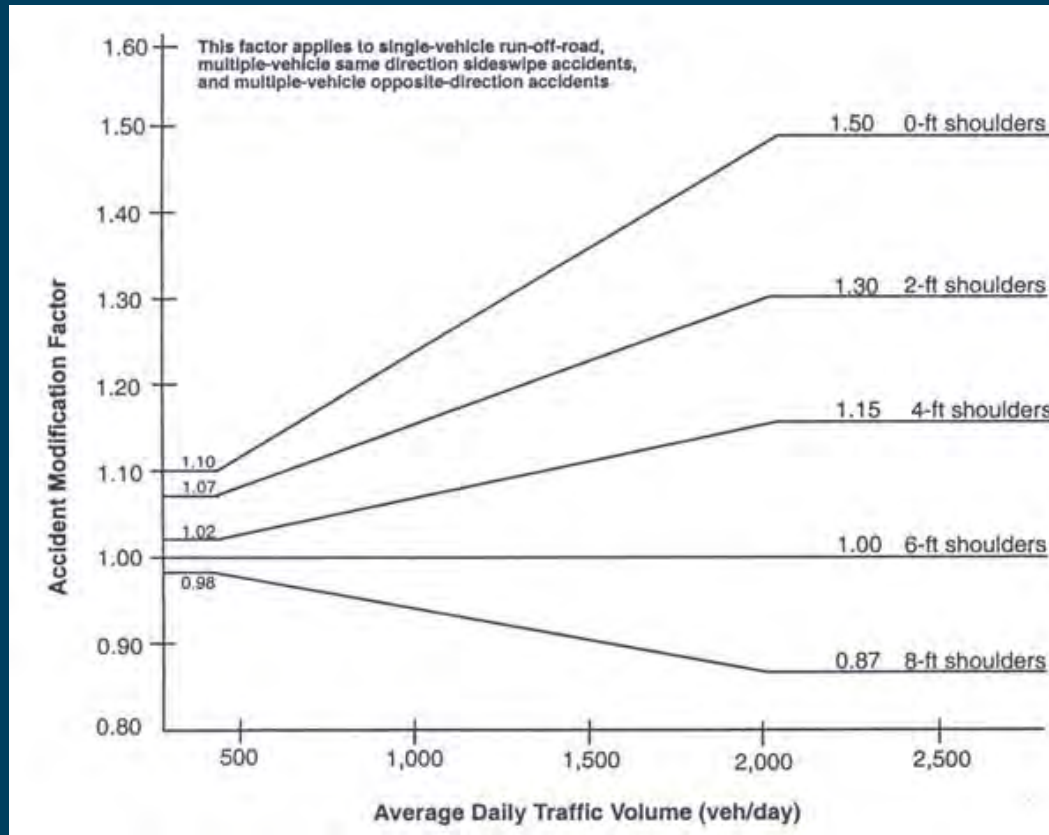
# Known safety effects



Travel lane width – rural two-lane



# Known safety effects



Shoulder width – rural two-lane

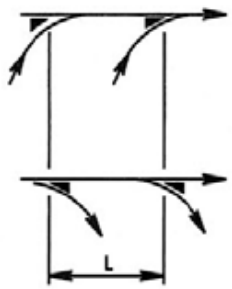
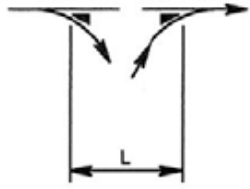
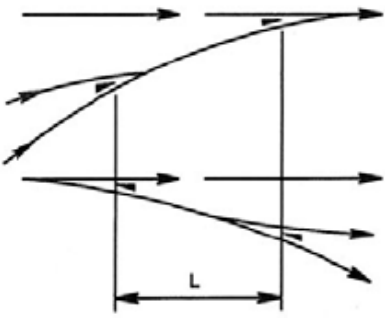
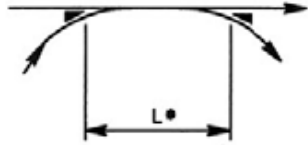


# Piecing things together





# “Code-based” design

EN-EN OR EX-EX		EX-EN		TURNING ROADWAYS		EN-EX (WEAVING)			
									
						* NOT APPLICABLE TO CLOVERLEAF LOOP RAMPS			
FULL FREEWAY	CDR OR FDR	FULL FREEWAY	CDR OR FDR	SYSTEM INTER- CHANGE	SERVICE INTER- CHANGE	SYSTEM TO SERVICE INTERCHANGE		SERVICE TO SERVICE INTERCHANGE	
						FULL FWY.	CDR OR FDR	FULL FWY.	CDR OR FDR
MINIMUM LENGTHS MEASURED BETWEEN SUCCESSIVE RAMP TERMINALS									
300 m [1000 ft]	240 m [800 ft]	150 m [500 ft]	120 m [400 ft]	240 m [800 ft]	180 m [600 ft]	600 m [2000 ft]	480 m [1600 ft]	480 m [1600 ft]	300 m [1000 ft]

## Ramp terminal spacing



# “Code-based” design

AASHTO—Geometric Design of Highways and Streets

EN-EN OR EX-EX		EX-EN		TURNING ROADWAYS		EX-EX (WEAVING)	
FULL FREEWAY	CDR OR FUR	FULL FREEWAY	CDR OR FUR	SYSTEM INTERCHANGE	SERVICE INTERCHANGE	SYSTEM TO SERVICE INTERCHANGE	SERVICE TO SERVICE INTERCHANGE
MINIMUM LENGTHS MEASURED BETWEEN SUCCESSIVE RAMP TERMINALS							
300 ft (90 m)	240 ft (73 m)	100 ft (30 m)	80 ft (24 m)	240 ft (73 m)	80 ft (24 m)	500 ft (150 m)	400 ft (120 m)
1000 ft (300 m)	800 ft (240 m)	1400 ft (420 m)	1000 ft (300 m)	1400 ft (420 m)	1000 ft (300 m)	1600 ft (480 m)	1200 ft (360 m)

NOTES:  
 FOR - FREEWAY DISTRIBUTOR ROAD  
 CDR - COLLECTOR DISTRIBUTOR ROAD  
 EX - ENTRANCE  
 EN - EXIT  
 THE RECOMMENDATIONS ARE BASED ON OPERATIONAL EXPERIENCE AND NEED FOR FLEXIBILITY AND ADEQUATE SIGNING. THEY SHOULD BE CHECKED IN ACCORDANCE WITH THE PROCEEDING OUTLINED IN THE HIGHWAY CAPACITY MANUAL (H) AND THE LARGER OF THE VALUES IS SUGGESTED FOR USE. ALSO, A PROCEDURE FOR MEASURING THE LENGTH OF THE WEAVING SECTION IS GIVEN IN CHAPTER 10 OF THE 2000 HIGHWAY CAPACITY MANUAL (H).  
 THE "L" DISTANCES NOTED IN THE FIGURES ABOVE ARE BETWEEN LINE POINTS, NOT NECESSARILY PHYSICAL CORNERS.  
 A MINIMUM DISTANCE OF 50 ft (15 m) IS RECOMMENDED BETWEEN THE END OF THE TAPER FOR THE FIRST ON RAMP AND THE THEORETICAL CORNER FOR THE SUCCEEDING ON RAMP FOR THE EN-EN (SIMILAR FOR EX-EN).

Exhibit 10-68. Recommended Minimum Ramp Terminal Spacing

**Speed-change lanes.** Drivers leaving a highway at an interchange are required to reduce speed as they exit on a ramp. Drivers entering a highway from a turning roadway accelerate until the desired highway speed is reached. Because the change in speed is usually substantial, provision should be made for acceleration and deceleration to be accomplished on auxiliary lanes to minimize interference with through traffic and to reduce crash potential. Such an auxiliary lane, including tapered areas, may be referred to as a speed-change lane. The terms “speed-change lane,” “deceleration lane,” or “acceleration lane” as used herein apply broadly to the added lane joining the traveled way of the highway with that of the turning roadway and do not necessarily imply a definite lane of uniform width. This additional lane is a part of the elongated ramp terminal area.

A speed-change lane should have sufficient length to enable a driver to make the appropriate change in speed between the highway and the turning roadway in a safe and comfortable manner. Moreover, in the case of an acceleration lane, there should be additional length to permit adjustments in speeds of both through and entering vehicles so that the driver of the entering vehicle can position himself opposite a gap in the through-traffic stream and maneuver into it before reaching the end of the acceleration lane. This latter consideration also influences both the configuration and length of an acceleration lane.

Two general forms of speed-change lanes are: (1) the taper and (2) the parallel type. The taper type provides a direct entry or exit at a flat angle, whereas the parallel type has an added lane for changing speed. Either type, when properly designed, will operate satisfactorily. However, the parallel type is still favored in certain areas. Furthermore, some agencies use the taper type for exits and the parallel type for entrances.

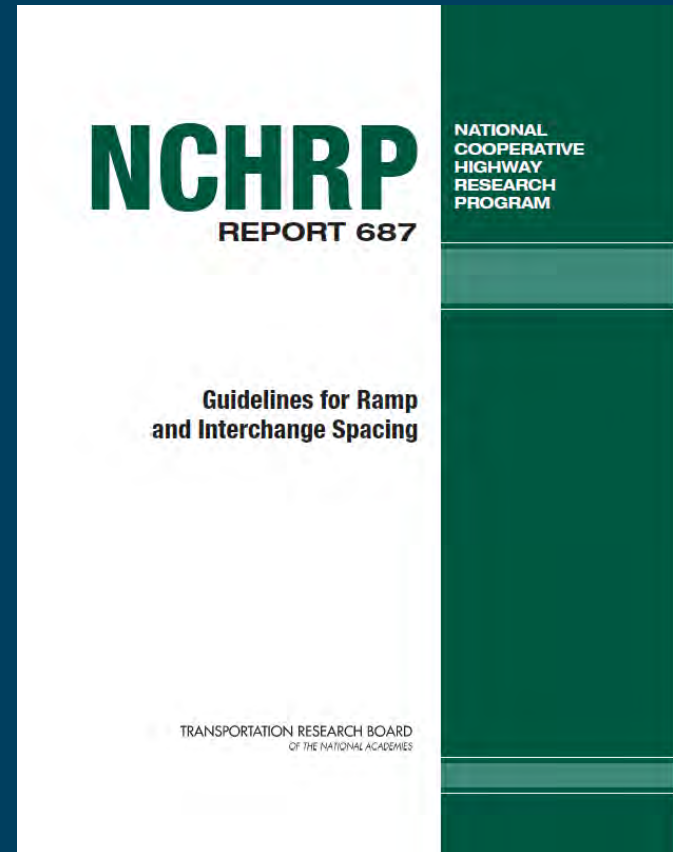
- It doesn't account for...
- Respective ramp volumes
- Mainline traffic density
- Speeds
- Geometry
- Signing considerations
- Cost or feasibility of attaining the standard
- Design context



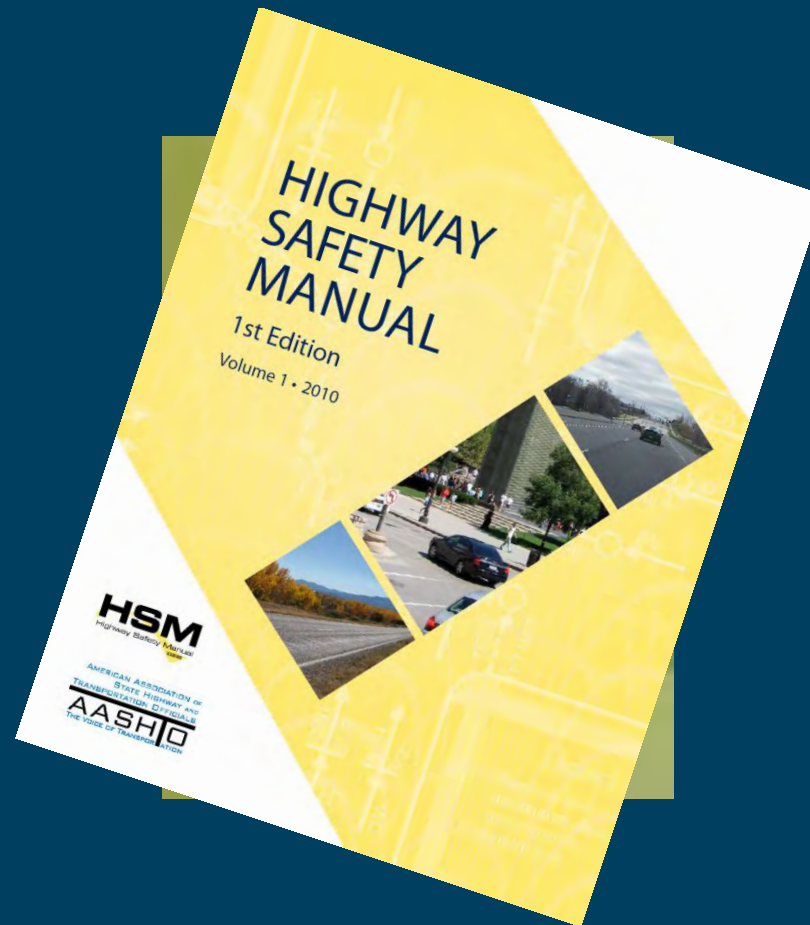
# Performance-based methodology

“...balance system efficiency and safety with the need to provide access...”

“The selection criteria include geometric design needs, operational performance, signing needs, and safety performance.”



# Code-based vs. performance-based design



# For example...



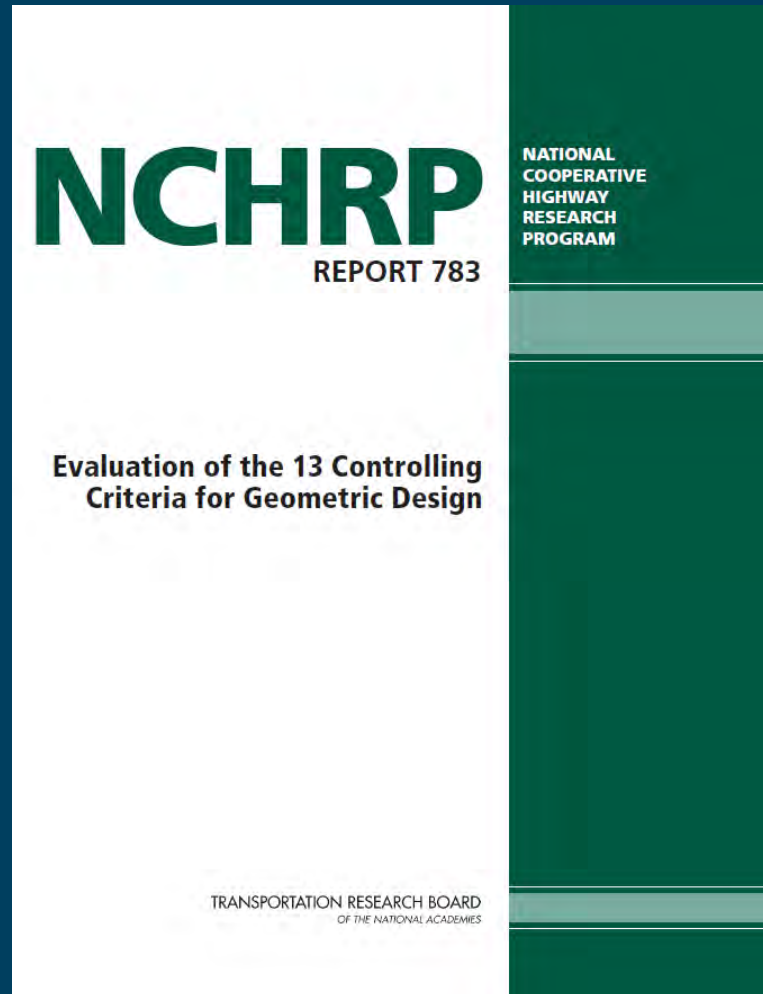
Parking lane width



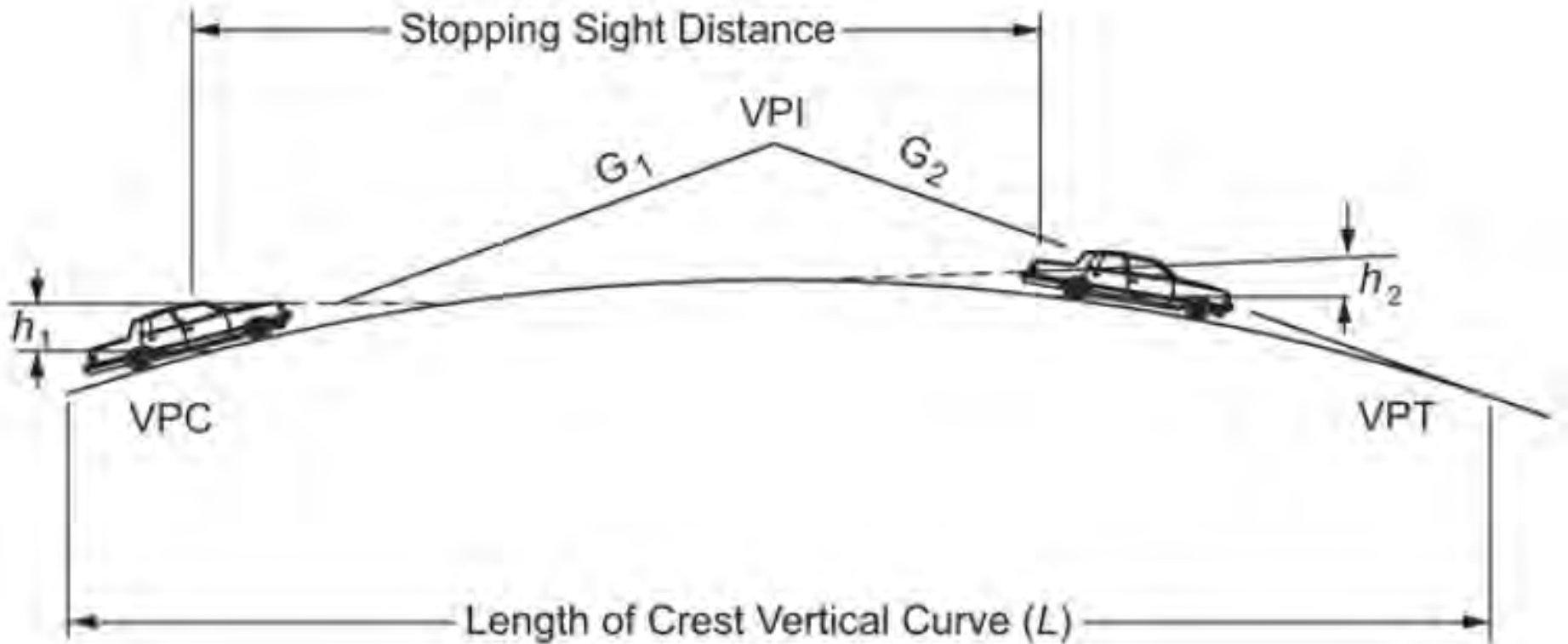
# Code-based vs. performance-based



# Performance-based evaluation of the code



# Stopping Sight Distance





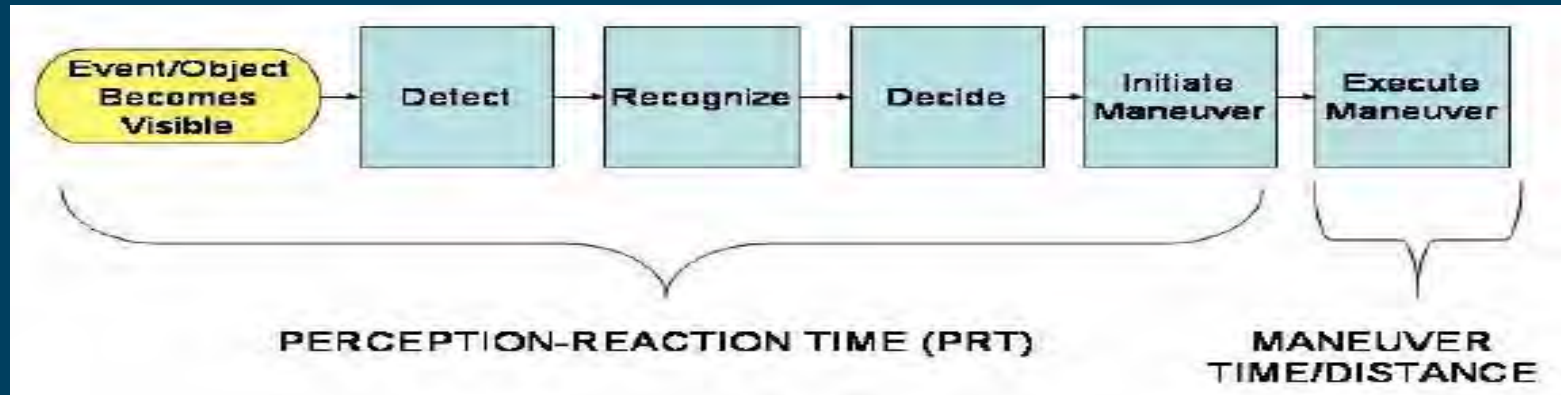
# Stopping Sight Distance

Based on two premises:

1. The ability to see the road ahead is critical to safety
2. The critical event is an emergency stop, which is comprised of perception/reaction time and stopping distance



# Stopping Sight Distance



$SSD = \text{perception/reaction distance} + \text{braking distance}$

$$SSD = 1.47Vt + 1.075V^2/a$$

$V$  = design speed in mph

$t$  = perception/reaction time (2.5 sec)

$a$  = deceleration rate (11.2 ft/sec<sup>2</sup>)



# Remember all that research...?

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Investigation of Alternative Geometric Highway Design Processes (Design Decision Support) (1.3)	8	12	<u>20</u>
Horizontal Curve Design Philosophy (Should it be for driver	4	14	18



# NCHRP

REPORT 785

NATIONAL  
COOPERATIVE  
HIGHWAY  
RESEARCH  
PROGRAM

## Performance-Based Analysis of Geometric Design of Highways and Streets

TRANSPORTATION RESEARCH BOARD  
OF THE NATIONAL ACADEMIES

presents an

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project,  
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ons on those  
measures,  
t **solutions**  
ne overall  
t **outcomes.**”



# A definition

...an **OUTCOME** based  
rather than  
**OUTPUT** based  
methodology



# All that research...

Topic (SORTED BY TOTAL VOTES)	AASHTO Votes (22)	TRB Votes (34)	Total Votes
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Horizontal Curve Design Philosophy (Should it be for driver comfort?) (1.1)/Determine FHWA Horizontal Curve Design Practices	4	14	18



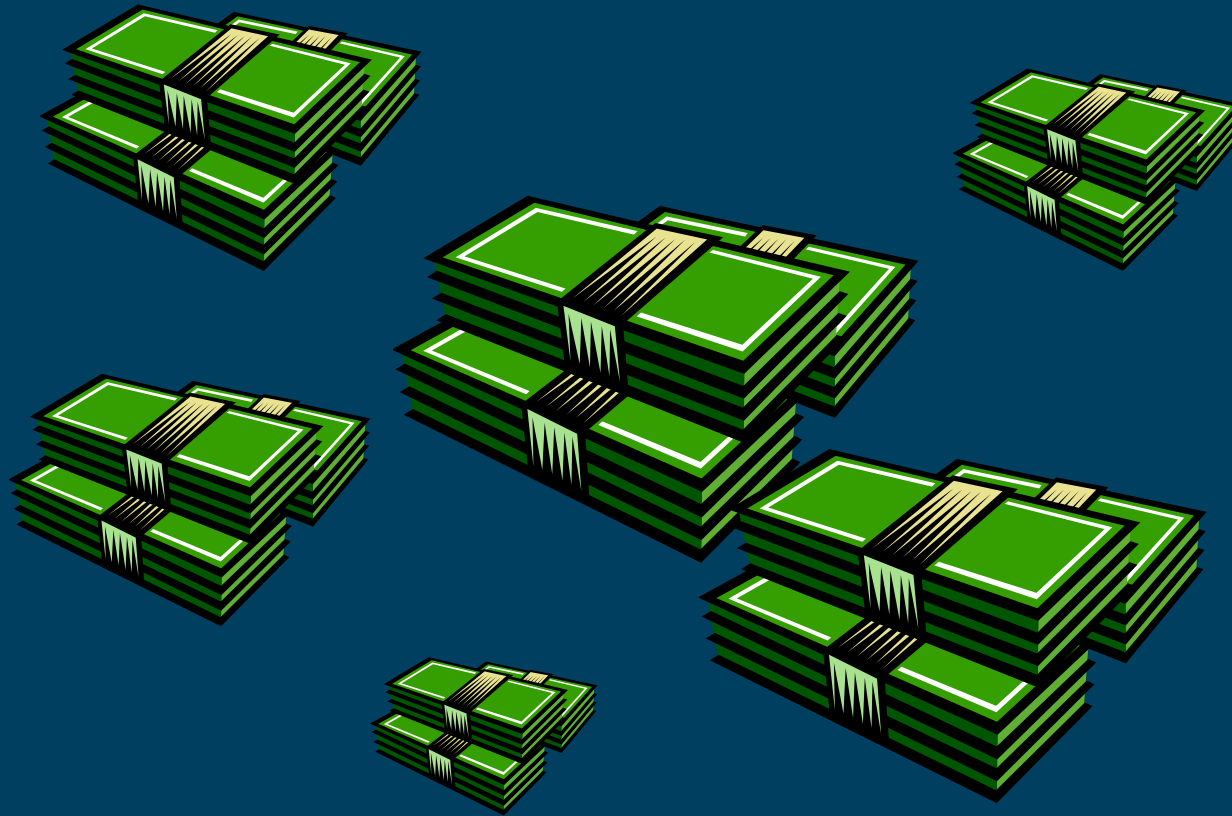
# Ongoing research

## NCHRP Project 15-47 “An Improved Geometric Design Process”

- ▶ AASHTO criteria should reflect known interactive effects
- ▶ AASHTO policy should replace dimensional guidance with direct performance
- ▶ Concept of “conservatism” needs to be reconsidered



# Why it's necessary





# Why it's necessary

**IN TERMS OF MONEY**

**WE HAVE NO MONEY.**



# Why it's necessary

## Context Sensitive Solutions

“You can always count on Americans to do the right thing – after they’ve tried everything else.”

Winston Churchill

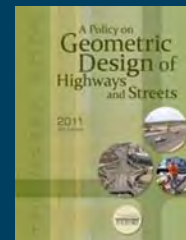
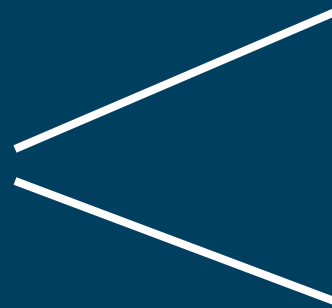


# Overall goal

## Context Sensitive Solutions

Tailoring solutions to the unique needs of each project context

Flexible ranges



Criteria



Tools



# So do design standards matter?

- ▶ Basically..... it depends
- ▶ Design standards provide a basis for consistent design of roads and highways
- ▶ A starting point in design, but not an absolute



# be more things change...

## 'Engineering and Contracting'

➤ August 12, 1914

### Engineering and Contracting

Devoted to the Economics of Civil Engineering Standards and to Methods and Cost of Construction

Volume XLII.

CHICAGO, ILL., AUGUST 12, 1914.

Number 7.

#### The Adverse Freight Rate Decision as an Incentive to Speedy Completion of Railway Appraisals.

The time required to appraise all the railroads in America has been put at five to eight years, according to those acting for the Interstate Commerce Commission. Yet it is not impracticable for every railway to finish its own appraisal within less than two years, and it would now seem to be desirable in most cases to do so. The somewhat adverse freight rate decision that left the railroads without general hope of an advance in rates until appraisal demonstrates the necessity of greater incentive if there is to be a "fair return" on the value of their investments.

Several months ago we expressed doubt as to the practicability of raising rates in general until such time as appraisals make such ratings imperative. The granting of a rate 15 per cent increase in average rates where a per cent was asked seems out of proportion and emphasizes the necessity of rapid work on the appraisals.

Comparatively few people, even among investors in railway securities, know that there exists a published appraisal of the New York, New Haven & Hartford Ry. (See *Economics of the Railroads*, Feb. 21, 1912, at the Appendix.) Still fewer have taken pains to know the results, and these would be less profitable as to the returns earned power of that property. Certainly if rates are to be based on cost of reproduction, the "New Haven" system is entitled to much higher rates than it now enjoys. We doubt not that the same holds true of most railway properties.

An appraisal of the Litchfield Valley Ry. has been completed, and it has been assumed that appraisals of several other large railway systems are practically completed. Even those railways that have thus far done little toward an appraisal could have a complete valuation completed by the end of 1915, were the necessity apparent. To us there seems to be necessity for such action on the part of every railway. And as fast as each railway completes its appraisal it should file its returns in rates—both interstate and intrastate—if existing rates do not yield a "fair return."

#### Classification of the Steel Production in 1913.

Data collected by the Bureau of Statistics of the American Iron and Steel Institute give some interesting information concerning the production of steel ingots and castings. The total production of all kinds of steel ingots and castings in 1913 was 31,010,717 tons, as against 28,127,000 tons in 1912. Of the 1913 production of steel, 26,800,150 tons were ingots and 1,424,714 tons were castings, while in 1912, 26,284,982 tons of ingots and 956,023 tons of castings were produced. The production of steel consisted of 9,545,704 tons of Bessemer steel, 11,559,081 tons of open-hearth steel and 149,933 tons of crucible and other kinds of steel. This output was produced by 104 works in 29 states, the District of Columbia and the Territories of Alaska and Arizona. The increasing use of alloy steel is shown by the fact that in 1913 1,413,017 tons of ingots and castings were treated with ferro-titanium, ferro-vanadium, ferro-chrome, nickel, or some other alloy, of which 63,453 tons were ingots and 84,027 tons were castings. Of the total production of alloy steels in 1913, 71,934 tons were Bessemer steel ingots or castings, 592,829 tons were open-

hearth steel, 28,279 tons were crucible, 11,204 tons were electric, and 10 tons were produced by miscellaneous processes.

The total production of Bessemer steel in 1913—9,545,704 tons—consisted of 4,855,000 tons of ingots and 85,000 tons of castings. Of this tonnage, 4,146,282 tons were made by the standard Bessemer process, 62,400 tons by the Trueman process, and 37,432 tons by other modifications of the standard Bessemer process. In connection with this output it is interesting to note that the production of Bessemer steel was a maximum in 1903, when 13,275,820 tons were produced.

The 1913 output of open-hearth steel—21,596,293 tons—consisted of 21,686,715 tons of ingots and 112,578 tons of castings. In 1908 the production of open-hearth steel for the first time exceeded that of Bessemer steel, the excess amounting to 1,719,714 tons, or about 28 per cent. In 1913 this excess amounted to 12,651,235 tons, or about 216 per cent, which shows the increasing popularity of open-hearth steel.

Of the total production of crucible steel in 1913—11,204 tons—about 28,729 tons consisted of various alloy steels, of which 25,262 tons were ingots and 2,467 tons were castings. The maximum production of crucible steel was reached in 1907, when 19,124 tons were produced.

Included in the 1913 output of electric steel—26,189 tons—were 21,370 tons of ingots and 8,297 tons of castings. The production of steel by the electric process reached its maximum value—141,141 tons—in 1916. In 1913 the total production was only 18,800 tons. On Dec. 31, 1914, there were 10 plants equipped to manufacture steel by the electric process, as compared with 34 at the close of 1912. In addition to those in operation in 1913, 3 plants were being built and 2 were projected.

The production of open-hearth ingots in 1913 by the basic process was 19,884,485 tons, while the production by the acid process was only 401,950 tons. Of the 1912 output of open-hearth steel castings, 460,351 tons were made by the basic process and 484,055 tons by the acid process.

Included in the 20,344,436 tons of basic open-hearth steel ingots and castings produced in 1913 are 2,136,718 tons, which were produced from metal partly refined in Bessemer converters and finally refined in basic open-hearth steel furnaces. The increase in the amount of steel produced by this acid process in 1913 over that produced in 1912 was about 24 per cent. In 1913 duplex steel ingots and castings were produced by three works, as against seven works in 1912.

At the close of 1913 there were 193 completed open-hearth steel plants; while 116 plants were equipped to make steel by the Bessemer process. At this time seven open-hearth steel plants were being built and five were projected, while only one Bessemer plant was being built, although eight modified Bessemer plants were projected.

#### The Use and Abuse of Road Standards.

Standards for road and bridge details are issued by most of the highway commissions. These standards comprise general set detailed plans of various kinds, illustrating typical structures frequently encountered in road, river and bridge design and are in effect a reconstructed method of design and construction for these structures.

It is perhaps somewhat unfortunate that the word "standards" should have been chosen to designate these plans. Strictly interpreted, the standard design would indicate that the design was the best design. This is by no means the case when it is intended to mean this. Standards are merely recommended designs which are to be selected under conditions which are to be selected under which it is proposed to use or build. They are not to be used as a guide in laying out and building structures with the idea that, thereby, simplicity of construction is favored, the work of designing reduced and greater efficiency and better workmanship secured in construction.

And yet these standards are accepted as criteria by many engineers. Doubtless they are, in most cases, excellent designs if constructed under which it is proposed to use or build. They are not to be used as a guide in laying out and building structures with the idea that, thereby, simplicity of construction is favored, the work of designing reduced and greater efficiency and better workmanship secured in construction. And yet these standards are accepted as criteria by many engineers. Doubtless they are, in most cases, excellent designs if constructed under which it is proposed to use or build. They are not to be used as a guide in laying out and building structures with the idea that, thereby, simplicity of construction is favored, the work of designing reduced and greater efficiency and better workmanship secured in construction.

If this point is kept in mind there are many advantages to be derived from a thorough knowledge of the standards in use in various sections of the country. As a rule they are designs prepared by engineers of wide experience and of prominence in their profession and they represent the crystallization of ideas imparted by nature's judgment and years of observation. A young engineer and an old engineer, inexperienced in the class of work to which they refer, may compare and study them with profit. There is no quicker or better method of becoming familiar with what is commonly called "good practice." But in this study the engineer must acquaint himself thoroughly with the conditions for which the standards were prepared.

For example, selecting the article on Iowa road standards published in this journal, a number of questions must be answered in order to secure the greatest benefit from a study of the article. What are the soil and climatic conditions existing in that state, how are they generally distributed, what are the labor conditions, of what type and how heavy is the road traffic, what is the average value of land in which conditions are the people principally engaged, are points which should be considered. With knowledge of conditions, a study of designs prepared to fulfill them is very instructive.

There is, however, a grave danger attendant on the use of standards of any kind. The temptation is to neglect the detailed study of local conditions and use a standard structure. This often results not only in an unnecessary increase in the cost of a standard structure, but may result in a type of construction which is not suited to the location where used.

The foregoing are some of the chief indications against the use of standards. They are old indications, as are those against the use of formulae and cost data, and yet in spite of criticism standards still remain the main aids of the engineer, and are in effect a reconstructed method of design and construction for these structures.

## The Use and Abuse of Road Standards.

"Strictly interpreted, the meaning would indicate that the standard design was the best design."

"Standards are merely recommended designs which are to be adhered to unless conditions indicate that a variation in the design would meet them better."

"The temptation is to neglect the detailed study of local conditions..."



# Safety Performance vs. Design Speed

Rural 2-Lane 2-Way Highways  
Examined 3,633 Miles

Posted Speed	Number of Miles	Average Crash Rate	Average Fatal and Serious Injury Rate
40	8.0	1.29	0.00
45	6.0	0.85	0.00
50	191	0.66	2.53
55	3,226	0.35	1.71
60	203	0.27	1.40
<b>STATEWIDE AVERAGE</b>	<b>8,369</b>	<b>0.32</b>	<b>1.60</b>



# Safety Performance vs. Design Speed

Rural 2-Lane 2-Way Highways  
Examined 3,633 Miles

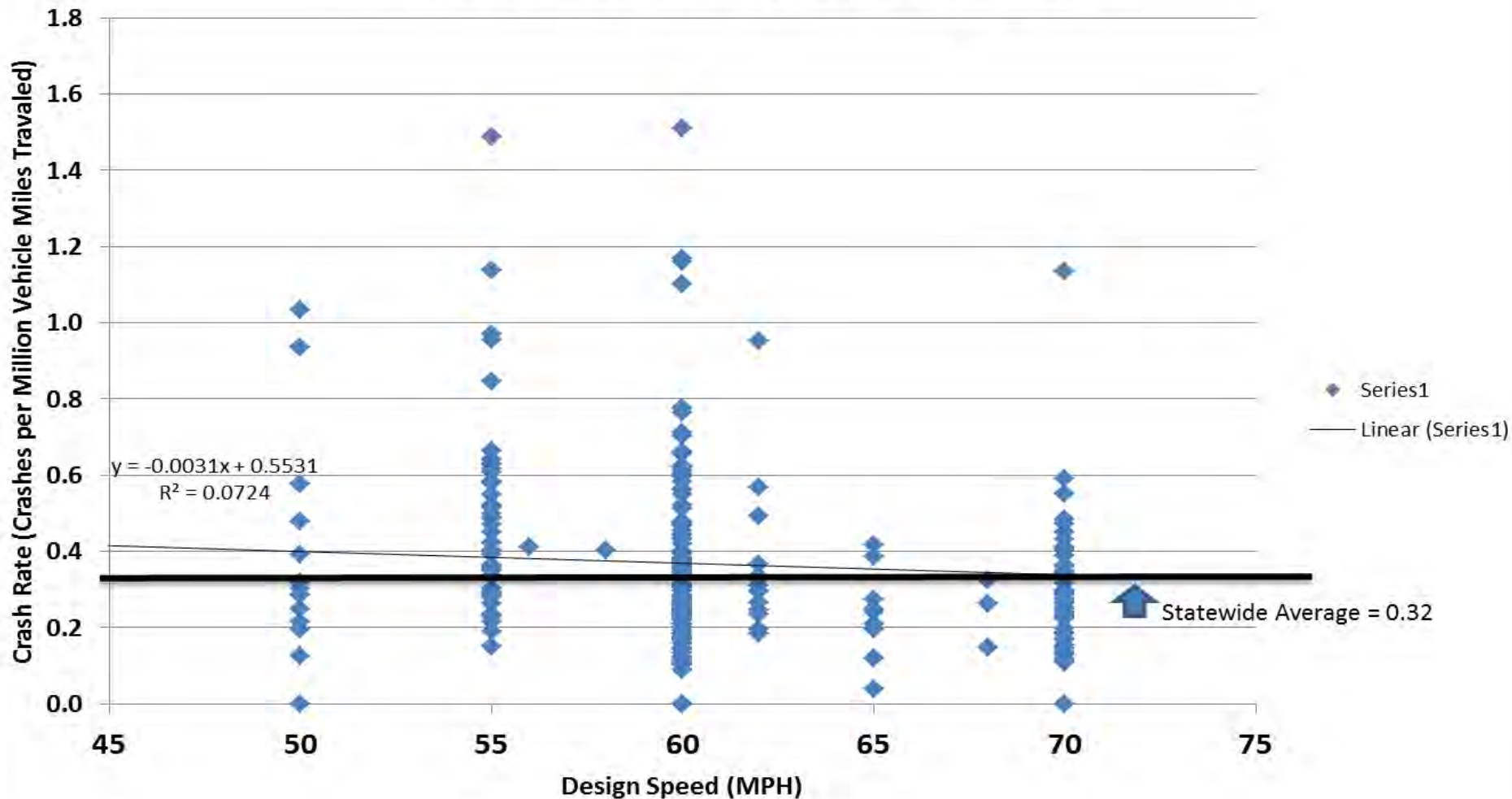
Design Speed	Number of Miles	Average Crash Rate	Average Fatal and Serious Injury Rate
No Design Speed	584	0.43	2.17
30-40	79	0.51	3.68
50	182	0.36	1.46
55-59	494	0.43	1.78
60-64	1,522	0.36	1.53
65-69	160	0.22	1.09
70+	612	0.28	1.85
<b>STATEWIDE AVERAGE</b>	<b>8,369</b>	<b>0.32</b>	<b>1.60</b>



# Safety Performance vs. Design Speed

Rural 2-Lane 2-Way Highways  
Examined 3,633 Miles

## Crash Rate (Seg Only) vs. Design Speed

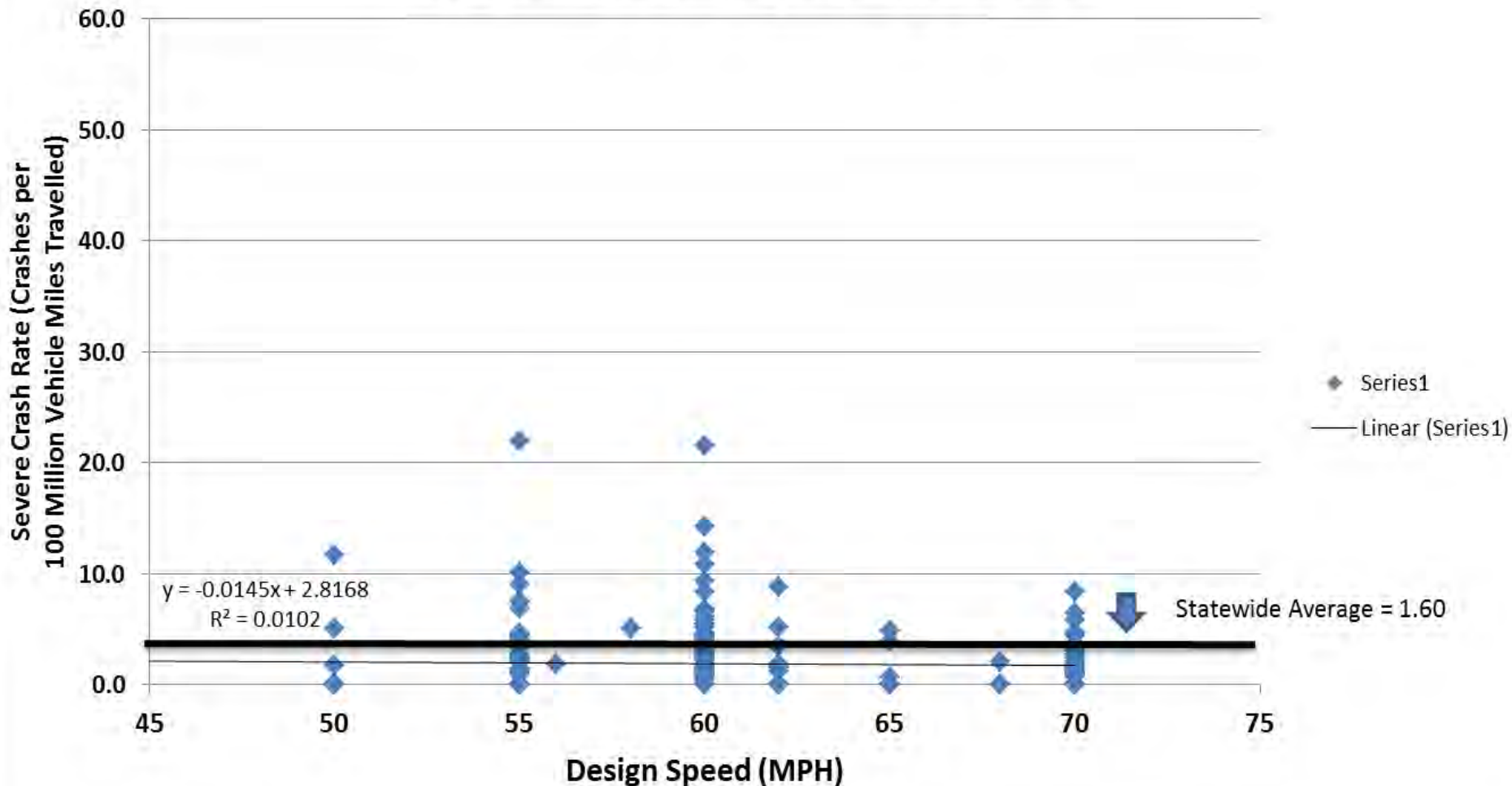




# Safety Performance vs. Design Speed

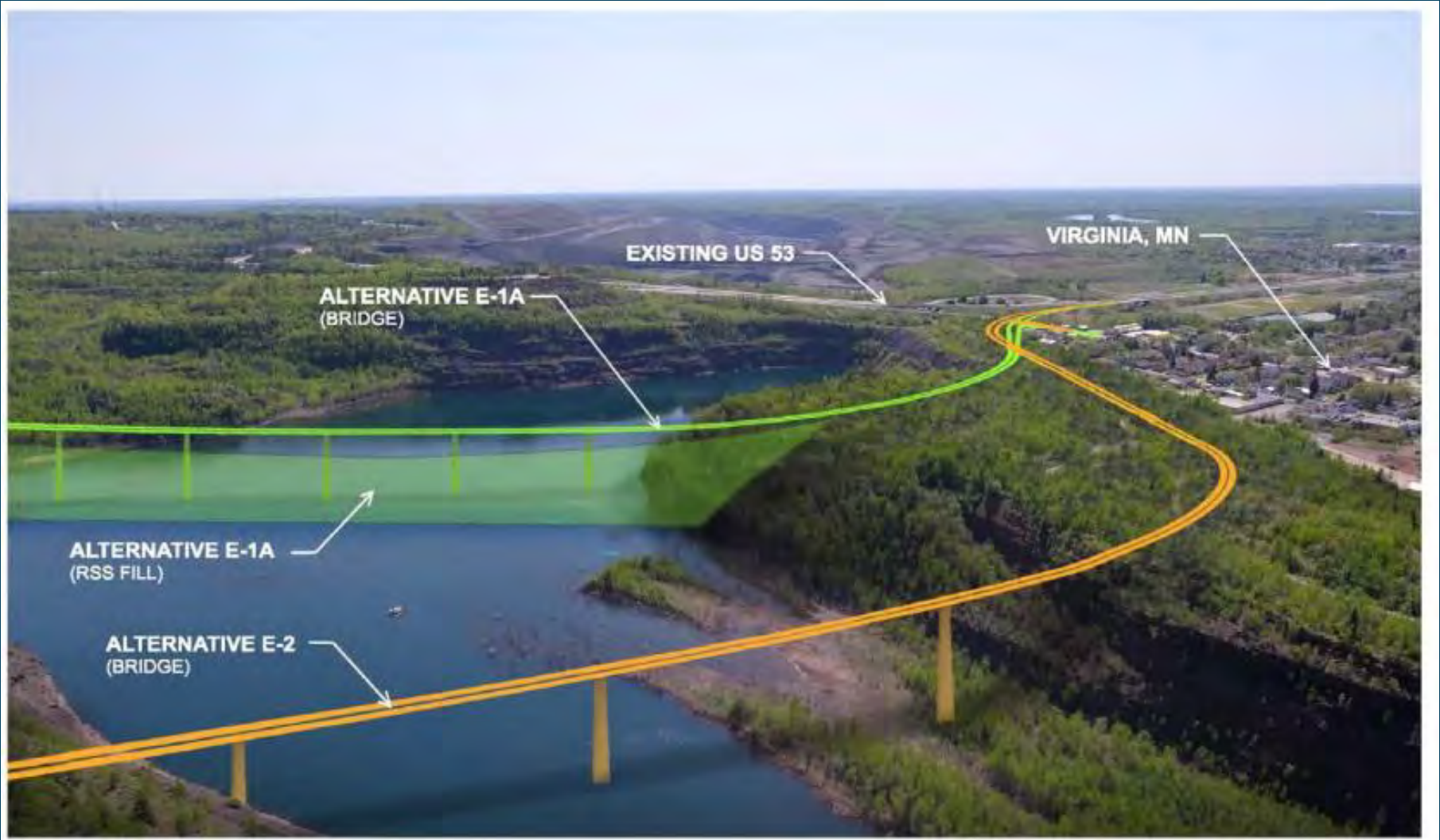
Rural 2-Lane 2-Way Highways  
Examined 3,633 Miles

## FA Rate (Seg Only) vs. Design Speed



# US 53 Alternates

## 1,135' Bridge Cross Section Analysis



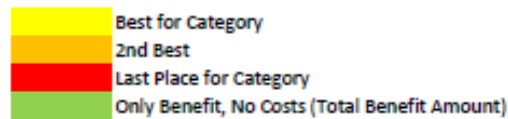
# US 53 Alternates

## 1,135' Bridge Cross Section Analysis

For the 1135' US53/ Virginia Bridge: 2017-2026, 10 years of Total Predicted Crashes , Both Directions

For 1135', for 10 years

Alt No.	Description	Total Typical Section (ft)	Injury	PDO	Total	Cost of Injury	Cost of PDO	Benefit over 10 years	Benefit over 30 Years	Cost Per Square Foot	Additional Square Footage (SQ FT)	Total Additional Cost	Benefit/Cost
1	4'-12'-12'-8' (BASE)	36	4.5	8.7	13.1	\$ 158,200	\$ 7,400	NA	NA	NA	NA	NA	NA
2	4'-12'-12'-10'	38	4.0	8.7	12.7	\$ 158,200	\$ 7,400	\$ 68,026	\$ 204,078	\$ 100.00	4,540	\$ 454,000.00	\$ 0.45
3	4'-12'-12'-12'	40	3.7	8.7	12.3	\$ 158,200	\$ 7,400	\$ 125,848	\$ 377,544	\$ 100.00	9,080	\$ 908,000.00	\$ 0.42
4	6'-12'-12'-10'	40	3.9	8.4	12.3	\$ 158,200	\$ 7,400	\$ 90,343	\$ 271,029	\$ 100.00	9,080	\$ 908,000.00	\$ 0.30
5	6'-12'-12'-12'	42	3.5	8.4	11.9	\$ 158,200	\$ 7,400	\$ 148,165	\$ 444,495	\$ 100.00	13,620	\$ 1,362,000.00	\$ 0.33
10	2'-12'-12'-10'	36	4.2	8.9	13.1	\$ 158,200	\$ 7,400	\$ 42,149	\$ 126,446	\$ 100.00	NA	No Cost/Only Benefit	
13	4'-11'-11'-8'	34	4.6	8.7	13.3	\$ 158,200	\$ 7,400	\$ (27,210)	\$ (81,631)	\$ 100.00	(4,540)	\$ (454,000.00)	\$ 5.56
14	4'-11'-11'-10'	36	4.2	8.7	12.9	\$ 158,200	\$ 7,400	\$ 40,816	\$ 122,447	\$ 100.00	-	No Cost/Only Benefit	
11a	2'-12'-12'-8'	34	4.6	8.9	13.5	\$ 158,200	\$ 7,400	\$ (29,279)	\$ (87,836)	\$ 100.00	(4,540)	\$ (454,000.00)	\$ 5.17
7a	2'-11'-11'-4'	28	5.9	8.9	14.9	\$ 158,200	\$ 7,400	\$ (233,357)	\$ (700,070)	\$ 100.00	(18,160)	\$ (1,816,000.00)	\$ 2.59
8a	4'-11'-11'-4'	30	5.7	8.7	14.4	\$ 158,200	\$ 7,400	\$ (200,677)	\$ (602,030)	\$ 100.00	(13,620)	\$ (1,362,000.00)	\$ 2.26
9a	4'-11'-11'-6'	32	5.1	8.7	13.8	\$ 158,200	\$ 7,400	\$ (108,842)	\$ (326,525)	\$ 100.00	(9,080)	\$ (908,000.00)	\$ 2.78



**\*Assumptions:**

Modeled as a rural freeway segment with barriers on both sides

2% Traffic Growth for 10 Years

The intersections/interchanges are not influencing the section.

There is no adjustment to the model for adverse weather or extreme circumstances, but are included within the crash frequency numbers.

No Congestion was added into the model.

The model is not calibrated for Minnesota Traffic Conditions. Prior calibrations have resulted in reducing the number of predicted crashes.

Rumble Strips added \$10,000 to the "Cost" side



# Questions?

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