NCHRP Project 3-88/Report 687: Guidelines for Ramp and Interchange Spacing

TRB Webinar

December 14, 2011

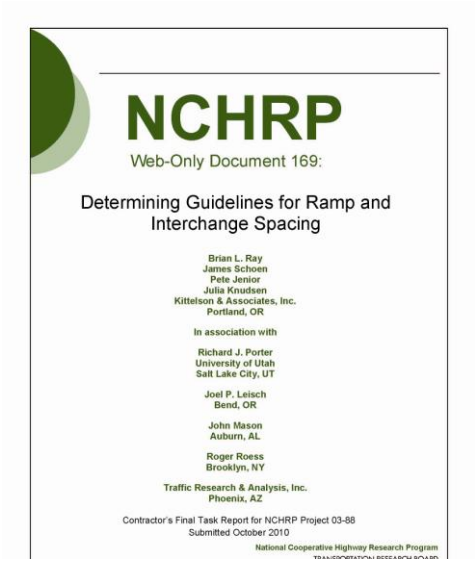
Moderator: Michael Ereti, City of Houston

Webinar Overview

- Project Introduction – Brian Ray
- Guidelines – Brian Ray
- Traffic Operations Work Plan – Pete Jenior
- Case Studies: Traffic Operations Focus – Pete Jenior
- Safety Work Plan – R.J. Porter
- Case Studies: Safety and Signing Focus – R.J. Porter
- Closing Remarks– Brian Ray
- Questions - All

Project Overview

- Team
  - *Kittelson & Associates, Inc. (Prime): Brian Ray, Jim Schoen, Pete Jenior, Julia Knudsen, Shaun Quayle, Alex Kiheri*
  - *Subs: University of Utah (R. J. Porter), Joel Leisch, John Mason, Roger Roess, and Traffic Research & Analysis*
- Schedule
  - *June 2008 to December 2010*
- Final Products Available on-line


NCHRP

Web-Only Document 169:

Determining Guidelines for Ramp and Interchange Spacing

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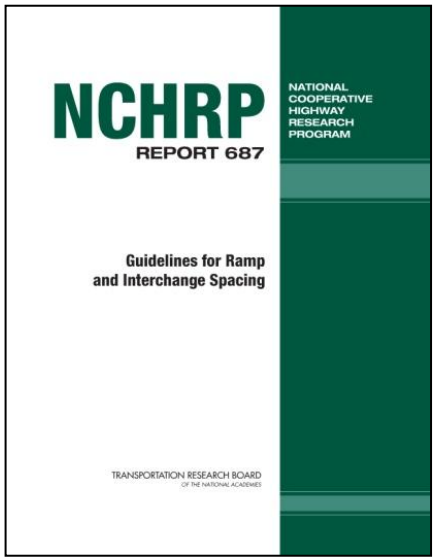
Contractor's Final Task Report for NCHRP Project 03-88
Submitted October 2010

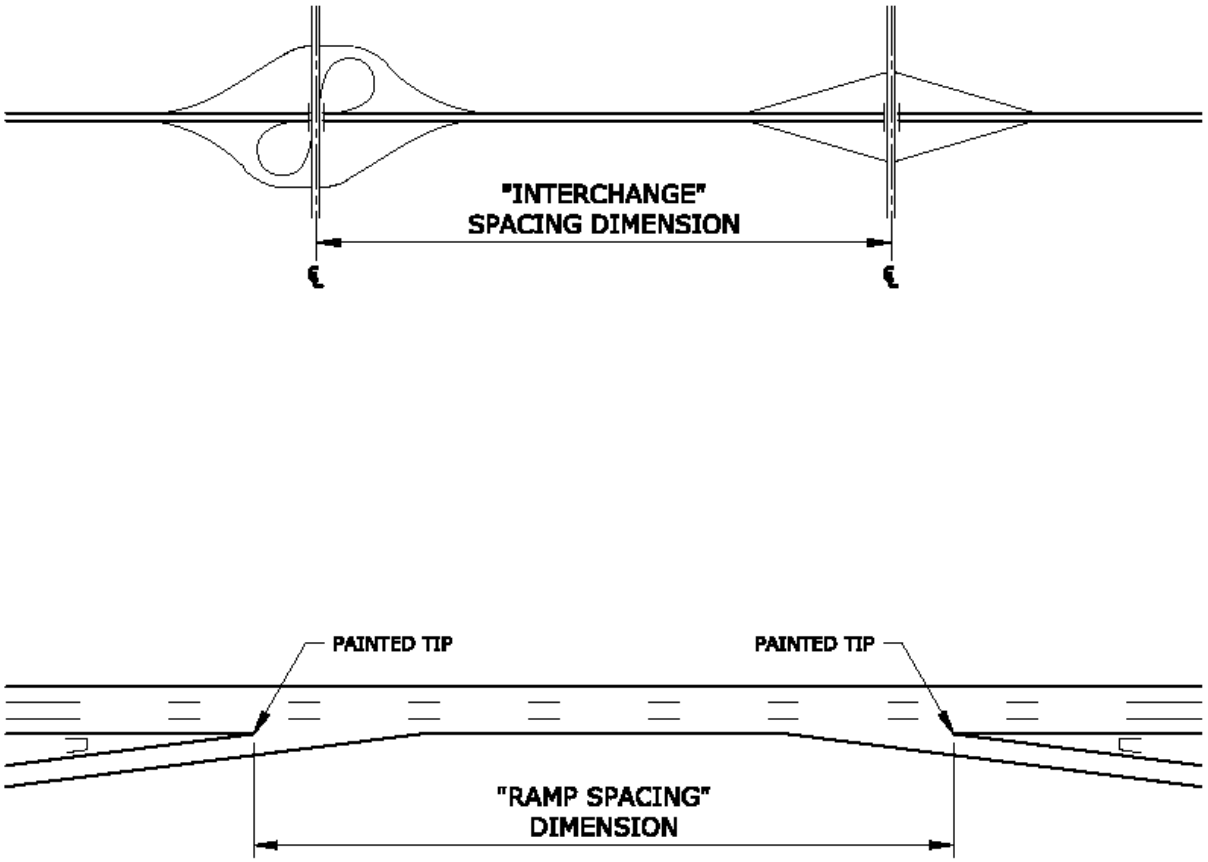
National Cooperative Highway Research Program



Project Introduction

- Identify factors that influence ramp and interchange spacing needs:
  - *Geometric Design*
  - *Traffic Operations*
  - *Safety*
  - *Signing*
- Conduct operations and safety research
- Develop Guidelines for ramp and interchange spacing

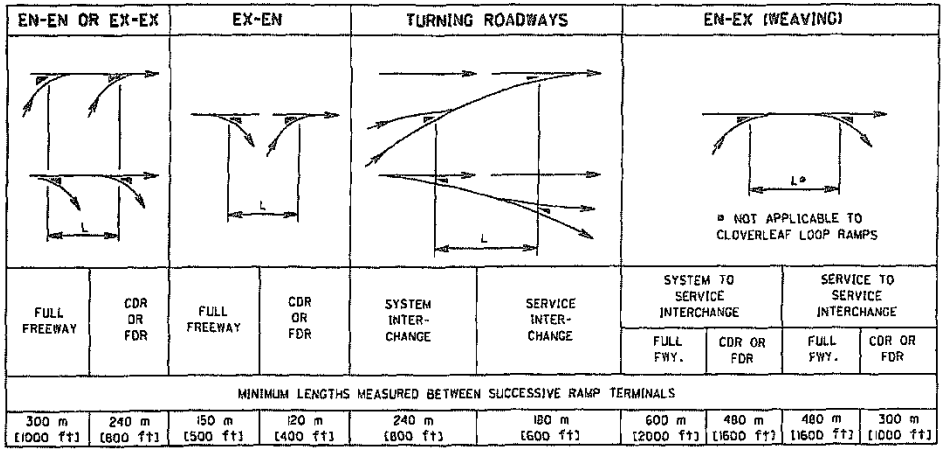
Definition of Spacing Used in Report 687



Report 687 emphasizes using ramp spacing versus interchange spacing

Current Spacing Guidelines

Guidance in 2004 AASHTO Green Book on ramp spacing:



EN-EN OR EX-EX		EX-EN		TURNING ROADWAYS		EN-EX (WEAVING)			
						SYSTEM TO SERVICE INTERCHANGE		SERVICE TO SERVICE INTERCHANGE	
FULL FREEWAY	CDR OR FDR	FULL FREEWAY	CDR OR FDR	SYSTEM INTER-CHANGE	SERVICE INTER-CHANGE	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]

a NOT APPLICABLE TO CLOVERLEAF LOOP RAMPS

NOTES: FDR - FREEWAY DISTRIBUTOR ROAD; CDR - COLLECTOR DISTRIBUTOR ROAD; EN - ENTRANCE; EX - EXIT

THE RECOMMENDATIONS ARE BASED ON OPERATIONAL EXPERIENCE AND NEED FOR FLEXIBILITY AND ADEQUATE SIGNING. THEY SHOULD BE CHECKED IN ACCORDANCE WITH THE PROCEDURE OUTLINED IN THE HIGHWAY CAPACITY MANUAL (4) 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 24 OF THE 2000 HIGHWAY CAPACITY MANUAL (4). THE "L" DISTANCES NOTED IN THE FIGURES ABOVE ARE BETWEEN LIKE POINTS, NOT NECESSARILY "PHYSICAL" GORES. A MINIMUM DISTANCE OF 90 m (270 ft) IS RECOMMENDED BETWEEN THE END OF THE TAPER FOR THE FIRST ON RAMP AND THE THEORETICAL GORE FOR THE SUCCEEDING ON RAMP FOR THE EN-EN (SIMILIAR FOR EX-EN).

Exhibit 10-68. Recommended Minimum Ramp Terminal Spacing

Guidance in AASHTO Green Book on interchange spacing: 1 mile urban, 2 miles rural

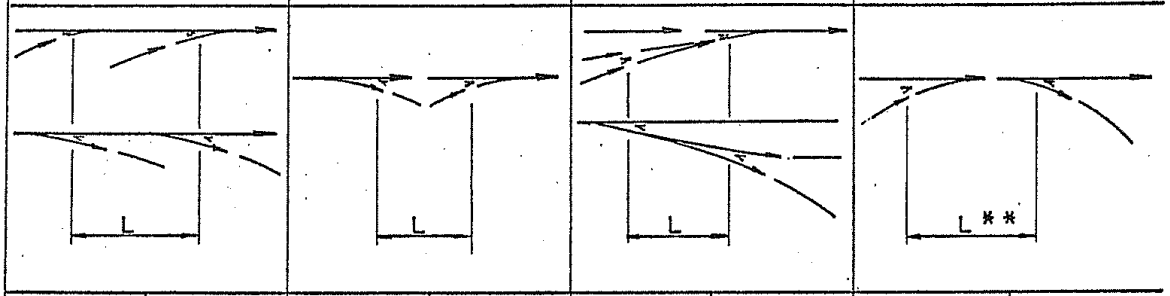
Origins of Current Guidelines

- Origins of current AASHTO Policy spacing guidance date to beginning of Interstate Highway era
- Early studies examined trade-offs
  - *Access to freeway versus mobility/performance of freeway*
  - *Performance of freeway versus performance of arterials*
- Interchange Spacing Guidance
  - *AASHTO Green Book (since 1984): 1 mile in urban areas, 2 miles in rural areas*
  - *Some states recommended longer spacings than this*
- Ramp Spacing Guidance
  - *AASHTO Green Book (since 1984) guidance based upon table on following slide*
  - *Dimensions are measured between "like points"*
  - *Previous AASHTO Policies (Red and Blue Books) offered other spacing dimensions*

Origins of Current Guidelines

Jack Leisch. Region 2 AASHTO Operating Committee on Design. 1975

*RECOMMENDED MINIMUM RAMP TERMINAL SPACING **



MINIMUM VALUES	EN-EN OR EX-EX: FULL FREEWAY	EN-EN OR EX-EX: C-D ROAD OR FWY. DIST.	EX-EN: FULL FREEWAY	EX-EN: C-D ROAD OR FWY. DIST.	TURNING ROADWAYS: SYSTEM INTERCHANGE	TURNING ROADWAYS: SERVICE INTERCHANGE	EN-EX (WEAVING): SYSTEM TO SERVICE INTERCHANGE: FULL FWY	EN-EX (WEAVING): SYSTEM TO SERVICE INTERCHANGE: C-D ROAD OR FWY DIST.	EN-EX (WEAVING): SERVICE TO SERVICE INTERCHANGE: FULL FWY	EN-EX (WEAVING): SERVICE TO SERVICE INTERCHANGE: C-D ROAD OR FWY DIST
DESIRABLE	1500	1200	750	600	1200	1000	3000	2000	2000	1500
ADEQUATE	1200	1000	600	500	1000	800	2500	1800	1800	1200
ABSOLUTE	1000	800	500	400	800	600	2000	1500	1500	1000

FIGURE 27

* BASED UPON OPERATIONAL EXPERIENCE AND NEED FOR FLEXIBILITY

** ALSO TO BE CHECKED IN ACCORDANCE WITH PROCEDURE OUTLINED IN THE HIGHWAY CAPACITY MANUAL, 1965 (LARGER OF THE VALUES TO BE USED)

Became Green Book Values

Guidelines

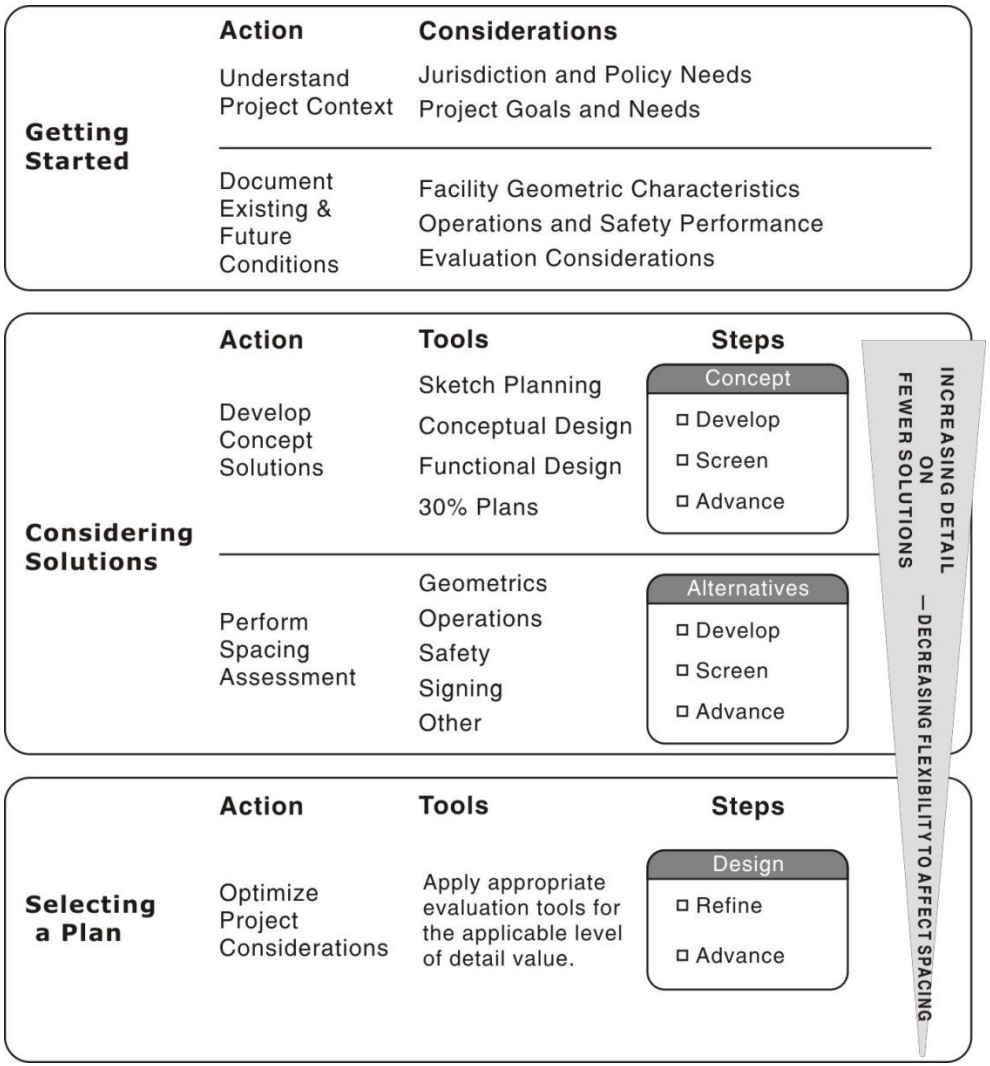
- Chapter 1 – Introduction
- Chapter 2 – Ramp and Interchange Spacing Overview
- Chapter 3 – Design and Signing Considerations
- Chapter 4 – Operational and Safety Considerations
- Chapter 5 – Spacing Guidance
- Chapter 6 – Scenario-Based Case Studies
- References
- Appendix A – Traffic Operations Tools

Guidelines - Principles

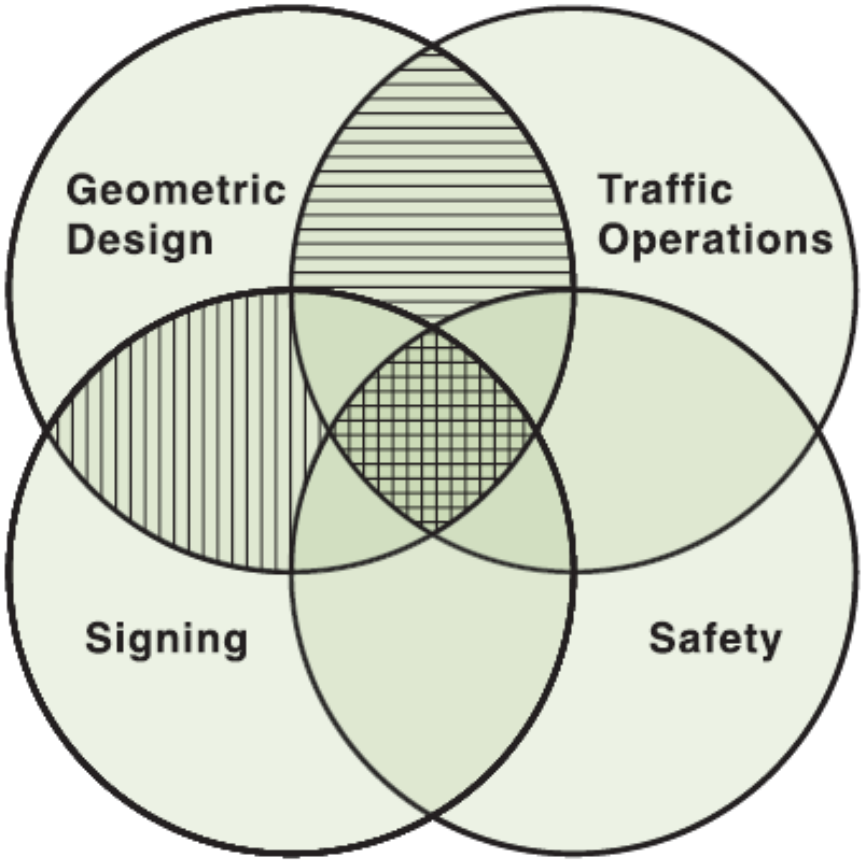
- Avoid “one size fits all” spacing values
- Customize spacing recommendations based on factors that affect ramp and interchange context
- Systematic approach that considers
  - *Geometric design*
  - *Traffic operations*
  - *Safety*
  - *Signing*
- Focus on ramp spacing
- Deemphasize interchange spacing

Guidelines Framework

- Understand the project context
- Consider ramp spacing at the earliest stages (including signing)
- Opportunities to affect spacing diminishes as design progresses
- Apply appropriate tools at the right time



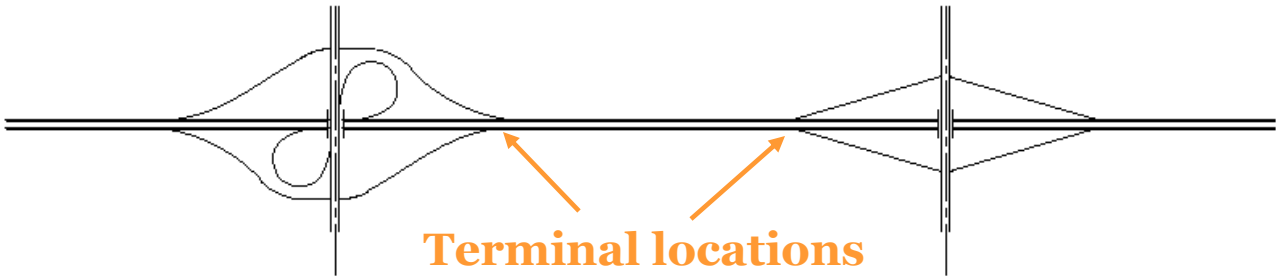
Guidelines – Chapter 5 (Spacing Guidance)



- Consider each of these four elements when assessing ramp spacing

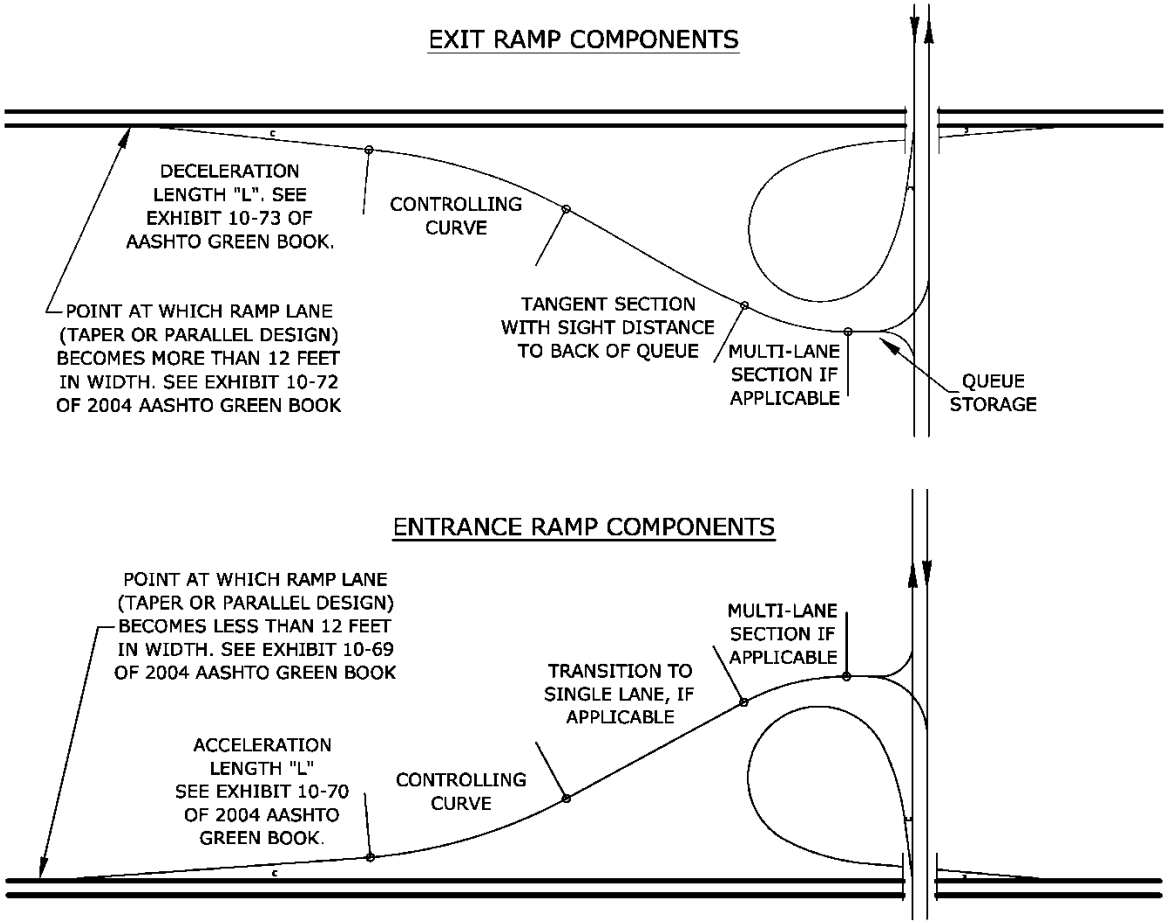
Spacing Guidance

- Minimum ramp spacing needs based up geometry vary due to differences in:
  - *Traffic volumes*
  - *Multi lane ramps*
  - *Interchange form*
  - *Terrain*
  - *Agency standards and preferences*
  - *Interchange configuration*
- Values recommended by Report 687 offer flexibility



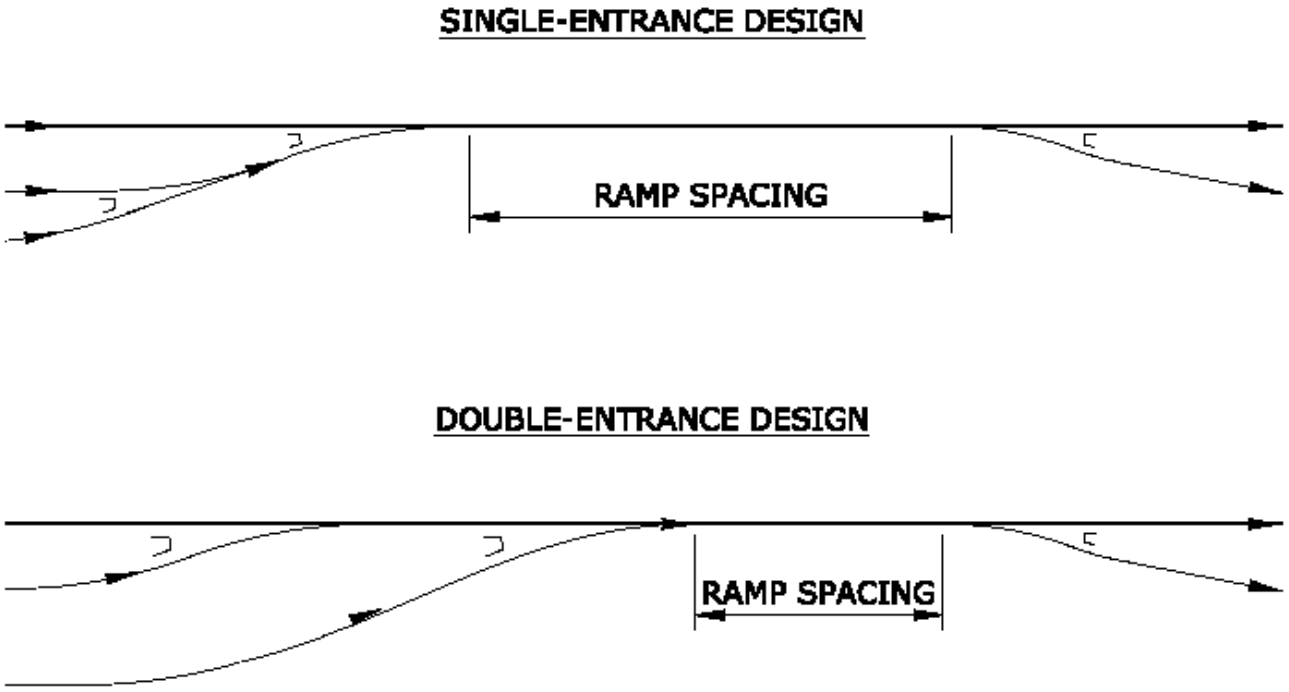
Design Elements Affecting Spacing Needs

- Ramp Design Components



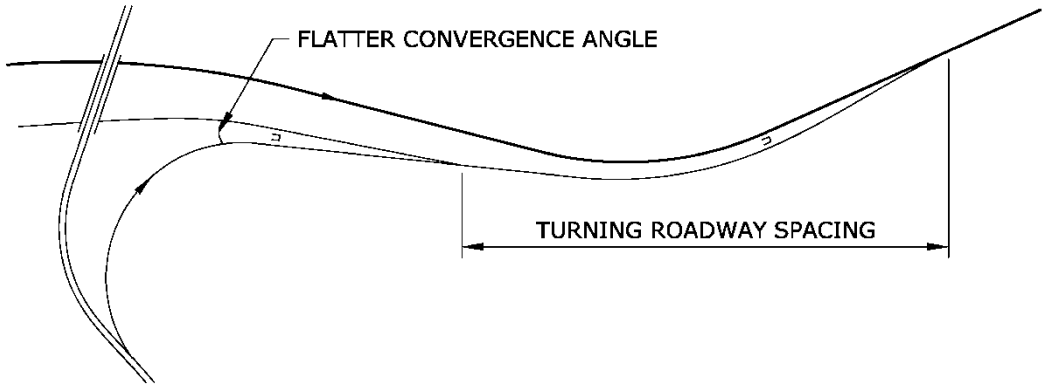
Design Elements Affecting Spacing Needs

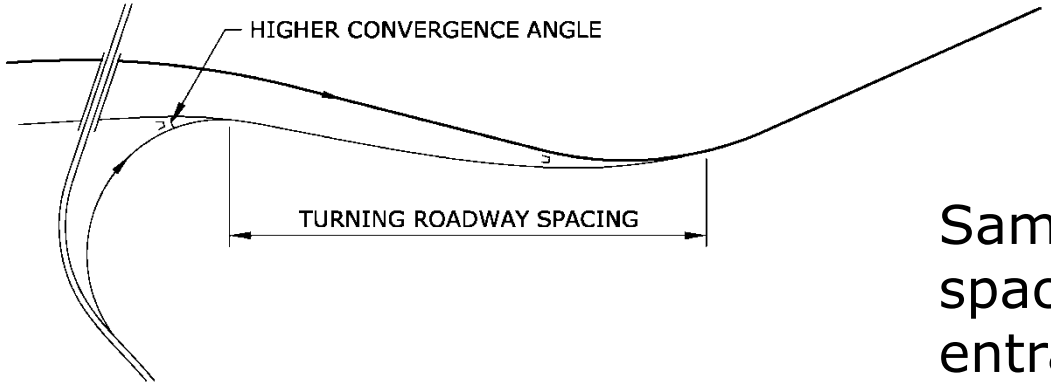
- Single entrance (or exit) versus double entrance design



Design Elements Affecting Spacing Needs

- Turning Roadways
  - *Convergence Angle*

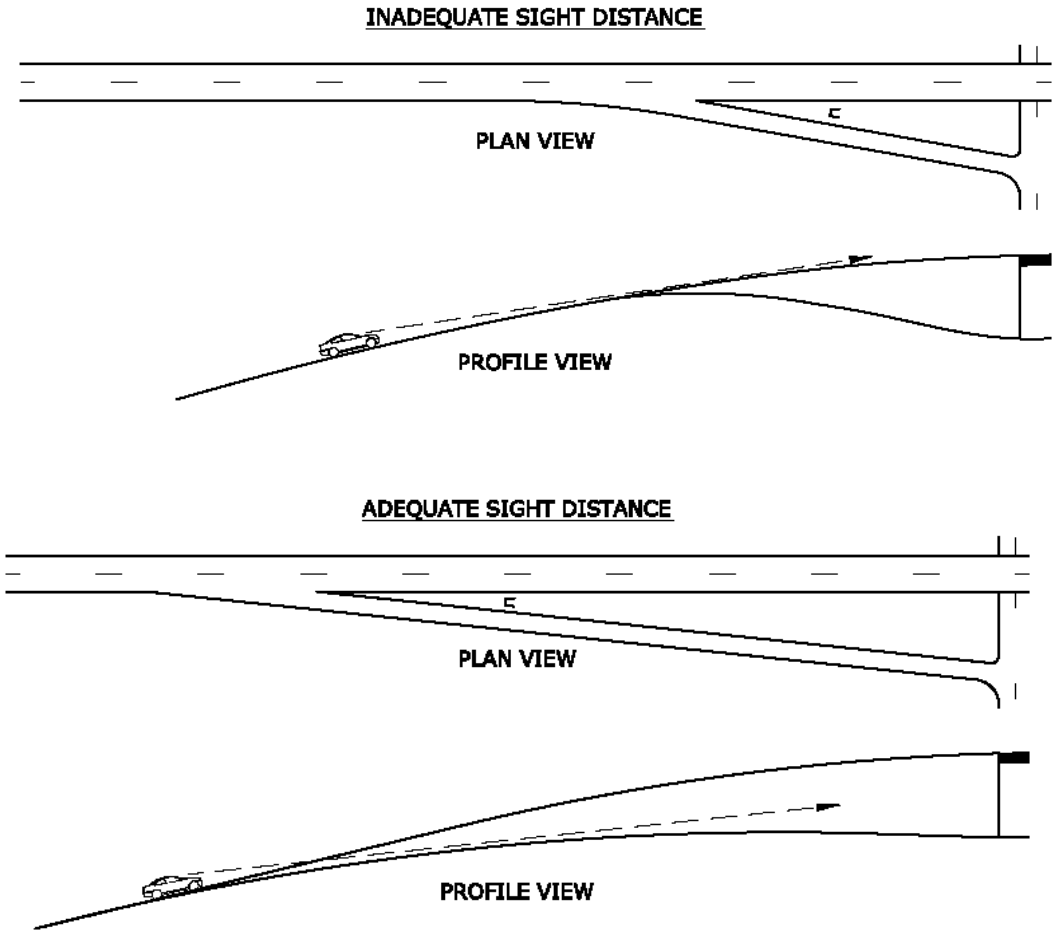




Same turning roadway spacing but a vastly different entrance terminal location

Design Elements Affecting Spacing Needs

- Sight Distance Needs



Spacing Guidance - Geometry

So, with design elements, traffic operations, safety considerations, and signing considerations, what is minimum spacing?

It depends, but…

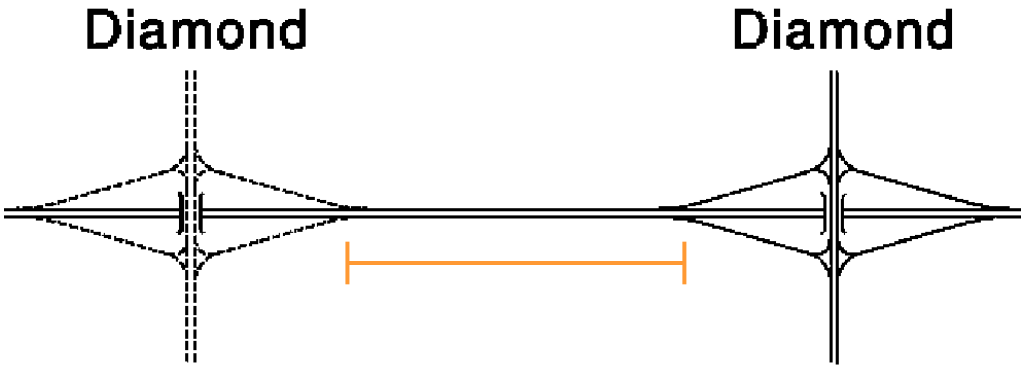
We can make some assumptions

Spacing Guidance - Geometry

- EN-EX Ramp Spacing Guidance

Between Diamond Interchanges

Ramp Spacing Dimension	Feasibility
Less than 1600'	Likely Not Geometrically Feasible
1600' to 2600'	Potentially Geometrically Feasible
Greater than 2600'	Likely Geometrically Feasible



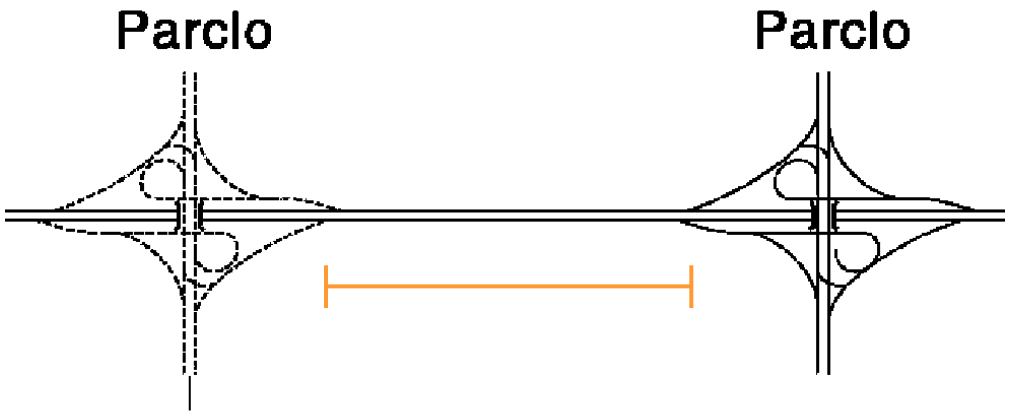
Spacing Guidance - Geometry

- EN-EX Ramp Spacing Guidance

Between Partial Cloverleaf Interchanges

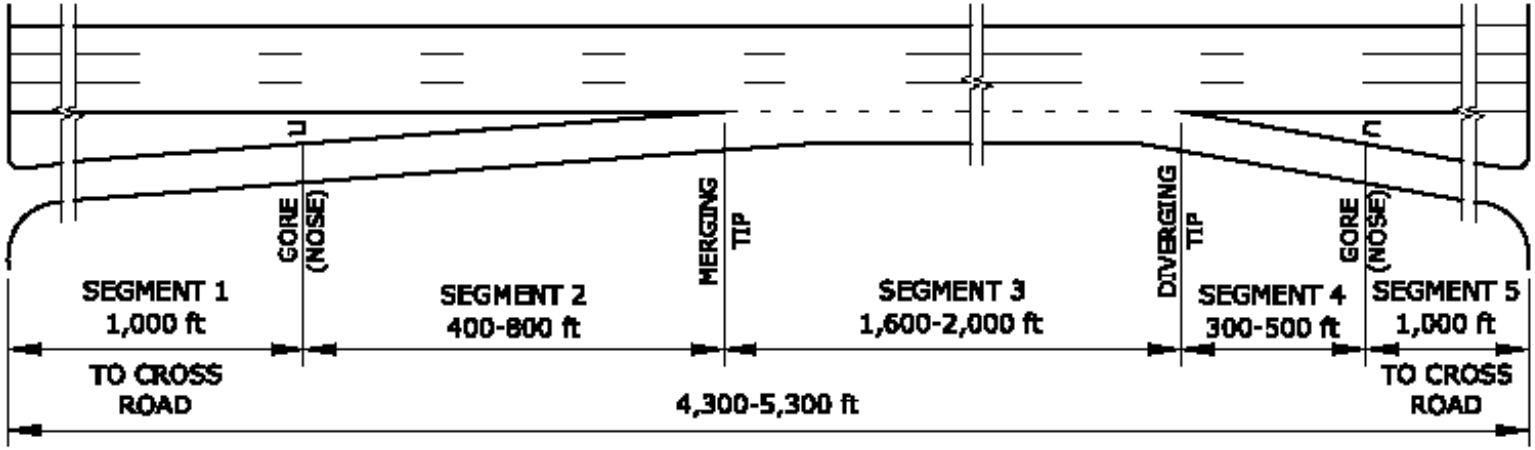
Ramp Spacing Dimension	Feasibility
Less than 1600'	Likely Not Geometrically Feasible
1600' to 1800'	Potentially Geometrically Feasible
Greater than 1800'	Likely Geometrically Feasible

Assumes single entrance and exit design for configurations with the loop in advance or beyond the cross street.



Spacing Guidance - Geometry

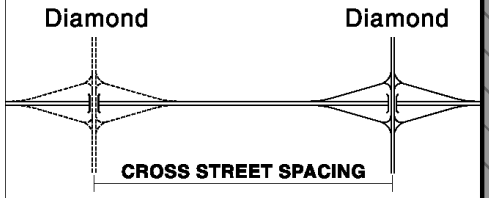
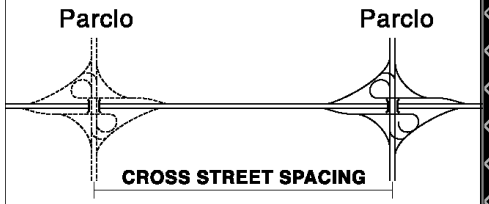
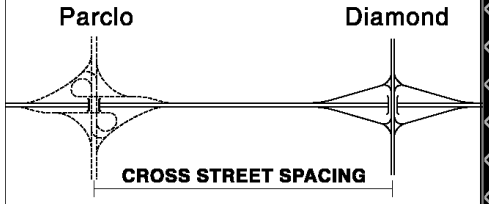
- From ramp spacing guidance and knowledge of design components, *interchange spacing* can be inferred



- **Source:** ITE Freeway and Interchange Geometric Design Handbook

Spacing Guidance - Geometry

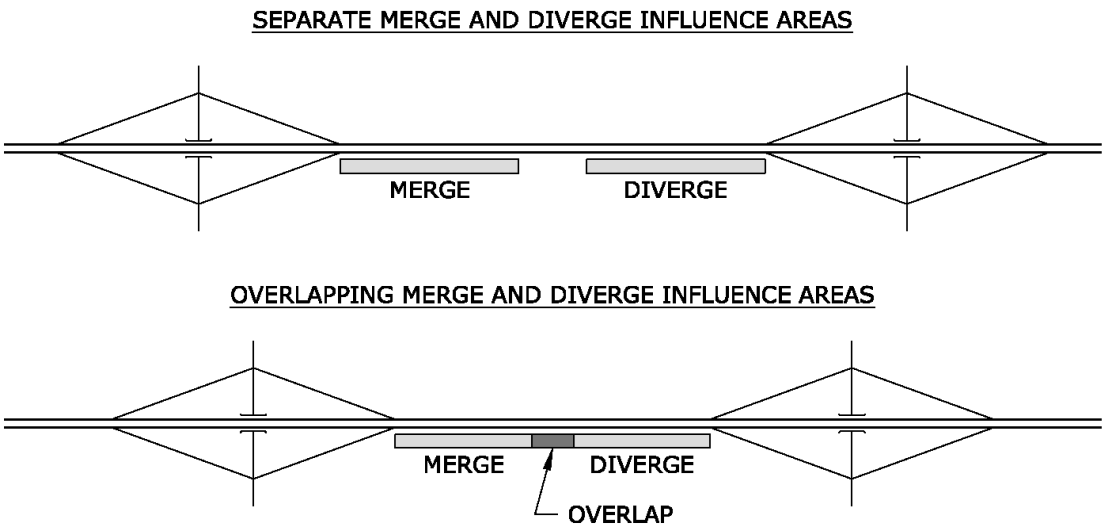
- Interchange Spacing GEOMETRIC DESIGN Feasibility

Interchange Form	Cross Street Spacing			
	4,000' – 4,500'	4,500' – 5,000'	5,000' – 5,500'	5,500' – 6,000'
	POTENTIALLY GEOMETRICALLY FEASIBLE	POTENTIALLY GEOMETRICALLY FEASIBLE	LIKELY GEOMETRICALLY FEASIBLE	LIKELY GEOMETRICALLY FEASIBLE
	LIKELY NOT GEOMETRICALLY FEASIBLE	LIKELY NOT GEOMETRICALLY FEASIBLE	POTENTIALLY GEOMETRICALLY FEASIBLE	LIKELY GEOMETRICALLY FEASIBLE
	LIKELY NOT GEOMETRICALLY FEASIBLE	POTENTIALLY GEOMETRICALLY FEASIBLE	LIKELY GEOMETRICALLY FEASIBLE	LIKELY GEOMETRICALLY FEASIBLE

- Use with caution! Consider your specific project context.

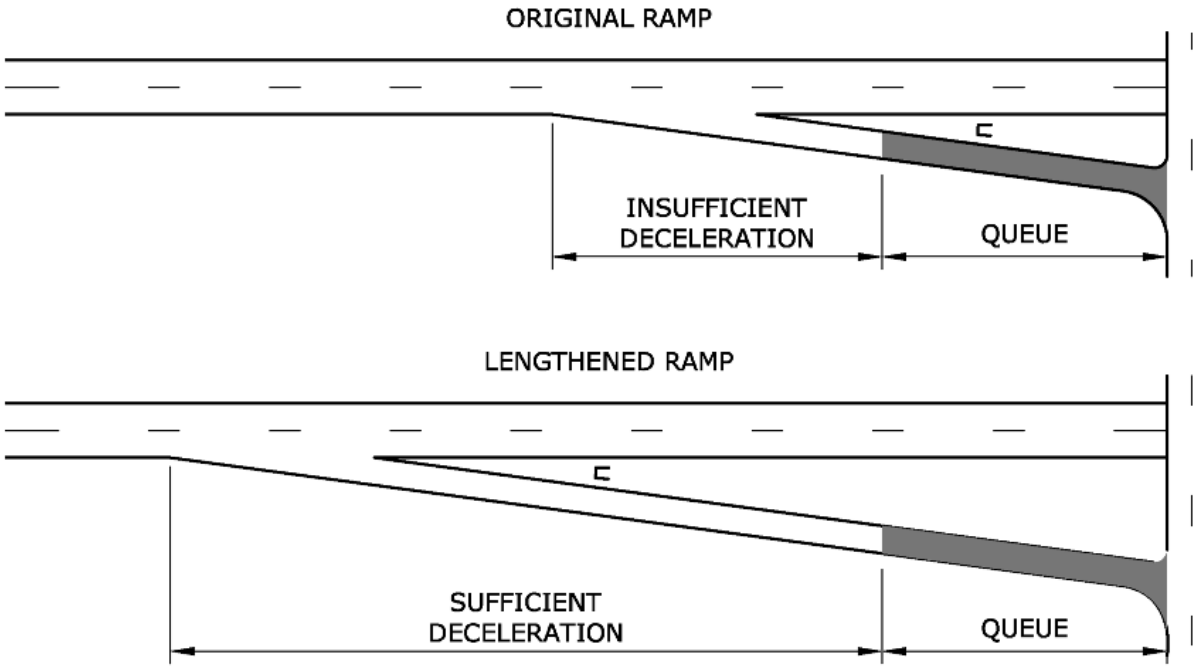
Spacing Guidance – Traffic Operations

- Considerations include
  - *Mainline freeway*
  - *Ramp terminal intersections*
  - *Isolated merges and diverges*
  - *Closely spaced merges and diverges*
  - *Weaving sections*



Operations Elements Affecting Spacing Needs

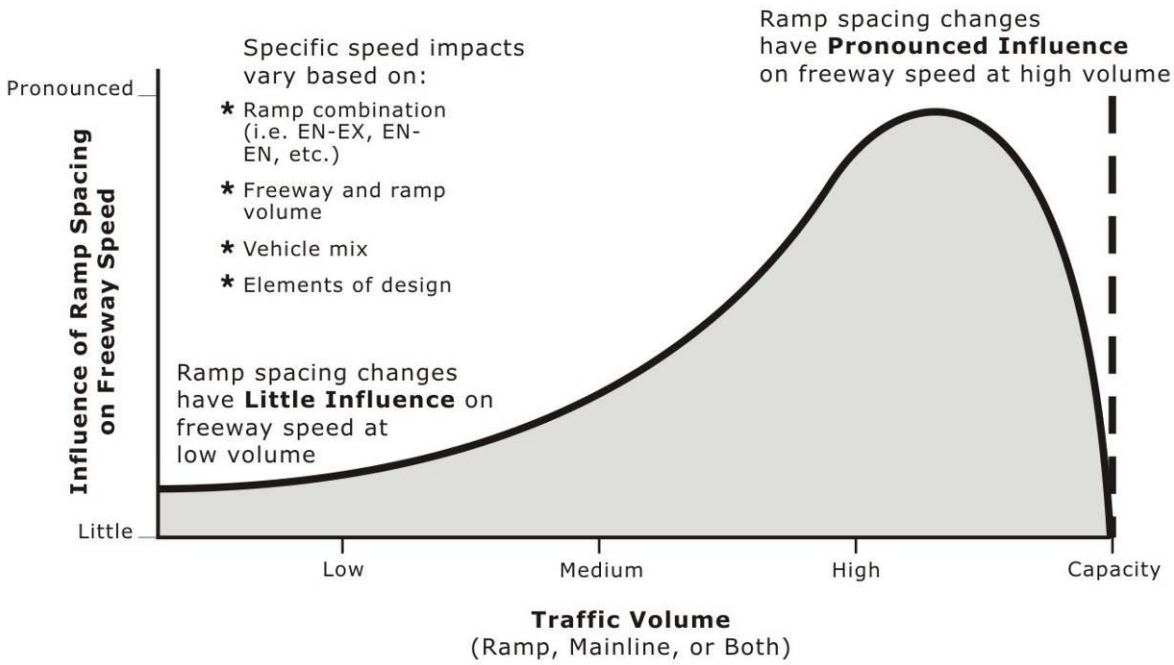
- Queue storage needs



- Terrain and grades
- Ramp meters (entrance ramps)
- Others

Spacing Guidance – Traffic Operations

- Spacing has the greatest impact on traffic operations when volumes are near capacity
- Spacing has less of an impact
  - *At lower volumes*
  - *At capacity, when major speed reductions have already occurred*



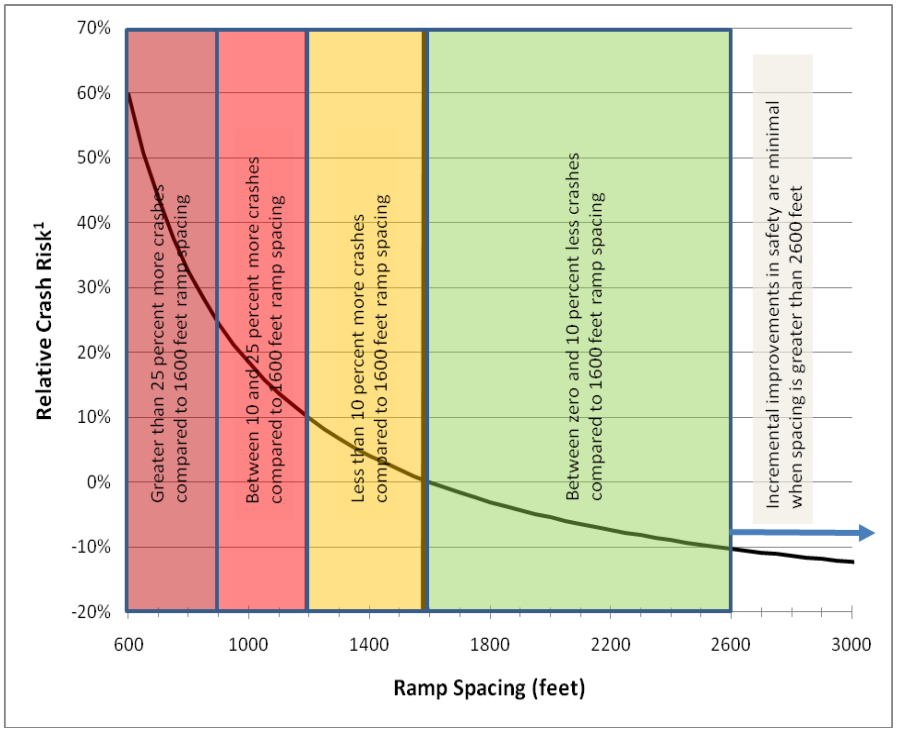
Spacing Guidance – Traffic Operations

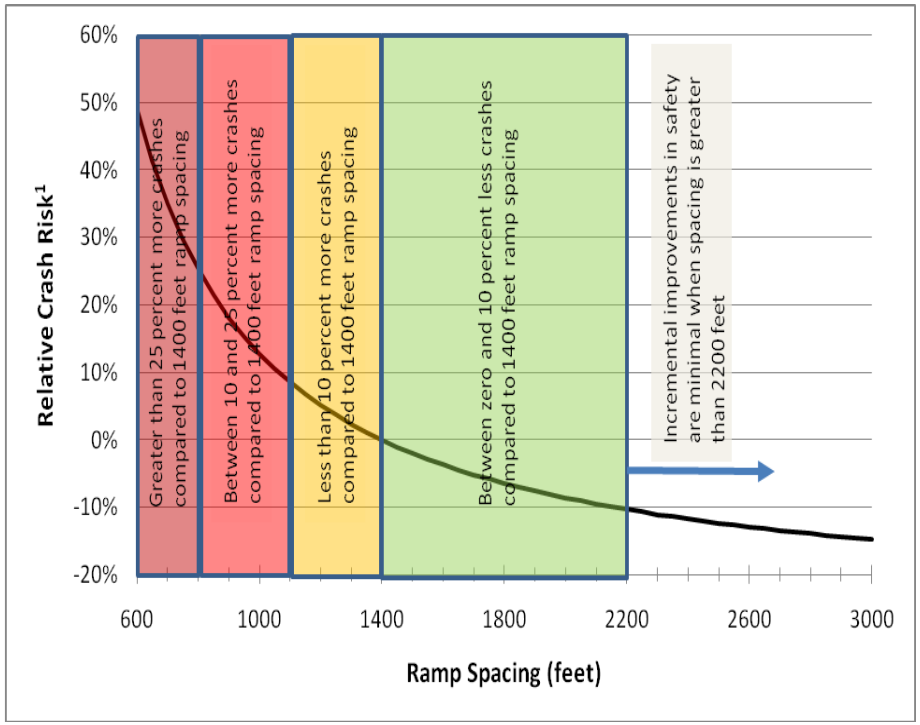
- Determine site-specific minimum values using:
  - *Planning-level tools*
    - ITE Ramp and Interchange Geometric Design Handbook
    - Tables in HCM
    - Findings of this project
  - *HCM Analysis*
  - *Microsimulation*
- Many variables involved – "one size fits all" spacing values cannot be provided.

Spacing Guidance - Safety

- Similar to traffic operations, many variables are involved
- These guidelines provide crash trends for entry-exit and entry-entry ramp combinations
- Graphs on following page illustrate trends based on our research

Spacing Guidance - Safety





[1] Relative crash risk is measured by the percent difference in crashes, of all types and severities, at some ramp spacing value compared to a ramp spacing of 1600 feet (for EN-EX) or 1400 feet (for EN-EN)

Entry – Exit

Entry - Entry

Spacing Guidance - Signing

- Usually other elements require greater spacing than signing does
- MUTCD requirements effectively dictate:
  - *800 feet between exit ramps*
  - *Maximum of 3 exit ramps per mile (4 if two ramps are part of the same interchange)*
  - *Complex ramps/interchanges with greater signing needs will require greater exit-exit ramp spacing.*

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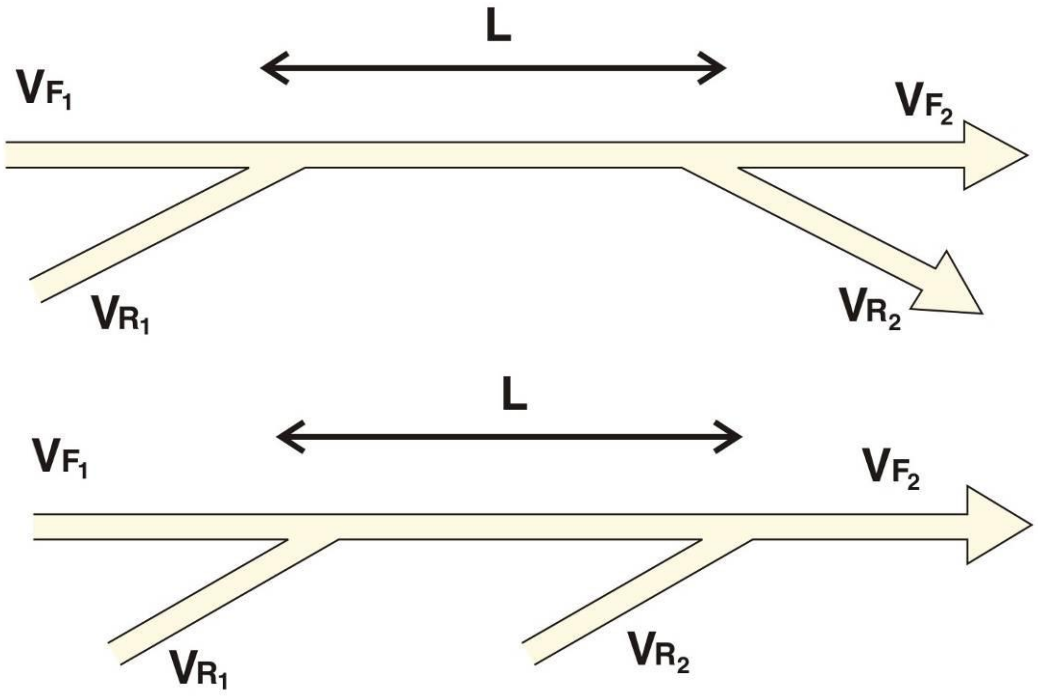
- Closing Remarks– Brian Ray
- Questions - All

Traffic Operations Work Plan (W.P.) - Goal

- How does changing "L" affect average vehicle speed?
- At what point does it "breakdown"?



V_F = Freeway volume
V_R = Ramp volume

Traffic Operations – Literature Review

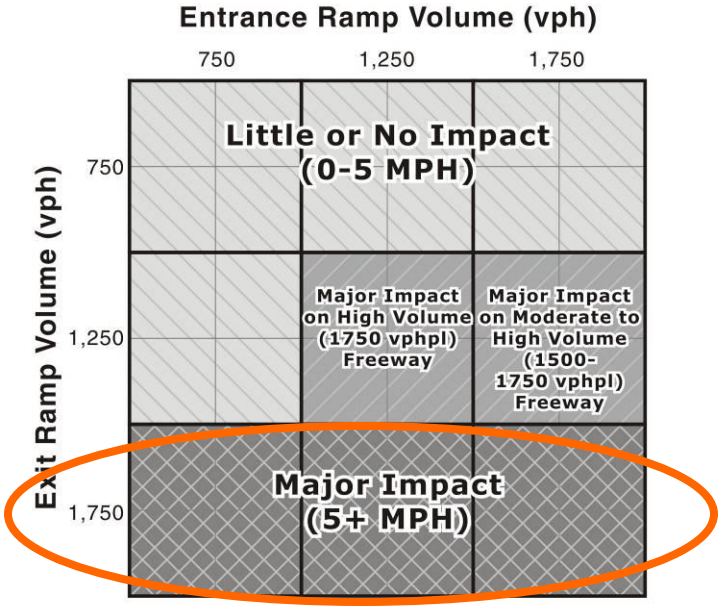
- 3 Highway Capacity Manual 2010 procedures relevant to ramp and interchange spacing
  - *Basic Freeway Segments*
    - Free-flow speed decreases as ramp density increases
  - *Freeway Weaving Segments*
    - Procedure applies only when auxiliary lane is present between entry ramp and exit ramp
    - Outcomes highly dependent upon site-specific factors (lane configuration, traffic volume, etc)
    - Procedure has changed dramatically in every major update of HCM (including 2010)
  - *Freeway Merge and Diverge Segments (formerly Ramp-Freeway Junctions)*
    - "Influence area" of ramp on freeway is 1500', measured from painted gore
    - Only 3-lane procedure sensitive to adjacent ramps or ramp spacing
- No clear thresholds below which ramp or interchange spacings "don't work"

Traffic Operations W.P. – Simulation Modeling

- VISSIM
- Calibrated with field data
- Used to estimate the effect of ramp spacing on the **mainline vehicle speed**
- Variables were systematically changed to determine their combined influence on average vehicle speed:
  - *Distance between the ramps (700' & 1000' to 2500')*
  - *Traffic volumes on each ramp and the freeway*
- Speeds measured at 5 locations in model, including both painted gores

Traffic Operations W.P. – EN-EX Findings

- Ramp spacing generally has little impact on freeway speed at low to moderate volume
- Major impacts (up to 15 MPH speed reduction) occur when ramp volumes approach capacity

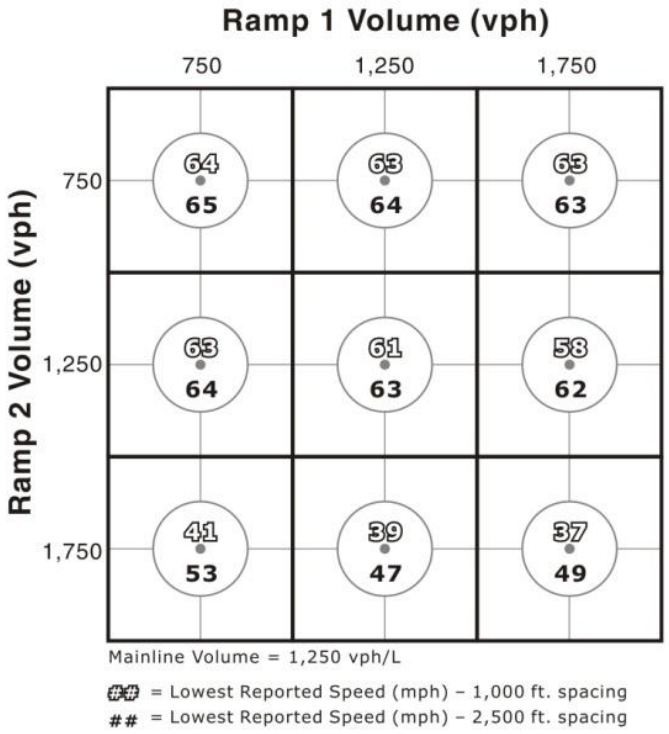


Spacing between EN-EX ramps will impact ops at high exit ramp volume

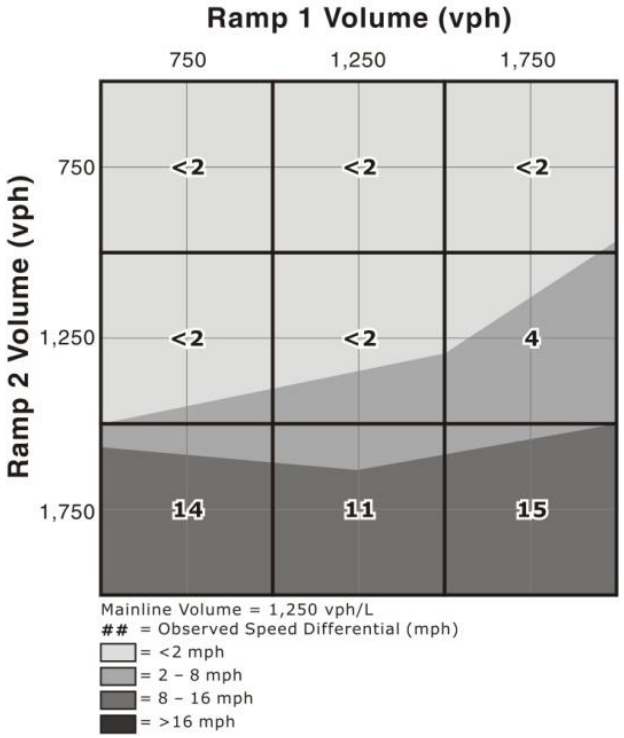
- EN-EN combinations were found to have less of an impact on mainline freeway speed than EN-EX

Traffic Operations W.P.– En-Ex Findings

- Example of results for specific conditions in appendix
  - *1250 vphpl*
  - *1000' ramp spacing vs. 2500' ramp spacing*



Comparison of lowest report speeds



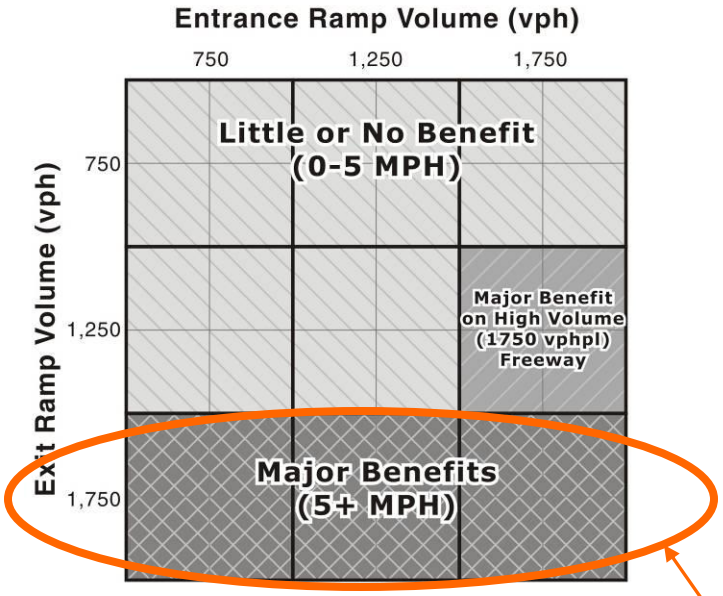
Maximum Point-Speed Difference

Traffic Operations W.P. – Aux Lane Findings

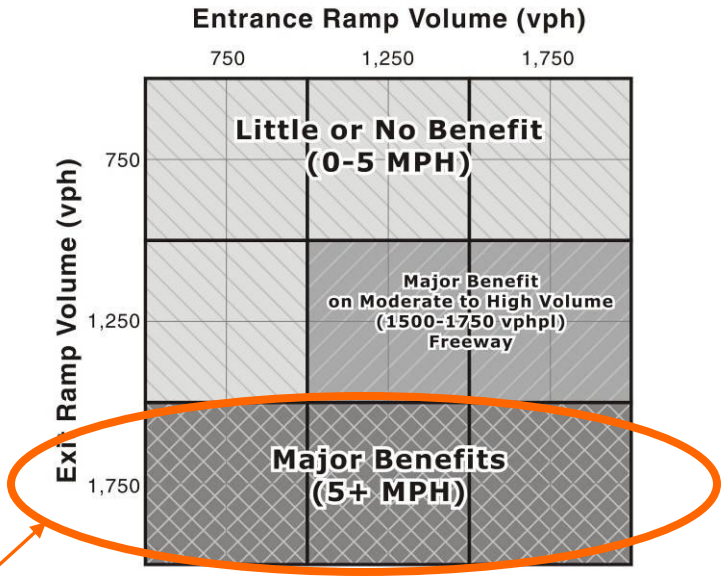
- As project progressed, gap in research identified:
  - *Wealth of research on EN-EX operation with aux lane (i.e. weaving)*
  - *Very little research on EN-EX operation without aux lane (i.e. what was studied in this project)*
- Additional VISSIM runs used to compare these two design options
- VISSIM runs identified major (5+ MPH) benefits to adding an aux lane with moderate to high exit ramp volumes, regardless of ramp spacing

Traffic Operations W.P. – Aux Lane Findings

Benefit of adding an aux lane:



1000’ Ramp Spacing



2500’ Ramp Spacing

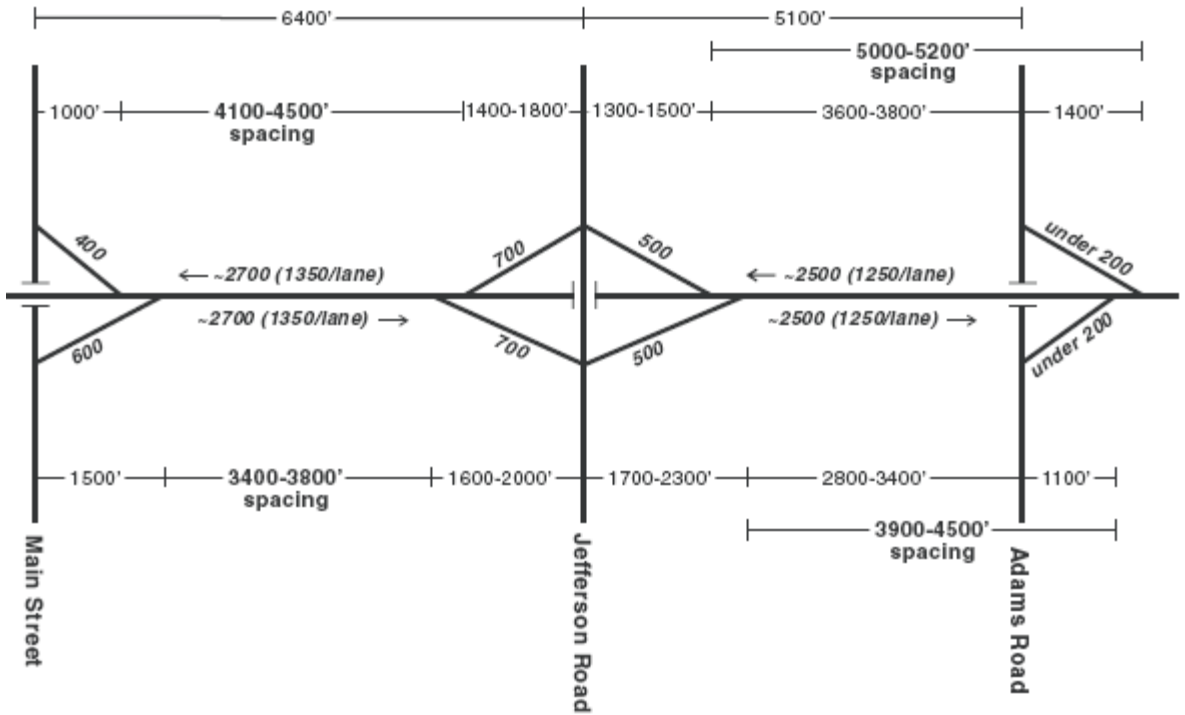
AUX Lane provides benefit with high exit ramp volume, regardless of ramp spacing

Case Study A

Source: NCHRP Report 687 Case Study #2

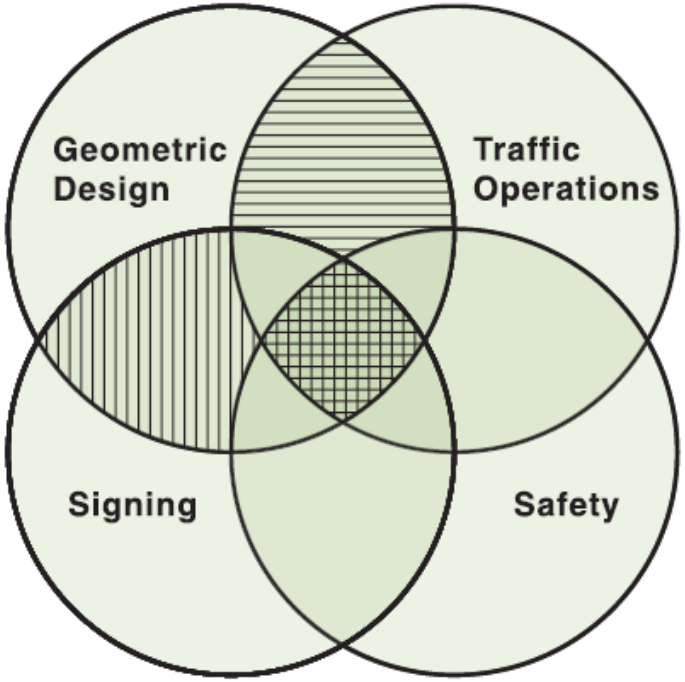
Case Study A

- Background
  - *New diamond interchange on an Interstate highway*
  - *Site has constrained geography between two half diamond interchanges*
  - *Traffic volumes and characteristics*



Case Study A

- Recall the 4 considerations



Case Study A

- Geometric considerations
  - *Determine interchange footprint*
  - *Determine approximate length of ramps*
  - *Ramp lengths governed by grade differences, and need to be lengthened*
  - *EN-EX ramp spacing to west:*
    - ~3600’ eastbound
    - ~4300’ westbound
  - *EX-EX and EN-EN ramp combinations to east*

Case Study A

- Traffic operations
  - *HCM ramp merge/diverge analysis performed for each ramp freeway junction. All meet LOS guideline for this area (LOS D)*
  - *New interchange creates four closely-spaced ramp combinations*
    - Consider aux lanes between En-Ex combinations

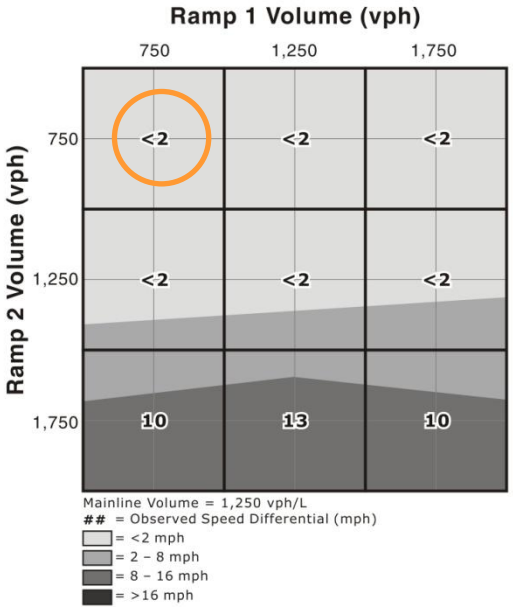
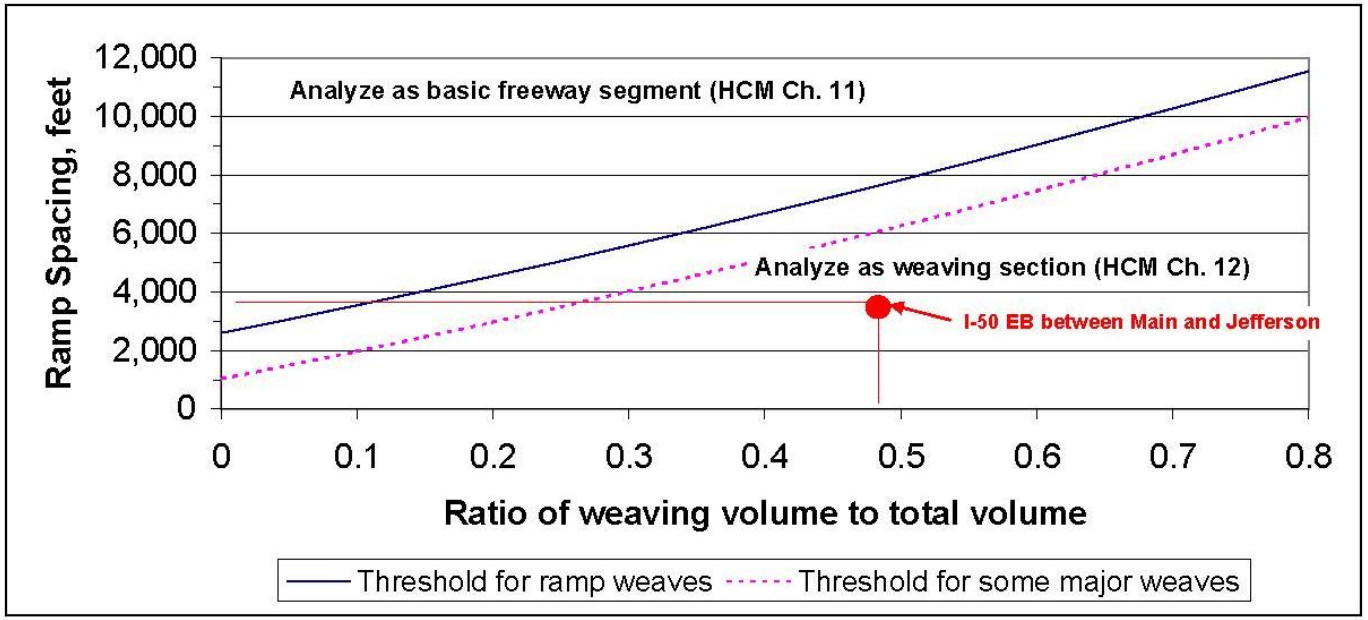


Chart from Appendix B for 1,250 vphpl and 2500' ramp spacing

Benefit of aux lane expected to be minimal based on traffic operations

Case Study A

- If aux lane used, will a weaving section (per HCM 2010) be created?



  - *Yes – conduct HCM weaving analysis*
  - *Analysis found LOS D or better operation of weaving section*

Case Study A

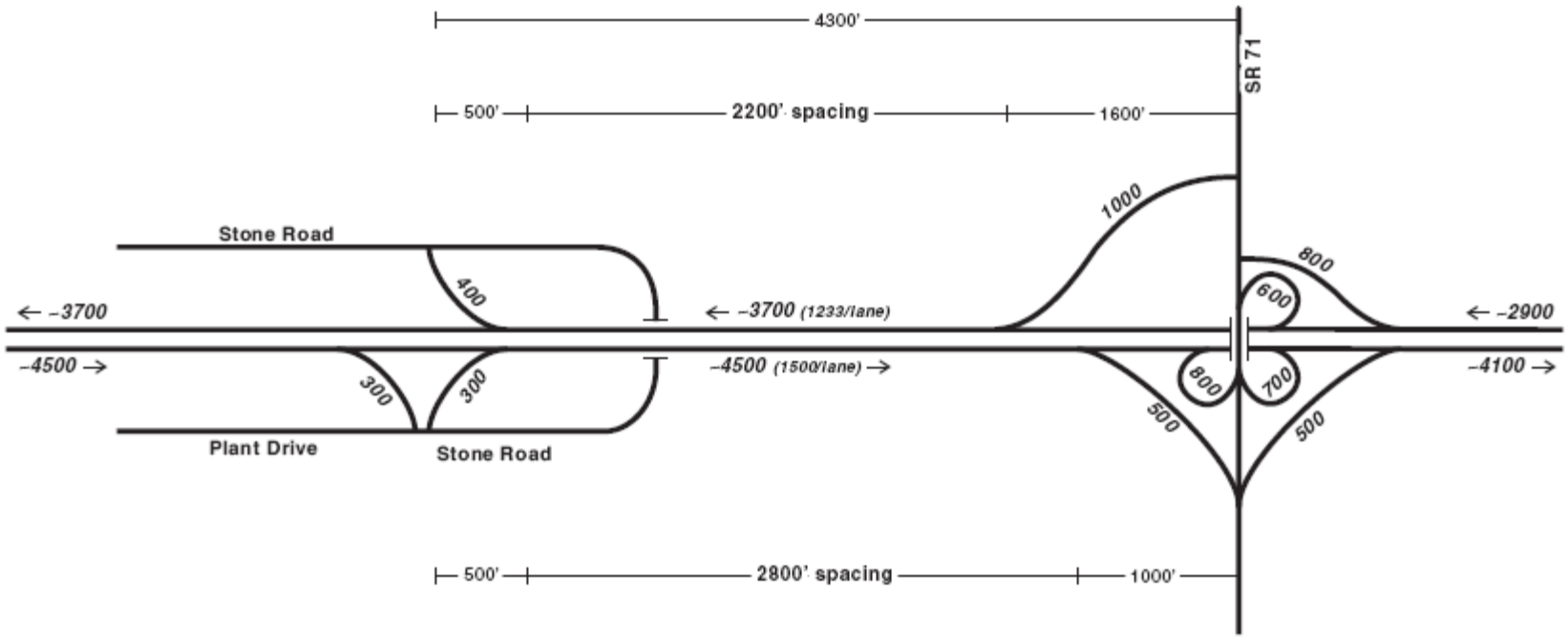
- Safety and Signing
  - *Assessed – no issues*
  - *An example of safety and signing evaluations is later in this presentation*
- Findings
  - *Interchange location appears to be feasible from a ramp and interchange spacing perspective*
  - *All ramp-freeway junctions will meet the facility's LOS Guideline*
  - *Benefit of aux lane between En-Ex will be minimal*
  - *If used, aux lane should be analyzed as a weaving section*
  - *No safety or signing issues*

Case Study B - Existing

Source: NCHRP Report 687 Case Study #4

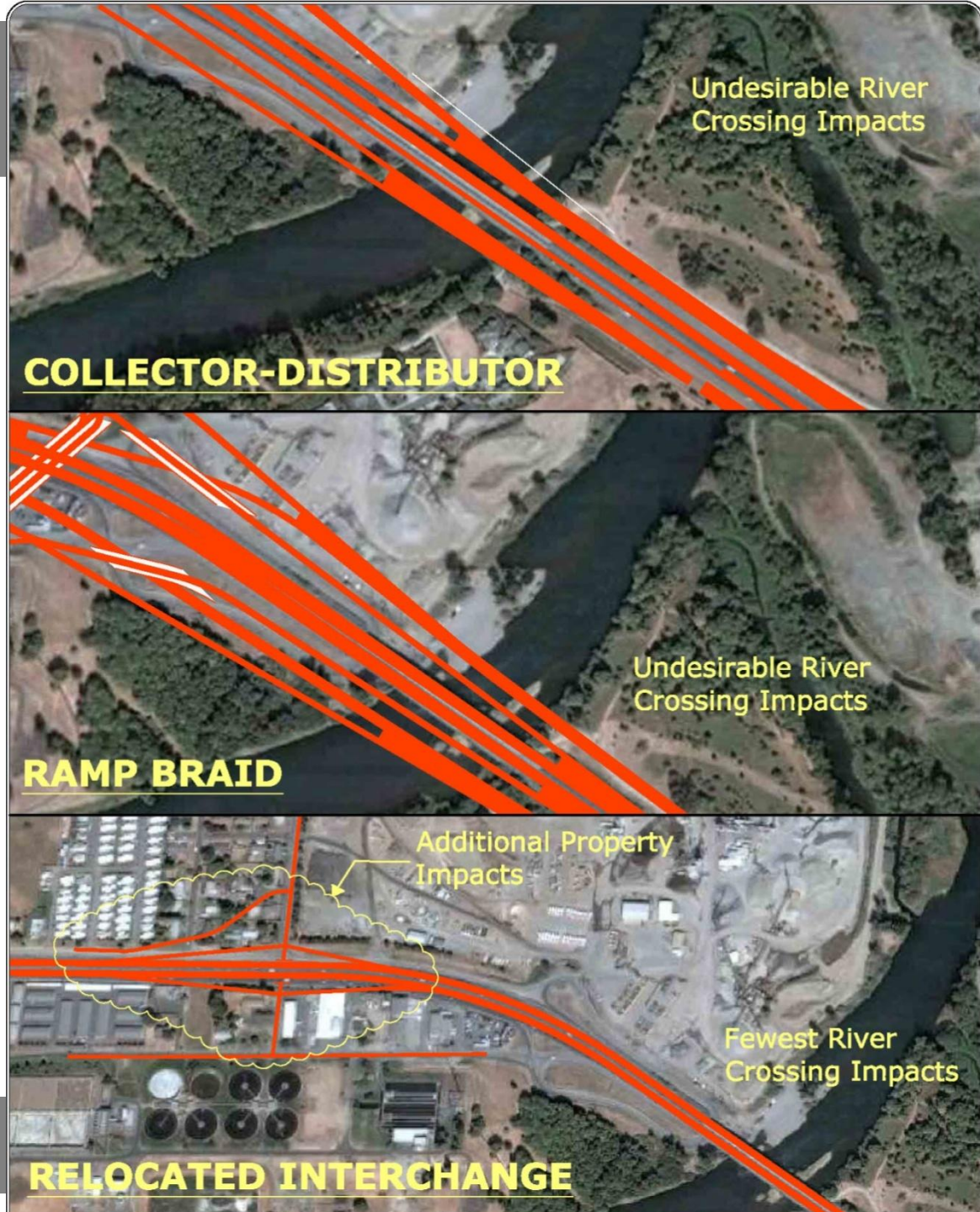
Case Study B

- Background
  - *Modernization of a 1950-era freeway*
  - *Evaluation of existing accesses for operational and safety issues*
  - *Consider removing interchange, or reconstruction options*
  - *Traffic volumes and characteristics*



Case Study B

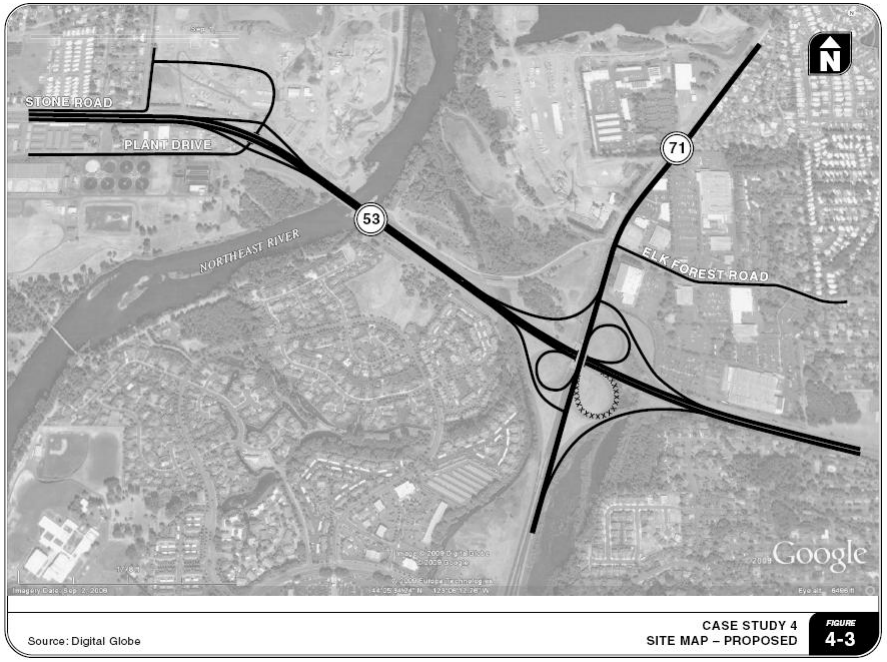
Potential Solutions & Site-specific Challenges



Case Study B - Proposed

Case Study B

- Geometric considerations
  - *Conceptually determine form of rebuilt interchanges*
  - *Minimize cost, ROW and environmental impacts*
  - *Optimize ramp geometry and spacing*
  - *Build full diamond interchange at Stone Road*
  - *Realign Plant Drive under rebuilt interchange*
  - *Remove SR 53 EB to SR 71 NB loop ramp and replace with direct connect ramp to eliminate weaving*
  - *Resultant spacing is 1,900 feet eastbound and 1,600 feet westbound*

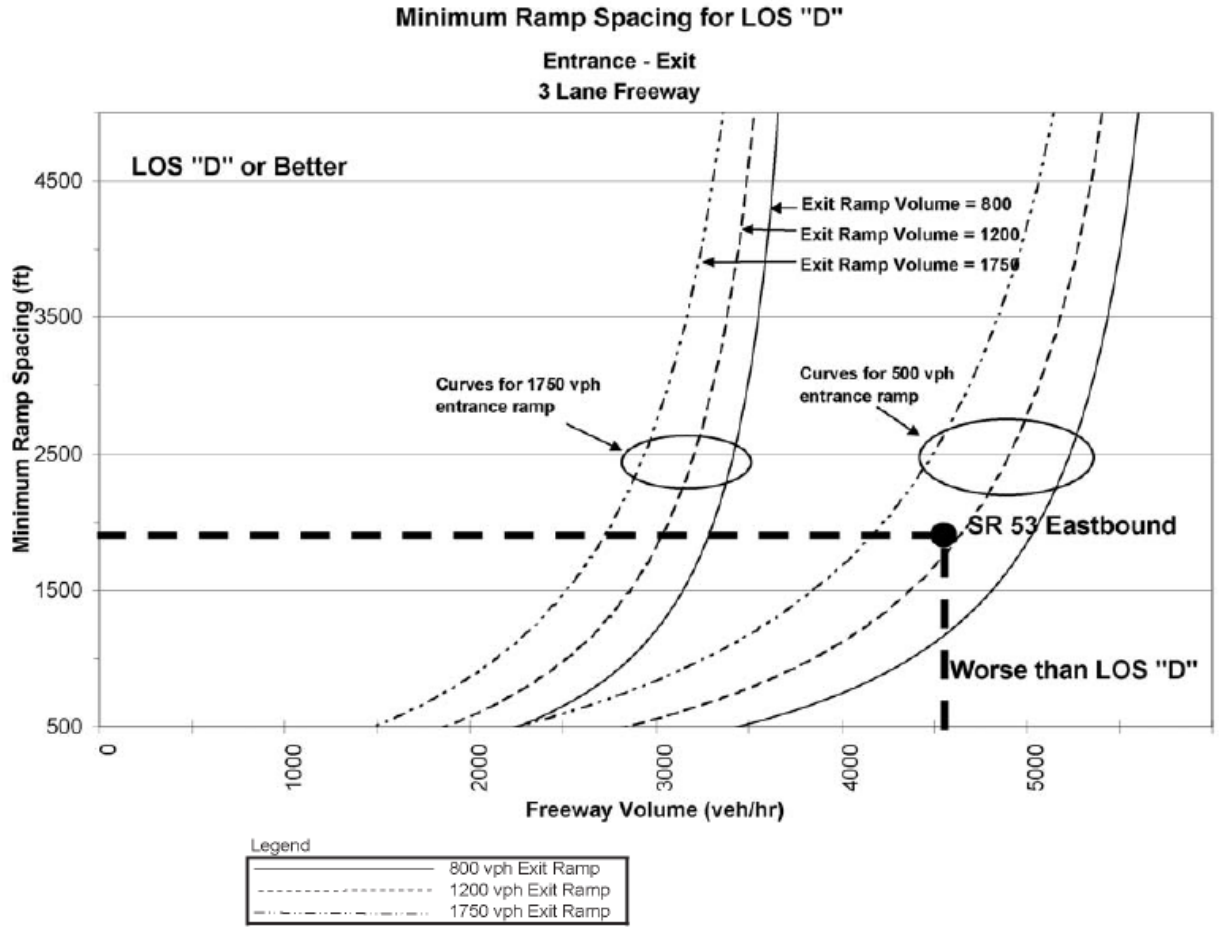


Case Study B

- Traffic operations for SR 53 eastbound
  - *Weaving between loop ramps eliminated*
  - *Initial operational analysis should assume no auxiliary lane due to potential costs and impacts with widening river bridge*
  - *HCM merge/diverge analysis finds each merge/diverge in isolation operates acceptably (LOS D or better for this area)*
  - *Ramp spacing:*
    - 1,900 ft proposed
    - 2,200 ft existing
  - *Volumes:*
    - Freeway: 4,500 vph
    - Entrance: 300 vph
    - Exit: 1,200 vph
  - *Assess spacing impacts (next slide)*

Case Study B

- Planning-level spacing assessment for 3-lane freeway



Case Study B

- Safety (not focus of this section of webinar)
  - *Ramps slightly closer together*
  - *Weaving segment removed*
  - *Hook ramps removed*
- Signing (not focus of this section of webinar)
  - *Current westbound signing is adequate*
  - *Eastbound signing is simplified by removing loop ramp*
    - Only one sign panel needed at the locations that currently have two
    - Each of the signs will have one less message unit
  - *Eastbound signing before rebuilt interchange is ok*
  - *All westbound signs adhere to MUTCD standards*
  - *No signing issues are anticipated*

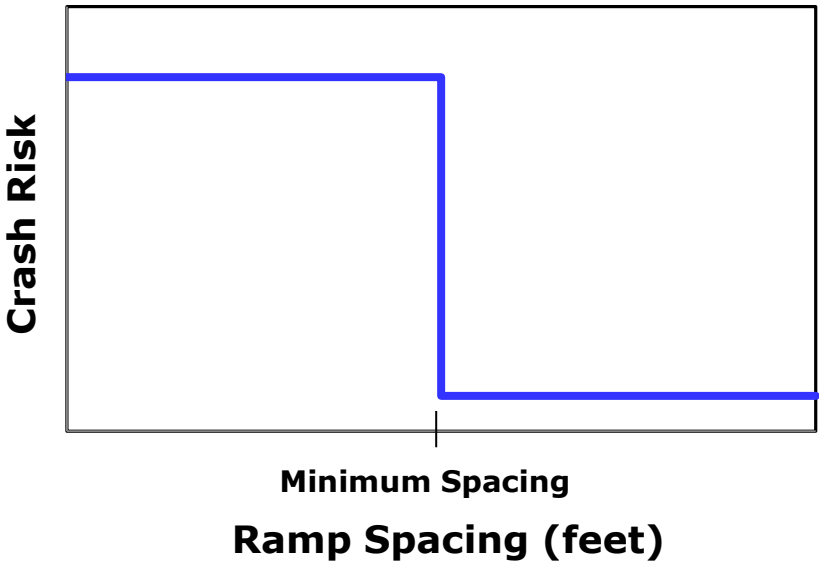
Case Study B

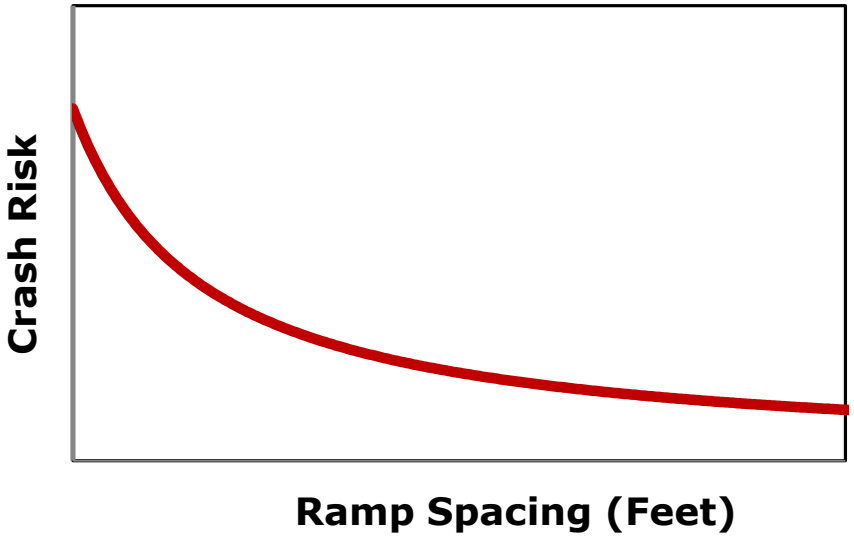
- Findings
  - *Rebuilding interchange appears feasible at conceptual development stage*
  - *Operations, safety and signing will improve or meet standards*
  - *Reevaluation will needed as design is more fully developed*

Webinar Overview

- Project Introduction – Brian Ray
- Guidelines – Brian Ray
- Traffic Operations Work Plan – Pete Jenior
- Case Studies: Traffic Operations Focus – Pete Jenior
- Safety Work Plan – R.J. Porter
- Case Studies: Safety and Signing Focus – R.J. Porter
- Closing Remarks– Brian Ray
- Questions - All

Safety Work Plan - Overview





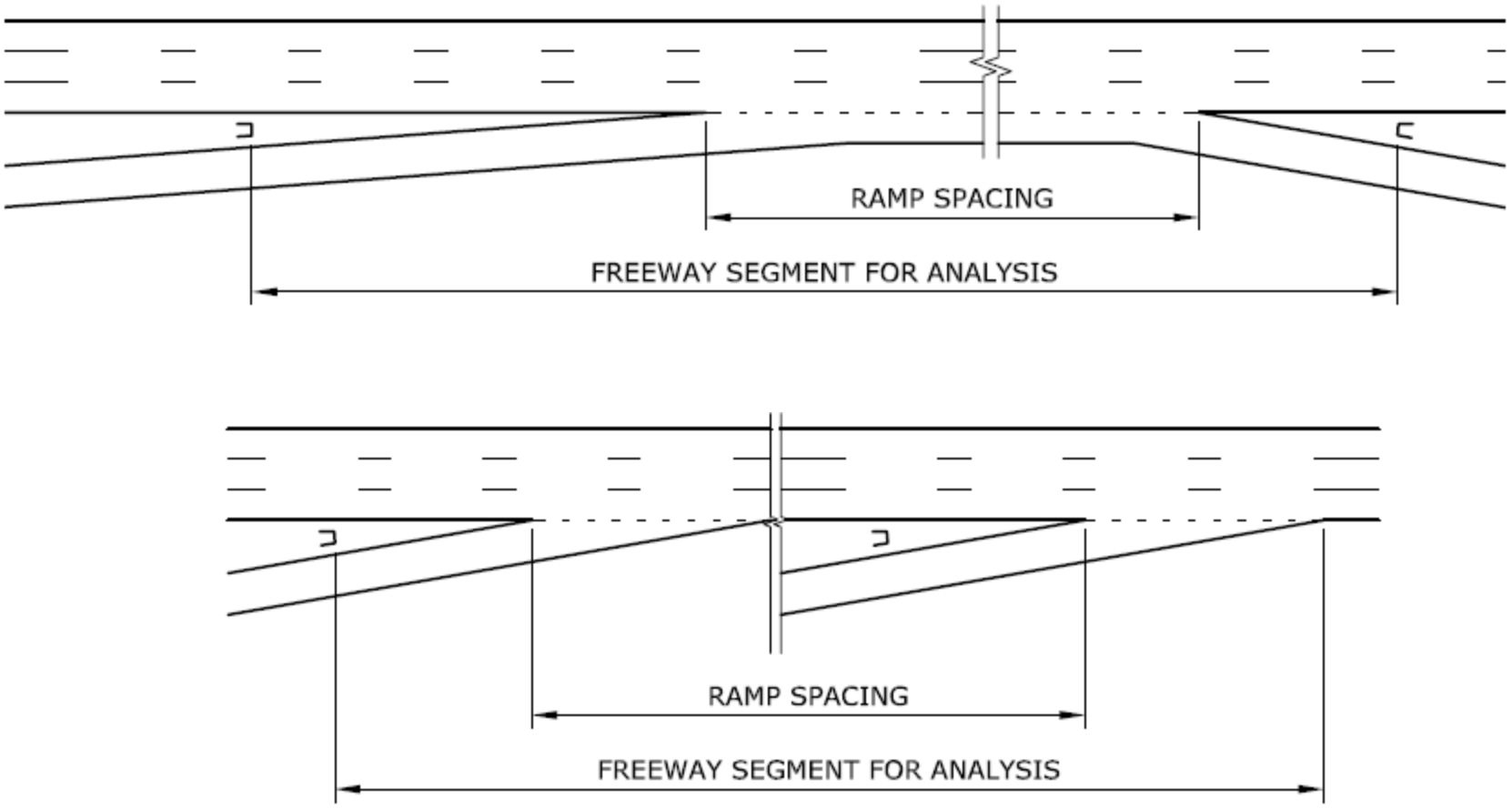
These Guidelines present a substantive safety discussion of ramp spacing, with safety defined as:

The number of crashes, or crash consequences, by type and severity, expected to occur on an entity during a specified time period.

Safety – Literature Review

- A number of previous studies on this topic have explored the effect of ramp and interchange presence on safety, without considering a spacing effect
- Others reported safety effects of a ramp or interchange count or density on a freeway segment
- Only three studies took a direct look at the relationship between interchange or ramp spacing and safety
- Conclusions prior to this project were that "Decreasing interchange spacing appears to increase crashes…the magnitude of the crash effect is not certain at this time" (Highway Safety Manual, 1st Edition)

Safety W.P. Scope and Segment Definitions



Safety W.P. – Modeled Variables

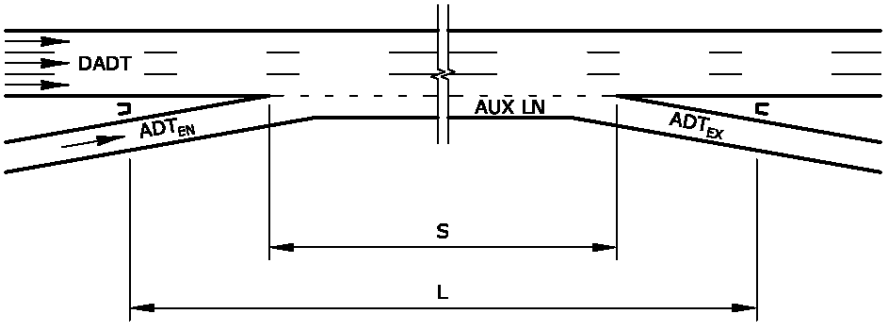
- Entry-Exit
  - *Segment length*
  - *Freeway mainline traffic*
  - *Entrance and exit ramp traffic*
  - *Ramp spacing*
  - *Presence of an auxiliary lane for weaving*
  - *Barrier presence and length*
  - *Vertical relationship between the freeway mainline and cross streets*
  - *Number of freeway through lanes*
- Entry-Entry
  - *Segment length*
  - *Freeway mainline traffic*
  - *Ramp traffic on both entrance ramps*
  - *Ramp spacing*

Spacing Guidance - Safety

- Total Crashes at Entry-Exit Ramp Combination

$$TOTAL = 9.7 \times 10^{-6} L^{1.0} (DADT)^{1.12} (ADT_{EN})^{0.18} (ADT_{EX})^{0.02} \exp\left(\frac{450}{S} - 0.23 \times AuxLn\right)$$

- Variable definitions:



L = segment length (in miles) defined from the physical gore of the entrance ramp to the physical gore of the exit ramp;

S = ramp spacing (in feet) defined from the painted entrance gore to the painted exit gore;

DADT = the average daily traffic (in vehicles per day) on the freeway mainline upstream of the entrance gore in the analysis direction;

ADTEN = the average daily entering traffic (in vehicles per day);

ADTEX = the average daily exiting traffic (in vehicles per day);

AuxLn = a variable indicated whether there is a continuous auxiliary lane between the entrance ramp and exit ramp provided for weaving (1 = auxiliary lane present; 0 = auxiliary lane not present); and

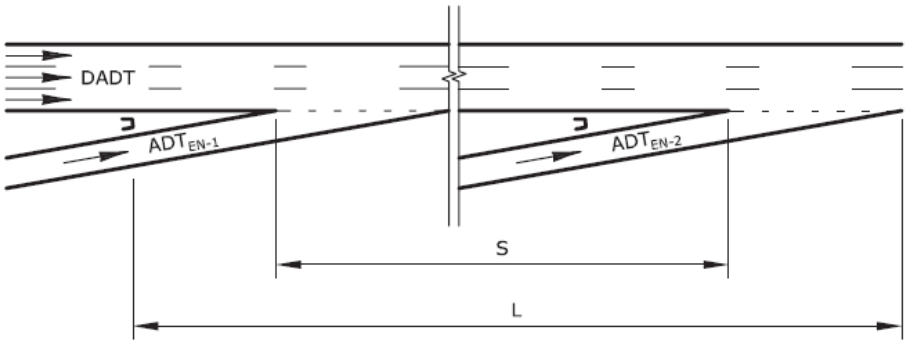
TOTAL = number of crashes (of all types and severities) expected to occur between the physical entrance gore and physical exit gore on the freeway mainline

Spacing Guidance - Safety

- Total Crashes at Entry-Entry Ramp Combination

$$TOTAL = 5.0 \times 10^{-5} L^{1.0} (DADT)^{0.81} (ADT_{EN-1})^{0.34} (ADT_{EN-2})^{0.09} \exp\left(\frac{420}{S}\right)$$

- Variable definitions:



L = segment length (in miles) defined from the physical gore of the first (upstream) entrance ramp to the end of the acceleration lane taper of the second (downstream) entrance ramp;

S = ramp spacing (in feet) defined from the painted tip of the first entrance ramp to the painted tip of the second entrance ramp;

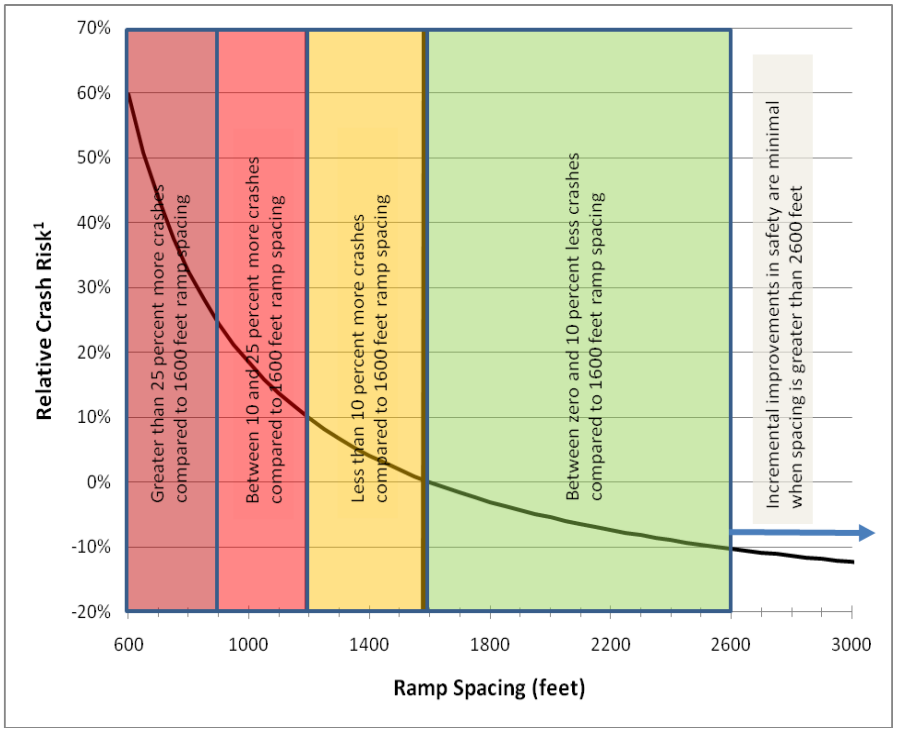
DADT = the average daily traffic (in vehicles per day) on the freeway mainline upstream of the first entrance gore in the analysis direction;

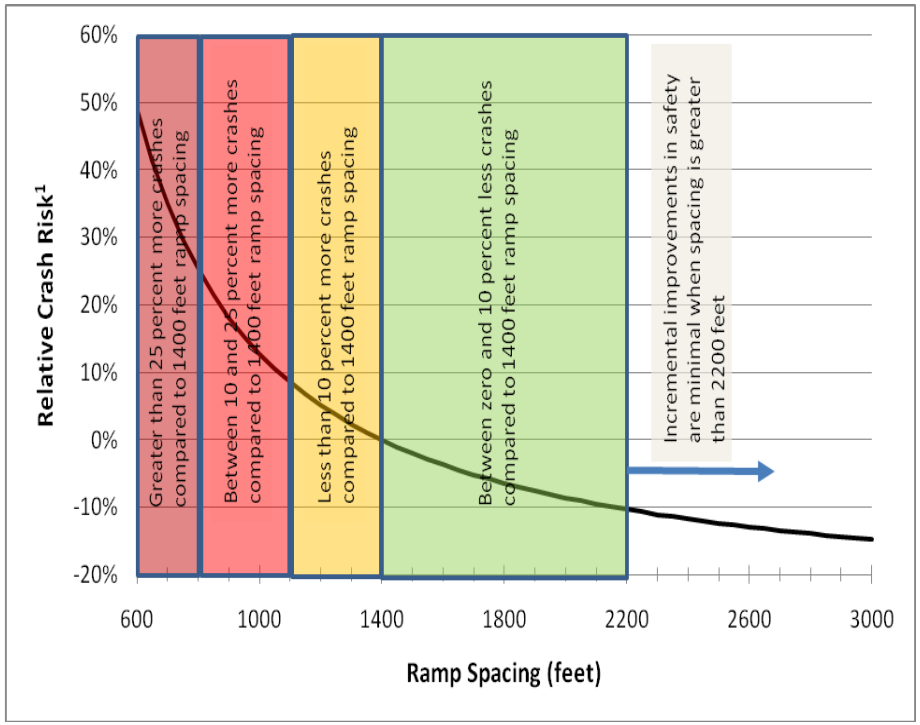
ADT_{EN-1} = the average daily entering traffic (in vehicles per day) from the first entrance ramp;

ADT_{EN-2} = the average daily entering traffic (in vehicles per day) from the second entrance ramp; and

TOTAL = number of crashes (of all types and severities) (crashes per year) expected to occur between the physical gore of the first

Spacing Guidance - Safety





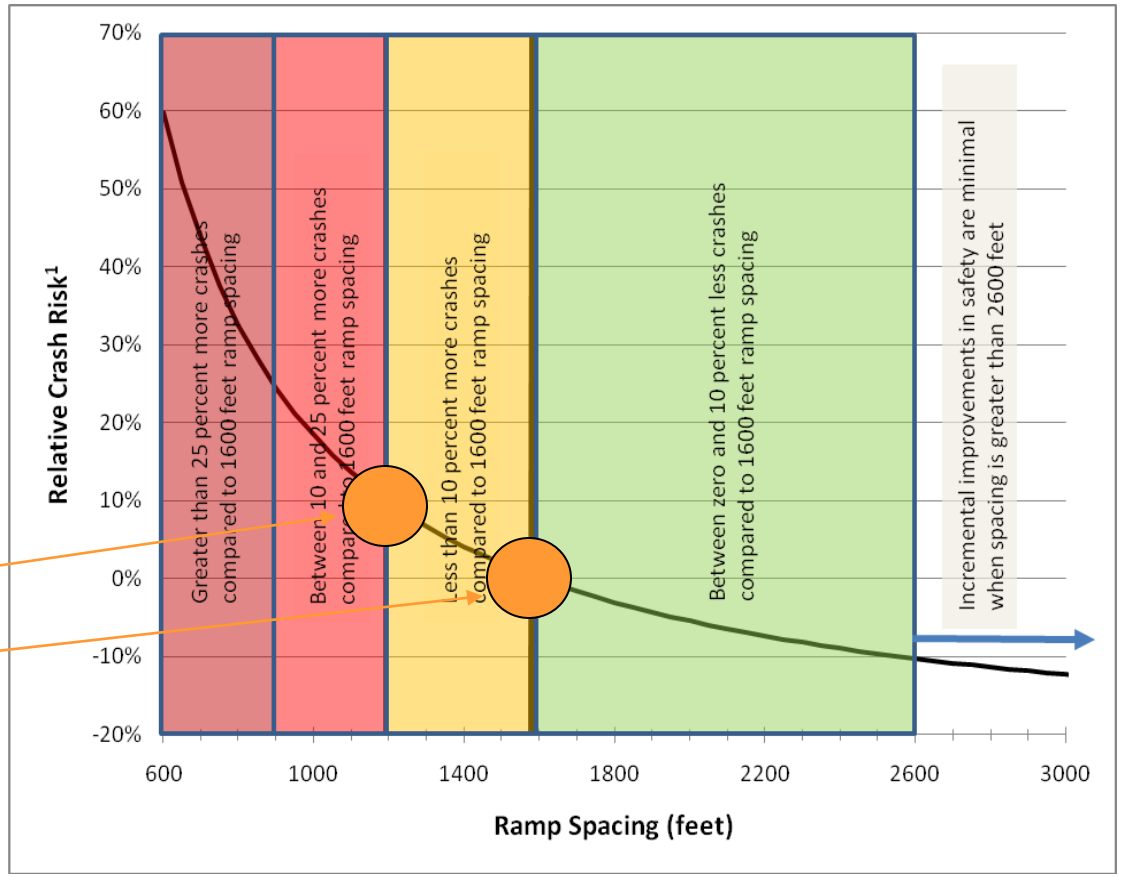
[1] Relative crash risk is measured by the percent difference in crashes, of all types and severities, at some ramp spacing value compared to a ramp spacing of 1600 feet (for EN-EX) or 1400 feet (for EN-EN)

Entry – Exit

Entry - Entry

Spacing Guidance - Safety

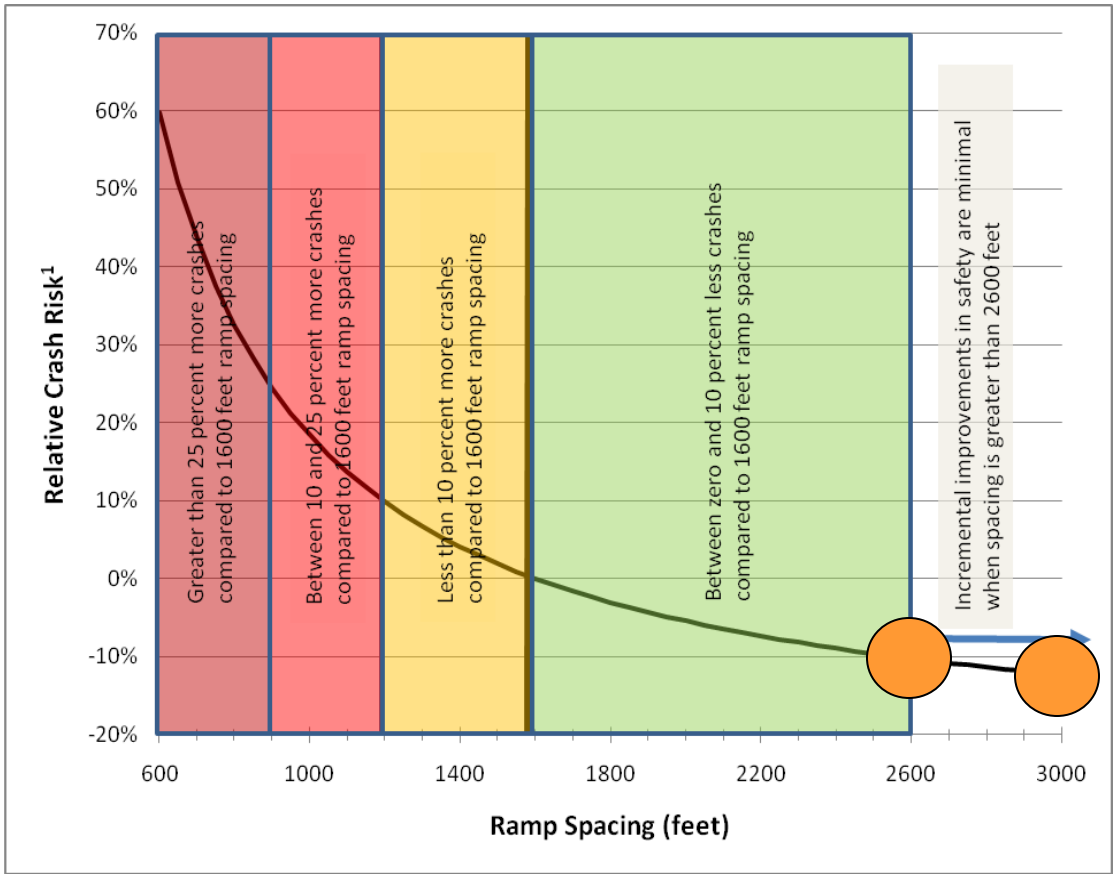
- Example: Planners must choose between 1600’ and 1200’ EN-EX ramp spacing – will there be a safety impact?



10% more crashes with 1200’ spacing

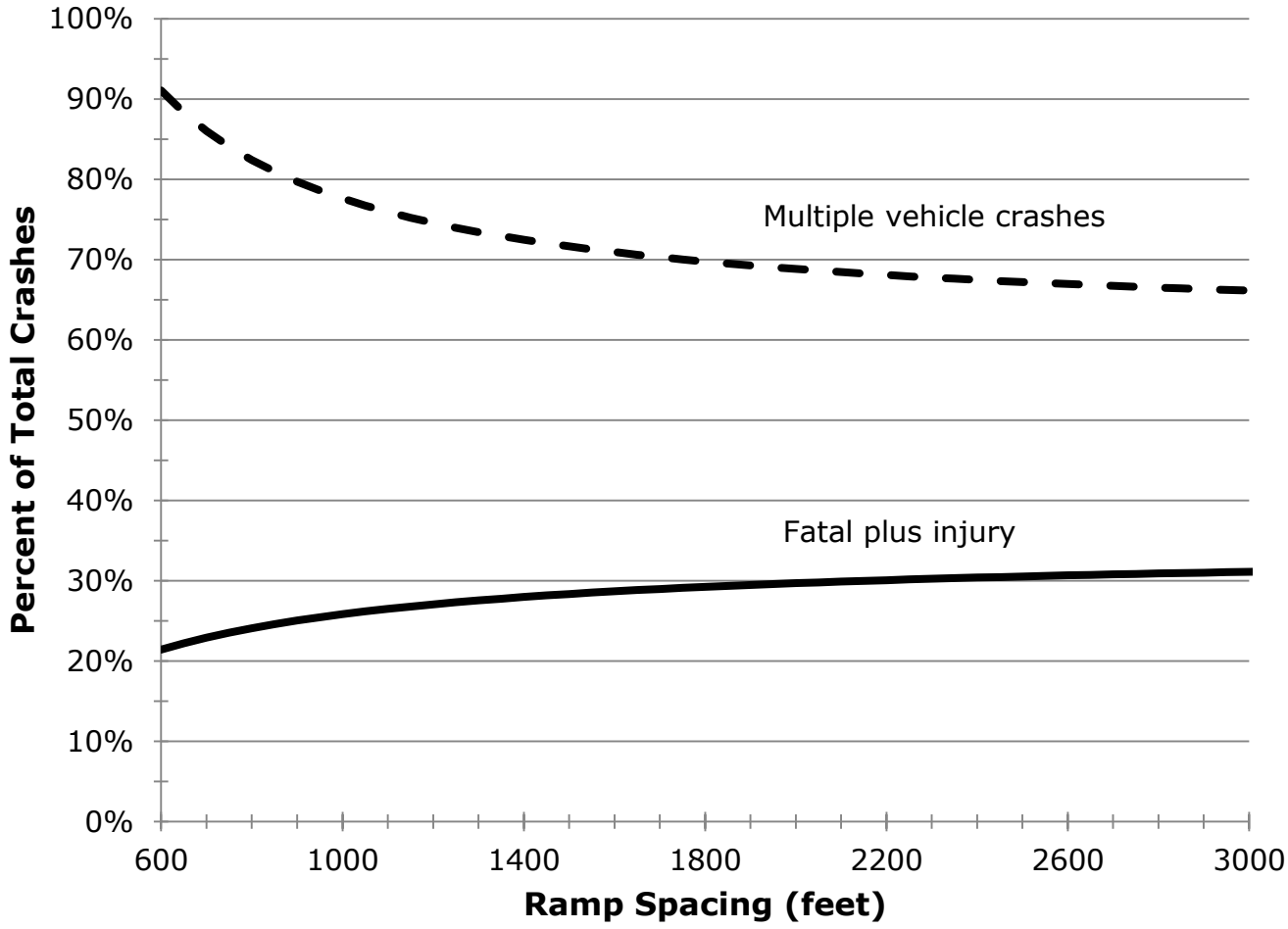
Spacing Guidance - Safety

- Example: Planners must choose between 2600’ and 3000’ EN-EX ramp spacing – will there be a safety impact?



No

Crash Type and Severity

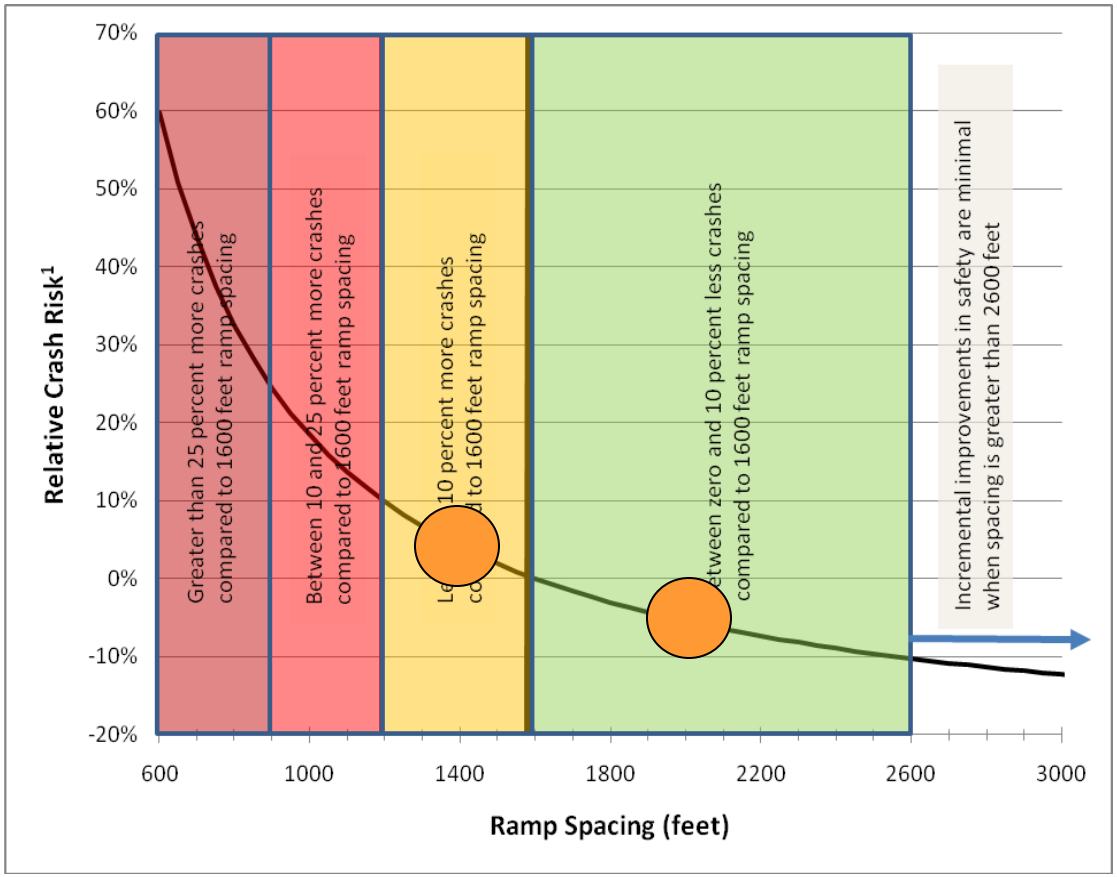


Safety W.P. – EN-EX Model Aux Lane Effects

- Like operations research, safety research found a benefit of having an aux lane between closely spaced entry ramp and exit ramp
- The presence of an auxiliary lane corresponded to approximately 20% fewer expected crashes for any given ramp spacing and projected level of traffic volumes.
- This overall reduction in crashes is due to reduction in multiple vehicle collisions.
- The presence of an auxiliary lane has no effect on single vehicle collisions. The presence of an auxiliary lane was also found to have an equal reduction in injury and non-injury crashes.

Spacing Guidance - Safety

- Example: comparing 2,000 foot and 1,400 foot spacing, the larger expected number of crashes for the 1,400 foot spacing is expected to be offset if an auxiliary lane is provided



Spacing Guidance - Safety

A comprehensive ramp spacing safety assessment should consider:

- Safety impacts on the freeway mainline (addressed in this section);
- Safety associated with speed-change lane presence and design;
- Safety along the ramp proper;
- Safety at ramp terminal intersections; and
- Safety on surrounding highways and streets (capabilities that intertwine travel demand modeling and safety are somewhat limited).

Signing – Literature Review

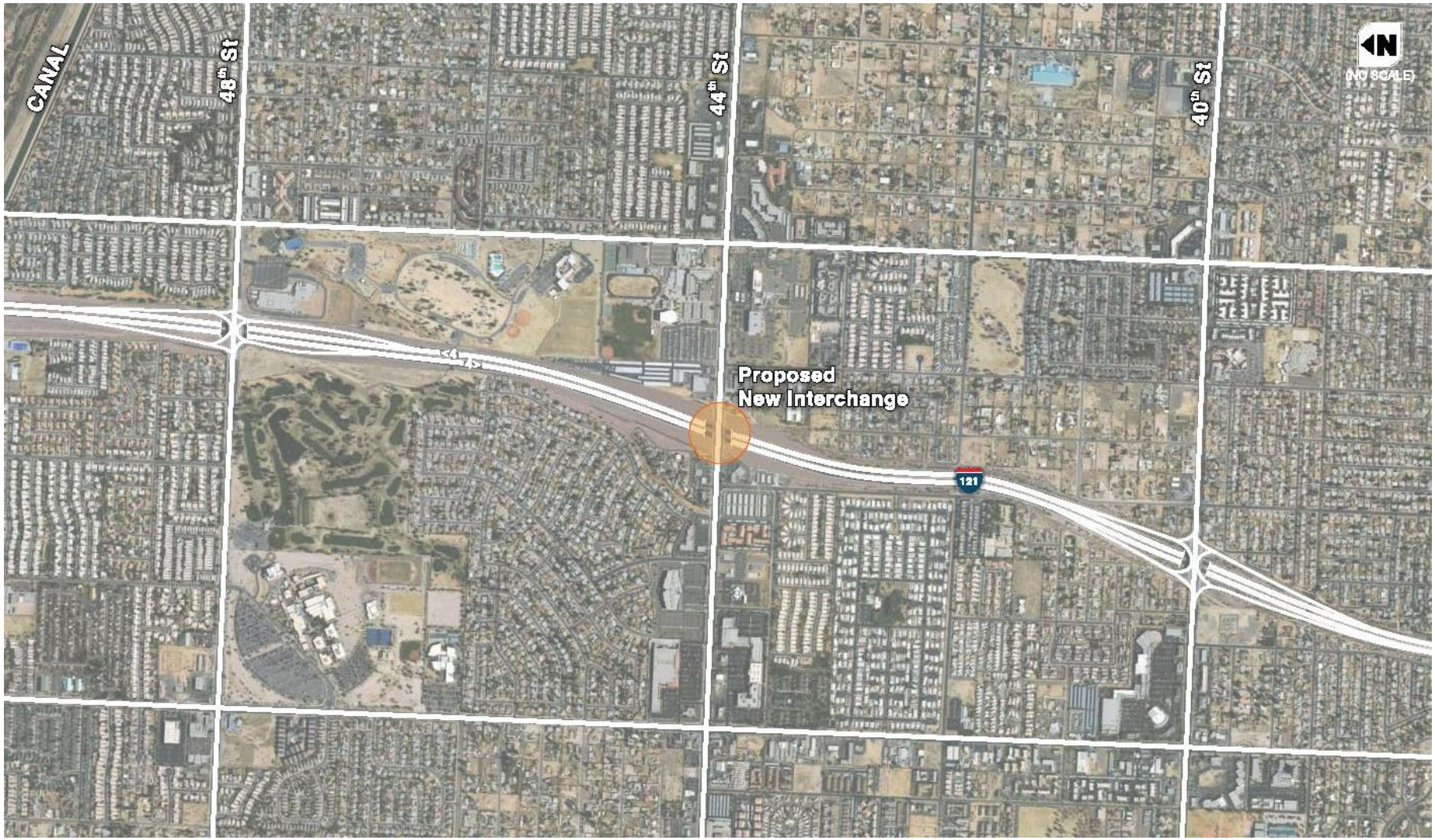
- MUTCD specifies limits on the amount of information that can be presented to freeway drivers
  - *Limits effectively set a maximum exit ramp density*
  - *Other factors such as geometric design usually require exit ramps to be far enough apart that signing does not influence spacing*

MUTCD limit

NUMBER OF SIGN PANELS IN SERIES AT ONE LOCATION		NUMBER OF MESSAGE UNITS*			
		MAX. PER SIGN		MAX. TOTAL ASSEMBLY	
NUMBER	APPLICATION	DESIRABLE	ABSOLUTE	DESIRABLE	ABSOLUTE
1 ▭	FREQUENTLY	5	6	5	6
2 ▭▭	OCCASIONALLY	4	5	8	10
3 ▭▭▭	SPECIAL CASE	3	4	9	11
4 ▭▭▭▭	NEVER	–	–	–	–

ITE Freeway and Interchange Geometric Design Handbook. 2005

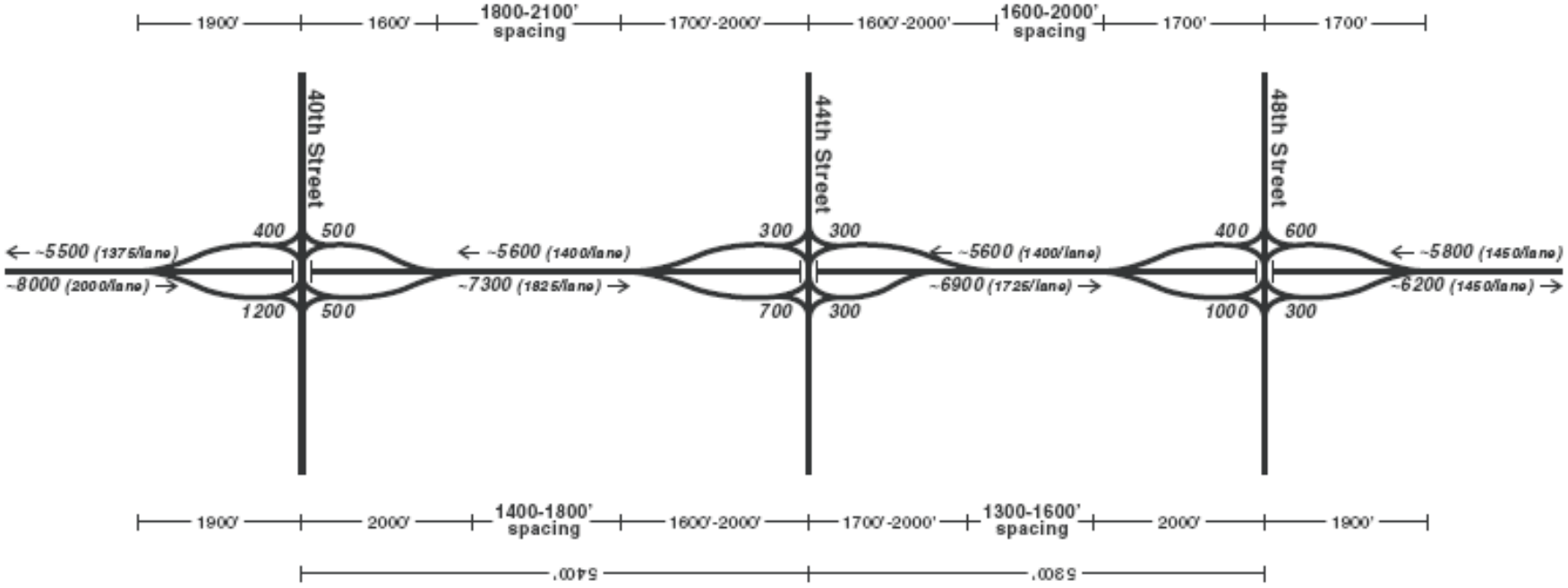
Case Study C



Source: NCHRP Report 687 Case Study #3

Case Study C

- Background
  - *New interchange a mile from adjacent interchanges in both directions*
  - *Single-point diamond is being considered, with auxiliary lanes to the north and south*
  - *High traffic volumes present operational and safety concerns*



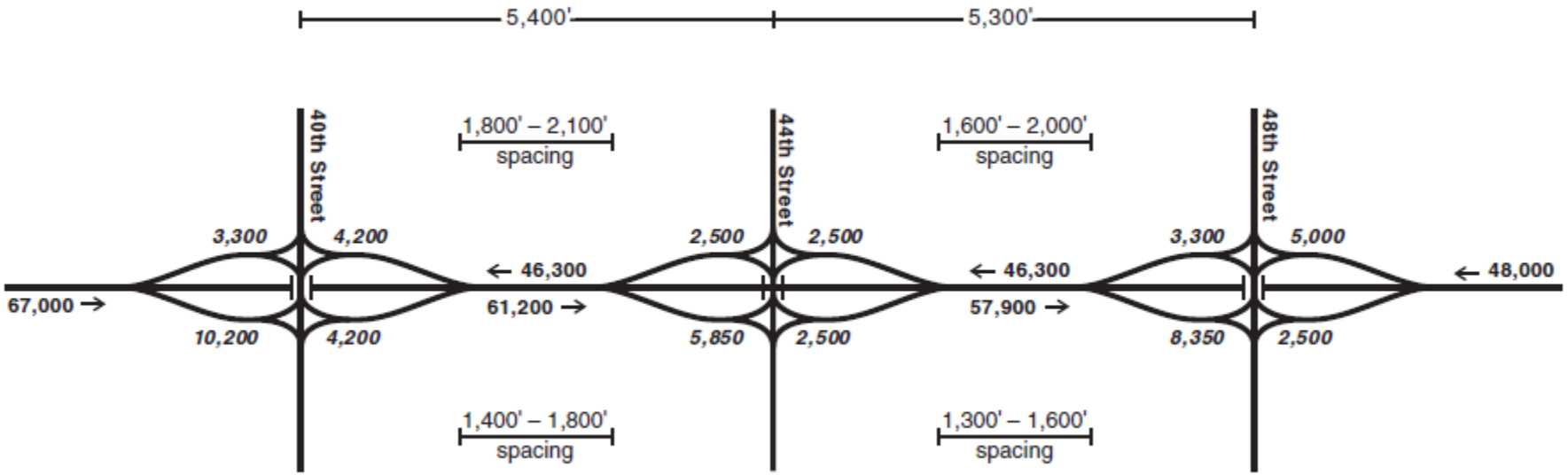
Case Study C

- Geometric considerations
  - *Single-point diamond interchange proposed*
  - *Exit ramps vary from 1,600 – 2,000 feet in length*
  - *Entrance ramps vary from 1,700 – 2,000 feet in length*
  - *Maintain adequate deceleration distance on exit ramps*
  - *Ramp meters will require longer entrance ramp to avoid queue spillback*
  - *Results in four closely spaced ramp combinations (< 2,000 feet)*

- Traffic operations
  - *Interchange found feasible from a traffic operations perspective*
  - *See NCHRP Report for details*

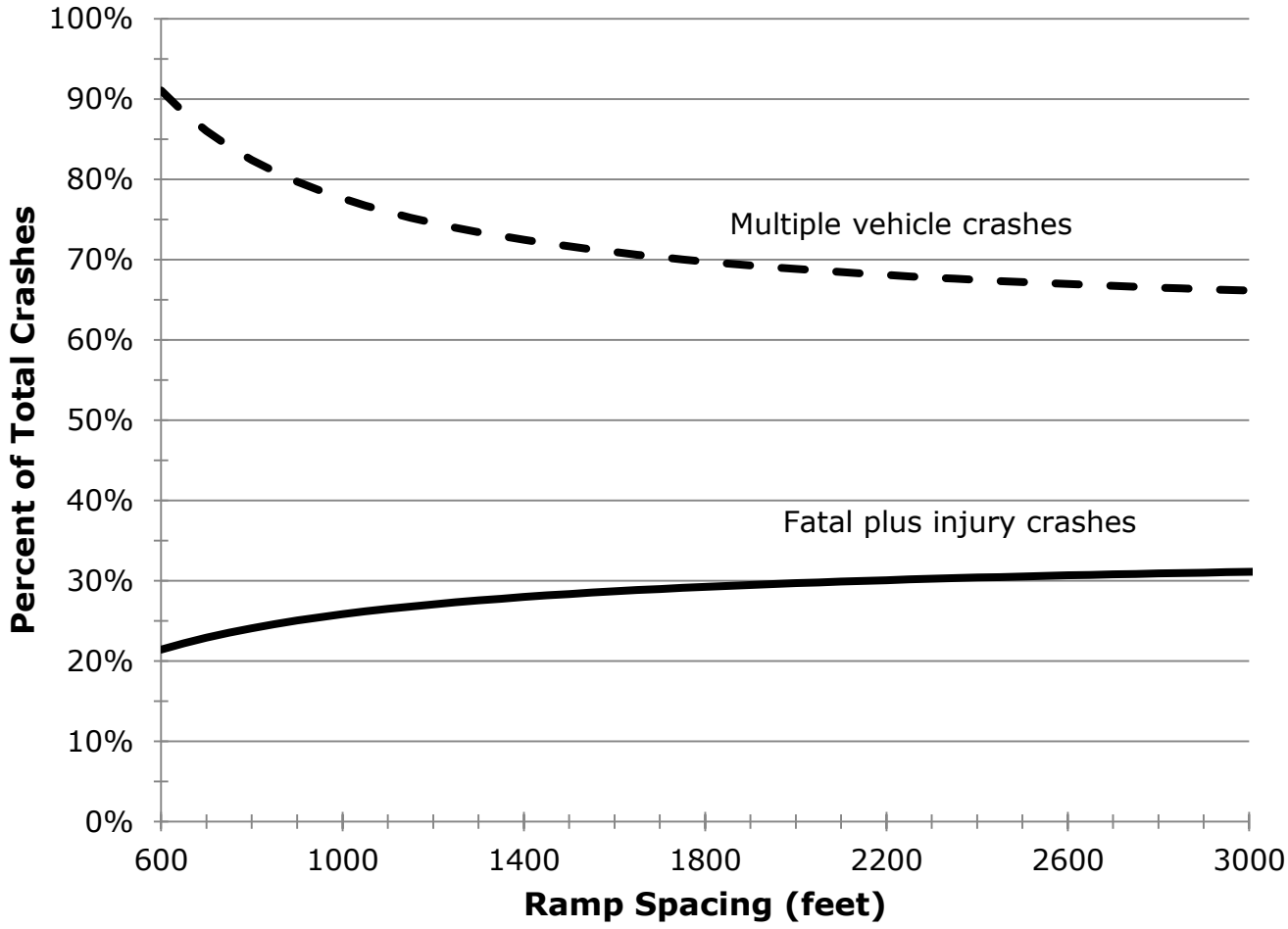
Case Study C

- Safety Based on Daily Volumes



$$TOTAL = 9.7 \times 10^{-6} L^{1.0} (ADT)^{1.12} (ADT_{EN})^{0.18} (ADT_{EX})^{0.02} \exp\left(\frac{450}{S} - 0.23 \times AuxLn\right)$$

Case Study C


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent of Total Crashes
Multiple vehicle crashes
Fatal plus injury crashes
600
1000
1400
1800
2200
2600
3000
Ramp Spacing (feet)

Case Study C

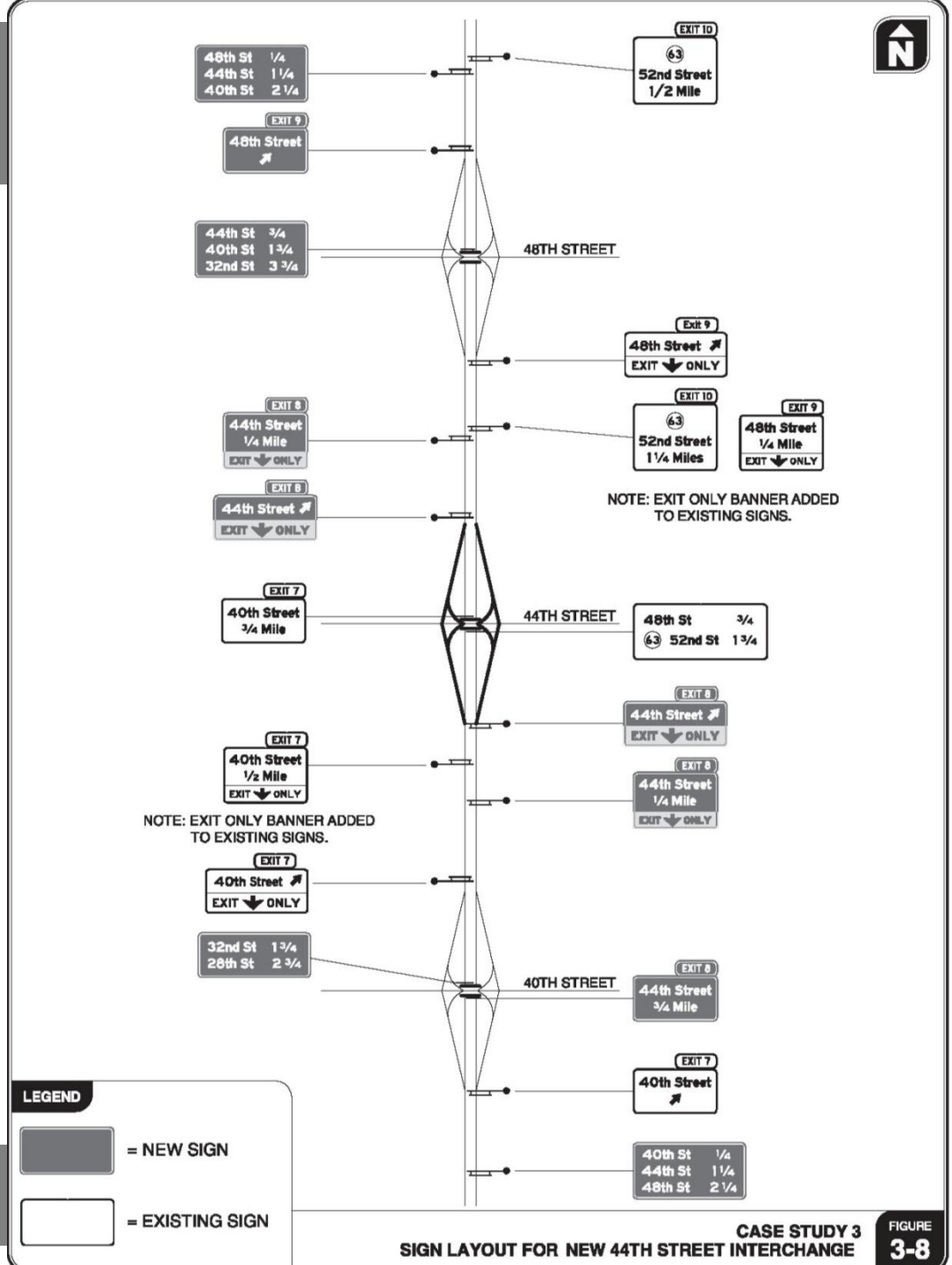
- Safety

Table 3-1 Expected Change in Safety Performance with addition of 44th Street Interchange

Scenario	Expected Change in Mainline Safety compared to 'No Build' (I.e., no 44th street interchange)
No Build	---
44th street interchange; no auxiliary lanes	17% increase in total crashes; 14% increase in fatal plus injury crashes
44th street interchange; auxiliary lane between 40th and 44th street ramps only	9% increase in total crashes; no change in fatal plus injury crashes
44th street interchange; auxiliary lane between 44th and 48th street ramps only	9% increase in total crashes; no change in fatal plus injury crashes
44th street interchange; auxiliary lane between both EN-EX combinations	No change in total crashes; 14% reduction in fatal plus injury crashes

Case Study C

- Signing
  - *Advanced guide signs at 1 ¼ and ¾ mile spacing because of 1-mile interchange spacing*
  - *¾ -mile advance guide signs would be followed by ¼-mile advance guide signs rather than ½–mile guide signs*
  - *All signs are overhead because of the number of lanes and potential for congestion*
  - *New interchange is feasible from a signing perspective*



Case Study C

- Findings
  - *New interchange does not have any fatal flaws*
  - *Weaving areas will be created*
  - *Auxiliary lanes are needed*
  - *HCM analysis necessary to see if segments meet LOS E operating guideline*
  - *If auxiliary lanes are provided, number of crashes would not be expected to increase*
  - *Signing is feasible with proposed interchange type*

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- Closing Remarks– Brian Ray
- Questions - All

Guidelines - Outcomes

- Clear definition of spacing terms
  - *Focus on ramp spacing*
  - *Deemphasize interchange spacing*
- Systematic approach that considers
  - *Geometric design*
  - *Traffic operations*
  - *Safety*
  - *Signing*
- Performance-based Transportation
  - *Avoid "one size fits all" spacing values*
  - *Customize spacing recommendations based on factors that affect ramp and interchange context*

Questions