Longer Combination Vehicles & Road Trains for Texas?

TxDOT Project 0-6095

August 18, 2010

Objective

- consider the impact that larger, productive trucks would have if permitted on Texas highways
- trucks range from a heavier tridem semi-trailer to a variety of combination trucks, including road trains, i.e. LCVs

TxDOT Project Monitoring Committee

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- Dar Hao Chen
- Raymond Hutchinson
- Don Lewis
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Research and Advisory Teams

Research Team:

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- Khali Persad
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- John Woodrooffe, Director, Transportation Safety Analysis Division, University of Michigan Transportation Research Institute

		FY 2009												FY 2010											
	Research Activity	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Task 1	LCV Background and Issues	■	■	■	■	■	■																		
Task 2	Representative Vehicle Classes, Demensions, and Specifications	■	■	■																					
Task 3	Highway Infrastructure for Larger Trucks	■	■	■	■	■	■																		
Task 4	First Project Advisory Meeting							■																	
Task 5	Bridge Impacts from LCV Operations	■	■	■	■	■	■	■	■	■	■	■	■												
Task 6	Pavement Consumption and LCV Operations	■	■	■	■	■	■	■	■	■	■	■	■												
Task 7	Larger Truck Operations	■	■	■	■	■	■	■	■	■	■	■	■												
Task 8	Policy Implications of LCV Operations	■		■		■			■	■	■	■	■												
Task 9	Summary of First Year Activities and Second Project Advisory Meeting												■	■											
Task 10	LCV Case Study 1. An Existing Interstate Highway														■	■	■	■	■	■	■	■	■	■	
Task 11	LCV Case Study 2. An Existing State Corridor														■	■	■	■	■	■	■	■	■	■	
Task 12	LCV Case Study 3. Trans-Texas Corridor - TTC-35														■	■	■	■	■	■	■	■	■	■	
Task 13	LCV Case Study 4. Truck Only Toll Road														■	■	■	■	■	■	■	■	■	■	
Task 14	Final Report and Third Project Advisory Meeting																				■	■	■	■	■

Agenda

1.	Introduction	All
2.	Structure of Project	Michael Walton
3.	Safety	Kara Kockelman
4.	Vehicle Types and Chosen Corridors	Rob Harrison
5.	Pavement Analysis: Methodology and Case Studies	Angela Weissmann
6.	Bridge Analysis: Methodology and Case Studies	José Weissmann
7.	Cost / Benefit Tradeoffs	Rob Harrison / José Weissmann
8.	Recommendations • Pilot test(s)	Research Team
9.	Feedback / Final Report	All

Safety

Kara Kockelman

Vehicle Types and Chosen Corridors

Rob Harrison

Pavement Analysis: Methodology and Case Studies

Angela Weissmann

Bridge Analysis:
Methodology and Case Studies

José Weissmann

Cost / Benefit Tradeoffs

Rob Harrison
José Weissmann

Open Discussion including recommendations and pilot test(s)

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Vehicle Types and Chosen Corridors

Rob Harrison

- Global interest in LCVs continues based on productivity and social costs

- Australia can be considered a mature LCV region.
- EU is growing

Nation Heavy Vehicle Accreditation Scheme

- Mass
- Maintenance
- Keeping accreditation/compliance

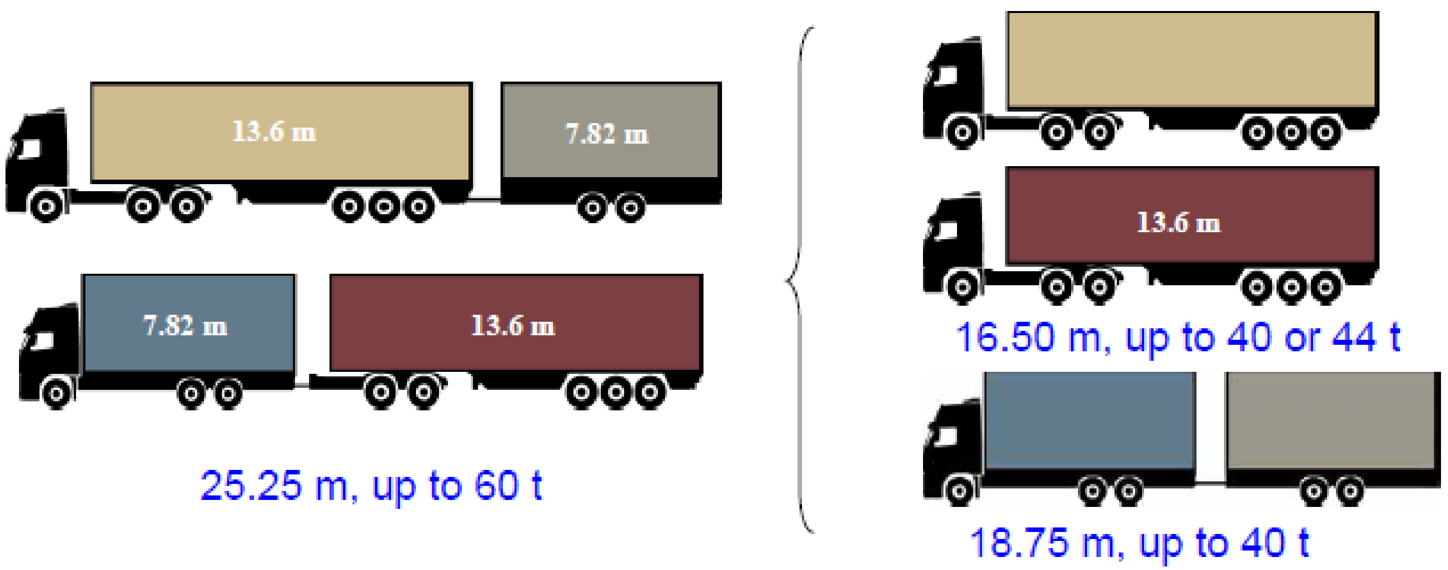
- EU exploring various LCV types
  - > 40 MT
  - Some reach 60 tons

EU Gigaliners

EU Gigaliners

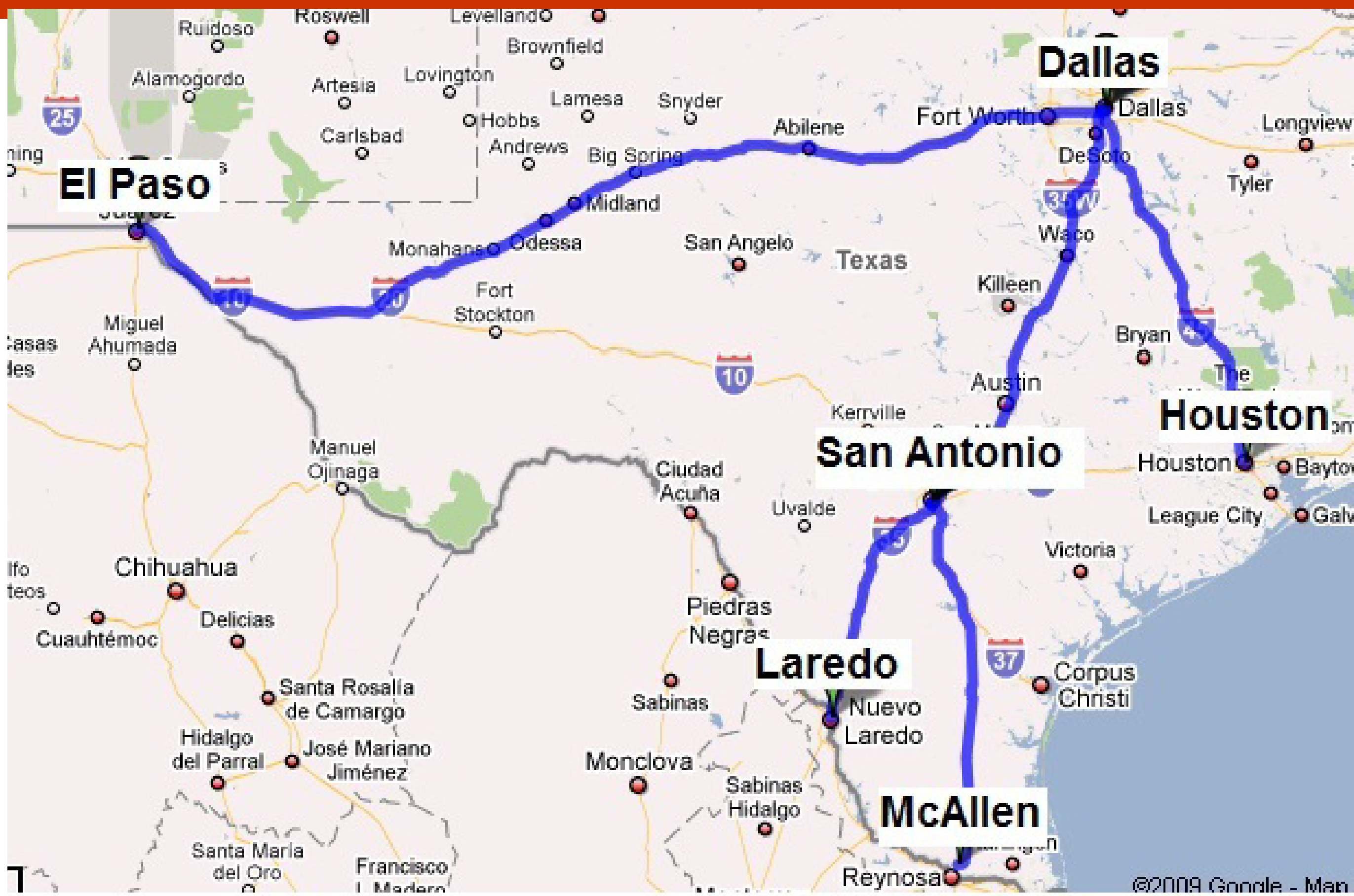
EU Gigaliners

LCVs in Europe



- Project considered a variety of highway/ LCV classes
- A single LCV scenario was applied to several key highway corridors used by truckers
  - 97 k tridem semi
  - 138 K Double 53’

Routes



Dallas
El Paso
San Antonio
Houston
Laredo
McAllen
Roswell
Ruidoso
Alamogordo
Artesia
Lovington
Brownfield
Carlsbad
Hobbs
Lamesa
Snyder
Andrews
Big Spring
Abilene
Fort Worth
Midland
Odessa
Monahans
San Angelo
Texas
Fort Stockton
Waco
Killeen
Bryan
Austin
Kerrville
Tyler
Longview
Miguel Ahumada
Manuel Ojinaga
Ciudad Acuña
Uvalde
Chihuahua
Cuauhtémoc
Delicias
Santa Rosalía de Camargo
Piedras Negras
Sabinas
Nuevo Laredo
Hidalgo del Parral
José Mariano Jiménez
Monclova
Sabinas Hidalgo
Santa María del Oro
Reynosa
League City
Victoria
Corpus Christi

- Pavement applied a factor which captivated an estimate of cube out and weigh out commodities

Analysis of Truck Crash Severity: Comparing LCVs to other HDTs

Jason Lemp
Kara Kockelman
Avinash Unnikrishnan

Current Approach *vs.* Last Year's Work

- **Previous** Analysis: ***y* = Police-reported** injury severity for all LTCCS observations
- **Current: *y* = Actual** severity, for injurious crashes only
- Crash-level maximum injury **severity statistics…**

Crash's Maximum Severity Outcome	**Previous** Analysis		**New** Analysis	
	Wtd. Freq.	Wtd. %	Wtd. Freq.	Wtd. %
No Injury	12	1.3%	n/a	**n/a**
Possible Injury	117	12.7%	n/a	**n/a**
Non-Incap. Injury	308	33.4%	501	54.3%
Incapacitating Injury	308	33.4%	343	37.2%
Killed	177	19.2%	78	8.5%

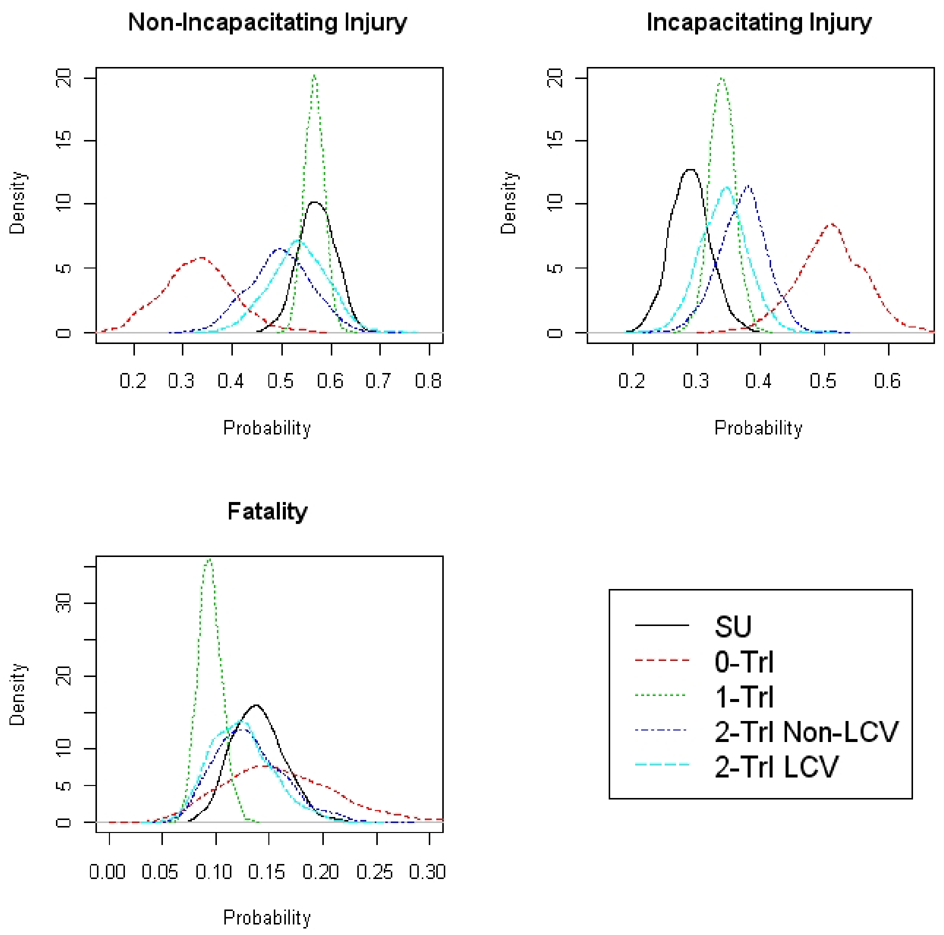
Max. Injury Severity (Crash Records)

- Likelihood of **fatal crash** (probability of fatality for average crash is about 0.085) ***increases***…
  - With each additional **truck** (by 0.057), **passenger vehicle** (by 0.048), **& non-motorist** (by **0.32**);
  - With each added **truck & passenger vehicle occupant** (by 0.038 & 0.027);
  - Under any **non-bright lighting** conditions (0.067 to 0.084);
  - On **rural non-freeways** (by 0.054);
  - On **snowy/icy surfaces** (by **0.188**) & when **fog** is present (by 0.379);
  - For each additional **10 mph speed limit** (by 0.019), &
  - For **each trailer** on the largest truck (by **0.058**) & if the largest truck is a **single unit** (by **0.050**).

Max. Injury Severity (2)

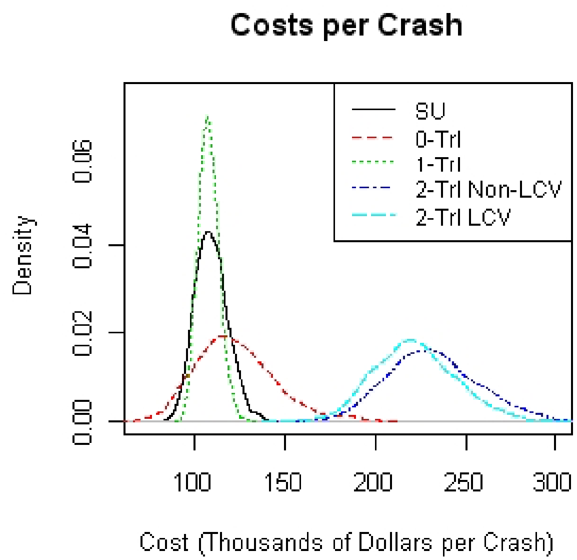
- Likelihood of a **fatal crash** ***decreases***…
  - On **curved roads** (by 0.037) & at road **crests & sags** (by 0.026 & 0.048);
  - On **wet surfaces** (by 0.045) & when ***other*** **weather conditions** are present (by 0.078);
  - When any involved **truck is overweight** (by 0.035);
  - When any driver is exhibiting **aggressive behavior** other than speeding (by 0.065); &
  - With each meter of the **largest truck's** **length** (by 0.003) & each 10,000 kg of its **GVWR** (by 0.015).

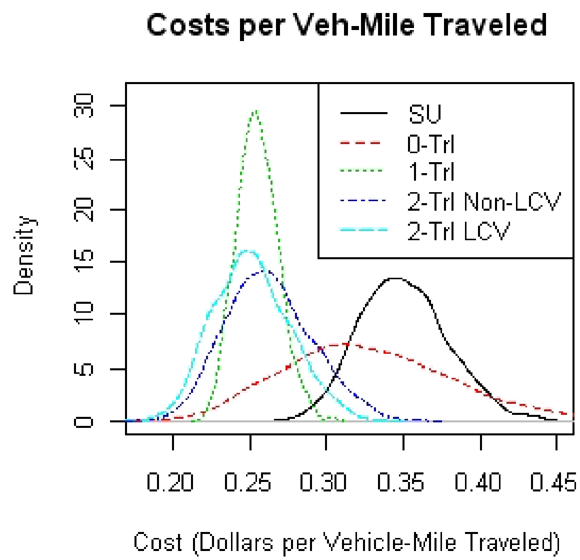
Maximum Injury Severity by Truck Type



Exposure Risk & Cost

- Zaloshnja and Miller (2007) estimated crash costs by severity.
- GES 2002 data provides share of no-injury crashes, & overall crash counts by truck type.
- VIUS 2002 data offers VMT by truck type.





Conclusions

- 2-trailer LCVs appear to enjoy **significantly lower crash rates, but higher crash costs**. In all, they offer **lowest crash costs per mile driven**.
- These results + interviews + literature suggest we can **recommend LCV use on freeways** for long hauls (with proper speed & other enforcement).

Model Specification

- Standard Ordered Probit (OP)

$$U_i = X_i'\beta + \varepsilon_i \qquad \forall\, i = 1, \ldots, N \qquad \varepsilon_i \sim N(0, \sigma^2)$$

$$y_i = s \ \text{ if } \mu_{s-1} < U_i < \mu_s \qquad s = 1, \ldots, S$$

$$P(y_i = s) = \Phi\left(\frac{\mu_s - X_i'\beta}{\sigma}\right) - \Phi\left(\frac{\mu_{s-1} - X_i'\beta}{\sigma}\right)$$

- Heteroskedastic Ordered Probit (HOP)

$$\sigma_i^2 = [\exp(Z_i'\gamma)]^2$$

$$P(y_i = s) = \Phi\left(\frac{\mu_s - X_i'\beta}{\sigma_i}\right) - \Phi\left(\frac{\mu_{s-1} - X_i'\beta}{\sigma_i}\right)$$

Bayesian Model Estimation

- Draw each set of parameters from conditional posterior distributions:
  - $\beta \sim N(C, D)$, $C = D\left(X'WU + \Sigma_\beta{}^{-1}\bar{\beta}\right)$ $D = \left(X'WX + \Sigma_\beta{}^{-1}\right)^{-1}$
  - $U_i \sim$ Truncated $N(X_i{'}\beta, \sigma_i^2)$,
  - $\mu_s \sim U(\max_{i \in Q_{s-1}}(U_i), \min_{i \in Q_s}(U_i))$,

$$p(\gamma \mid U, \beta, \mu, X, Y) \propto \left[\prod_{i=1}^{N}\left(\frac{1}{\sigma_i}\right)^{w_i}\right]\exp\left[-\frac{1}{2}\left(\sum_i \frac{w_i[U_i - X_i{'}\beta]^2}{\exp[2Z_i{'}\gamma]} + [\gamma - \bar{\gamma}]'\Sigma_\gamma{}^{-1}[\gamma - \bar{\gamma}]\right)\right]$$

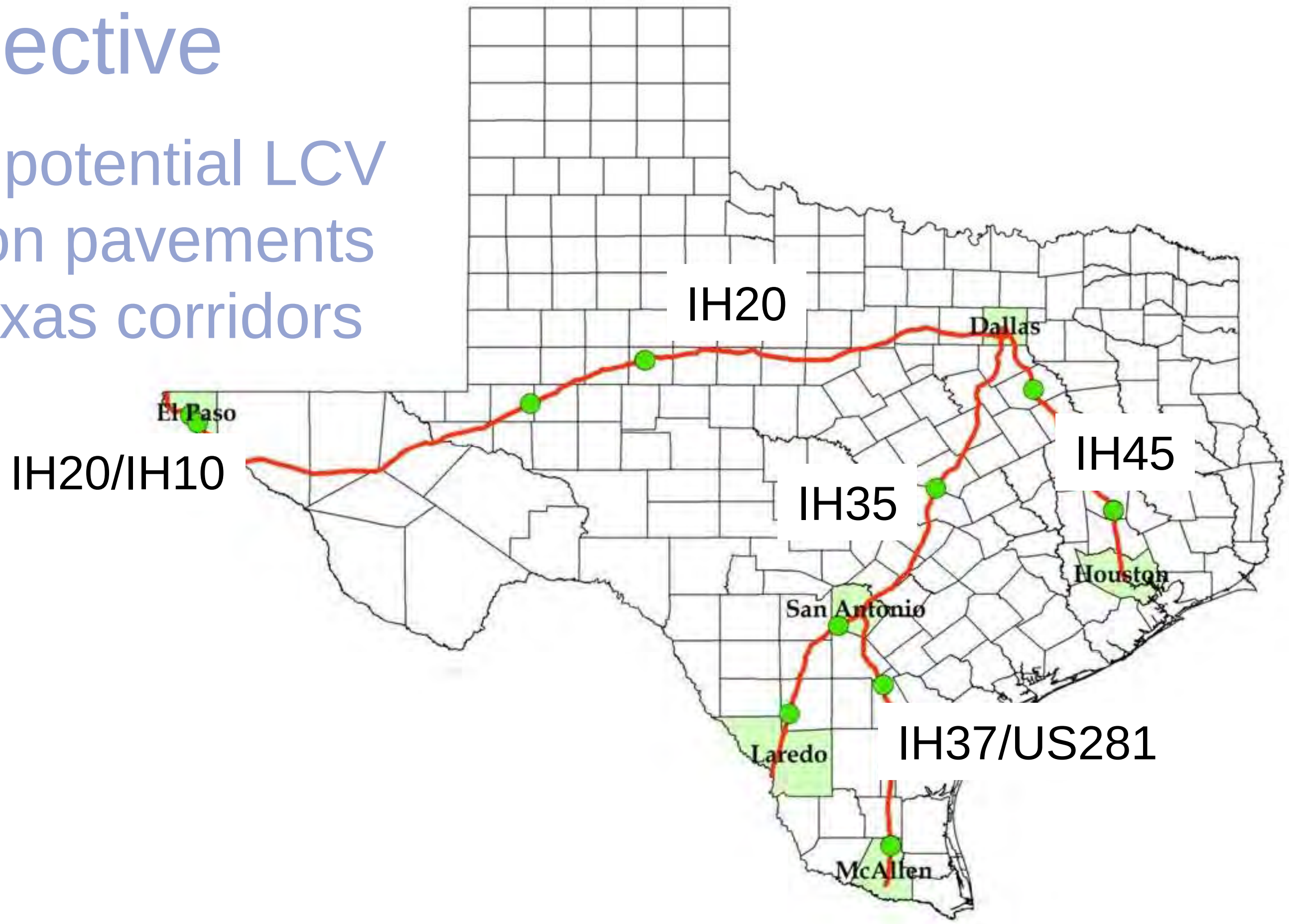
    - Metropolis-Hastings (MH) step used to draw γ.

THANK YOU!

Pavement Analysis

Objective

Estimate potential LCV impacts on pavements in four Texas corridors



Presentation Outline

- Pavement Analysis Objective
- Methodology
  - Data Treatment
  - LCV Scenario
  - Measures of LCV Impacts
- Results and Findings
- Conclusions and Recommendations

Data Treatment

Objective: prepare input files for the pavement analysis.

1. Divide each corridor into segments with uniform truck traffic, same pavement and same subgrade type;
2. Develop load spectra for existing and LCV scenarios; and
3. Obtain subgrade and material properties, tire pressures, detailed axle configuration.

Data Overview

Data Type		Main Sources
TRAFFIC	Average daily truck traffic	PMIS/RHiNo databases
	Vehicle classification Axle load distribution	TP&P / FHWA WIM data reports
	Tire pressures	FHWA's ME-PDG
	Axle configurations	-FHWA's vehicle classes -This project's LCV scenario
PAVEMENT	Pavement cross sections	CSJ database
	Subgrade types	PMIS database
	Pavement layers' properties	Miscellaneous references
	Pavement rehabilitation costs	-TxDOT Expressway- 6/2010 -Construction Division -2030 project data

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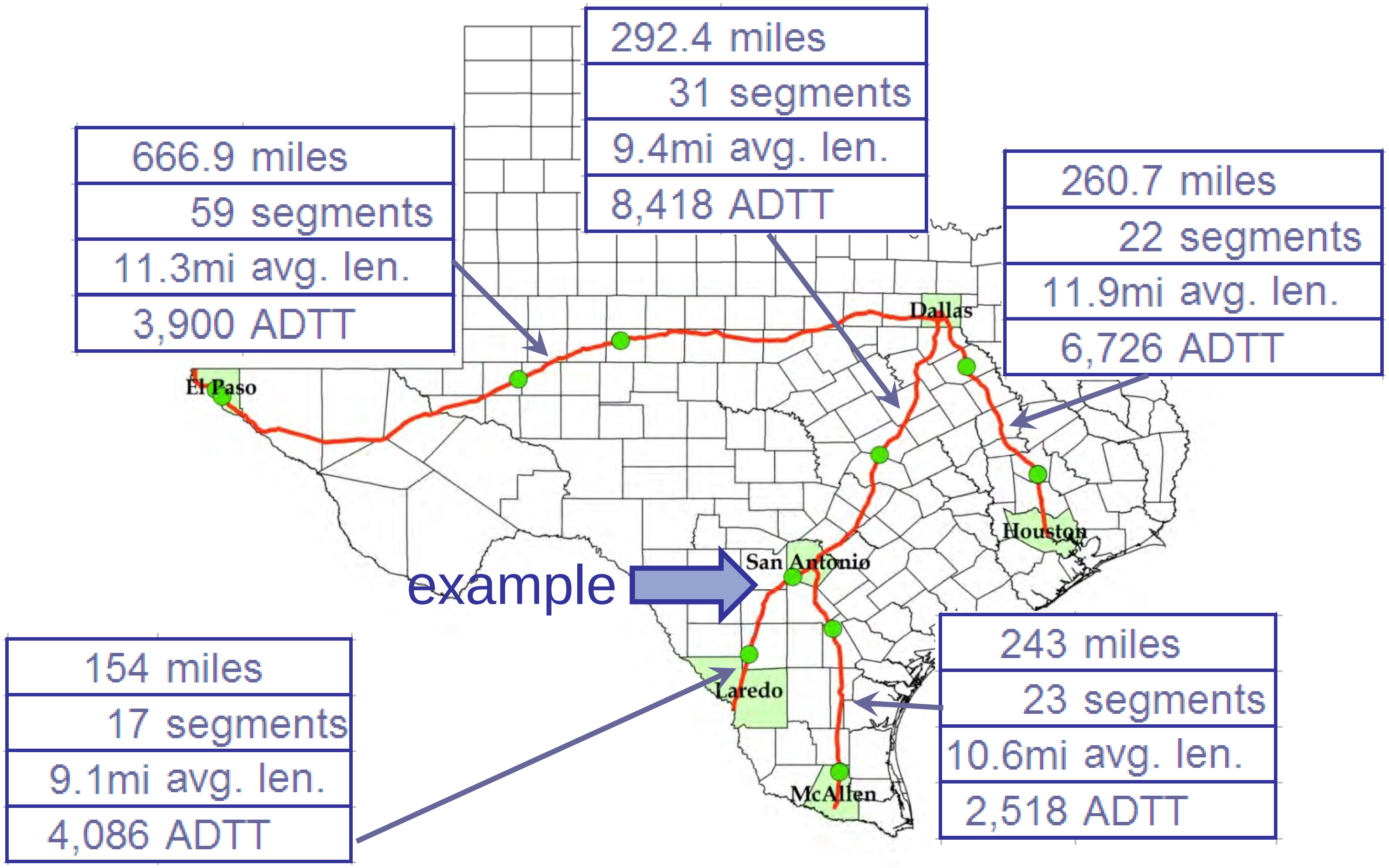
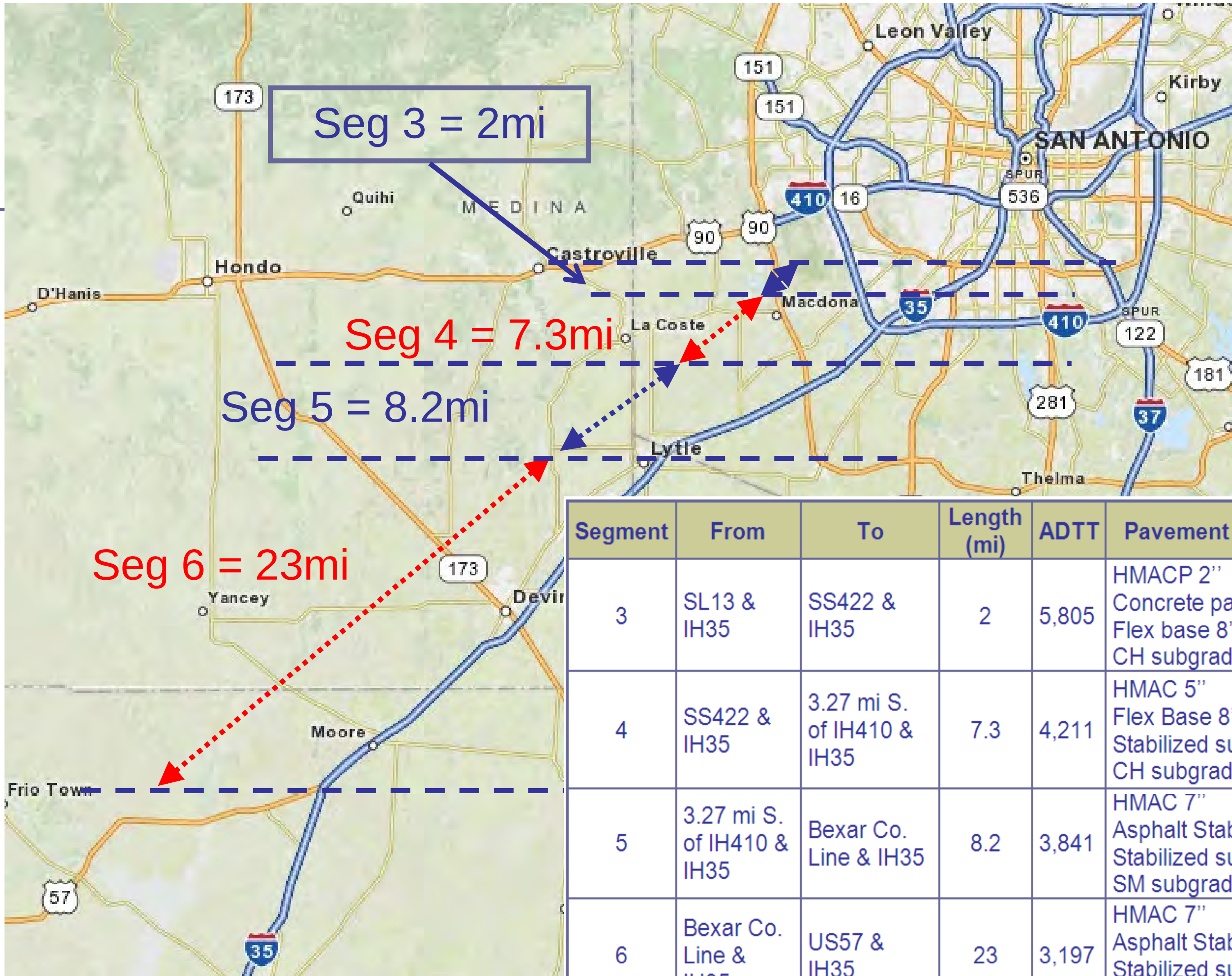
152 Analysis Segments





Segment	From	To	Length (mi)	ADTT	Pavement cross section
3	SL13 & IH35	SS422 & IH35	2	5,805	HMACP 2'' Concrete pavement 10'' Flex base 8'' CH subgrade
4	SS422 & IH35	3.27 mi S. of IH410 & IH35	7.3	4,211	HMAC 5'' Flex Base 8'' Stabilized subgrade 8'' CH subgrade
5	3.27 mi S. of IH410 & IH35	Bexar Co. Line & IH35	8.2	3,841	HMAC 7'' Asphalt Stabilized Base 4'' Stabilized subgrade 6'' SM subgrade
6	Bexar Co. Line & IH35	US57 & IH35	23	3,197	HMAC 7'' Asphalt Stabilized Base 4'' Stabilized subgrade 6'' SP-SM subgrade

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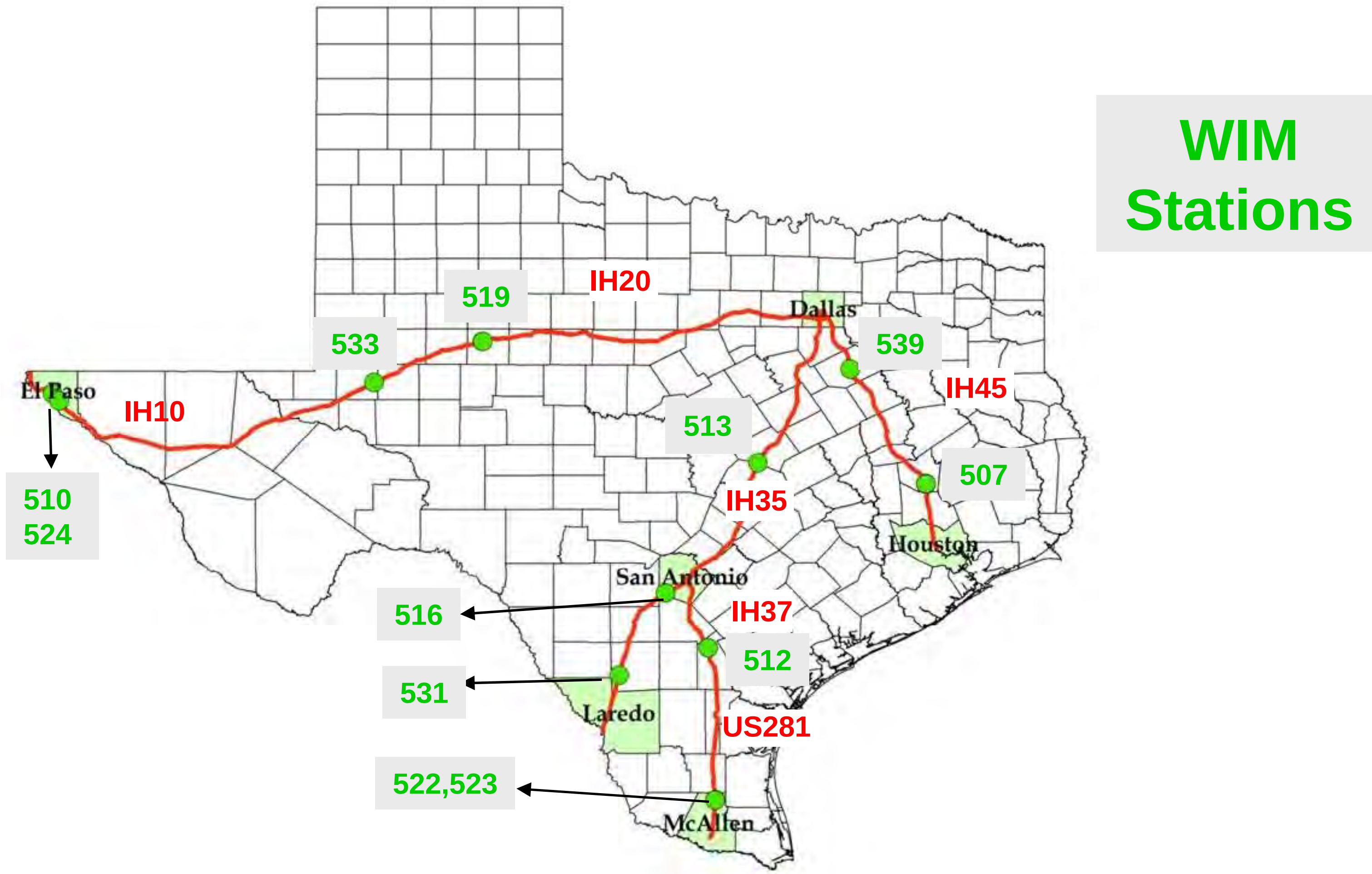
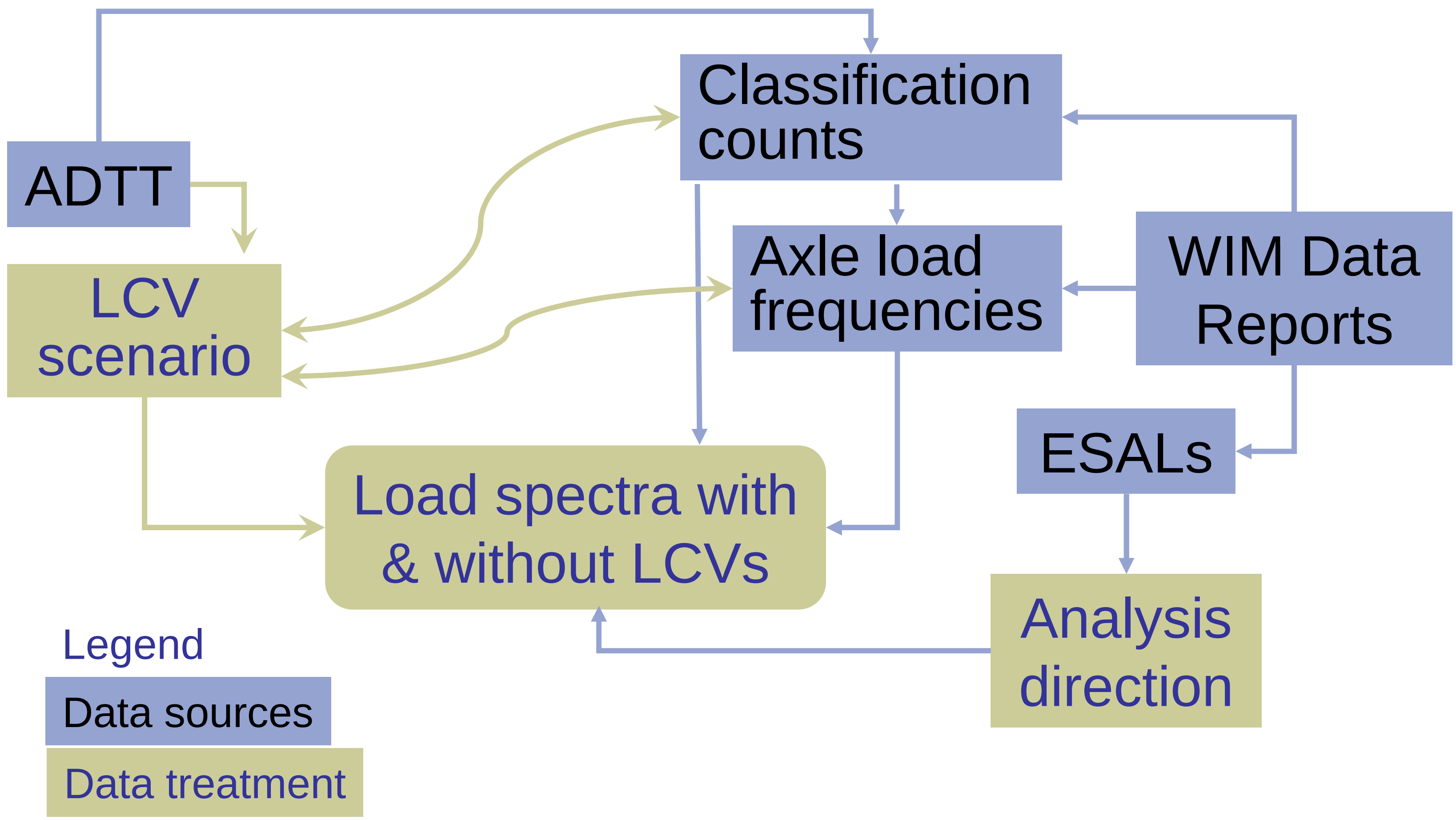
Weigh-in-Motion Locations



Load Spectra Analysis



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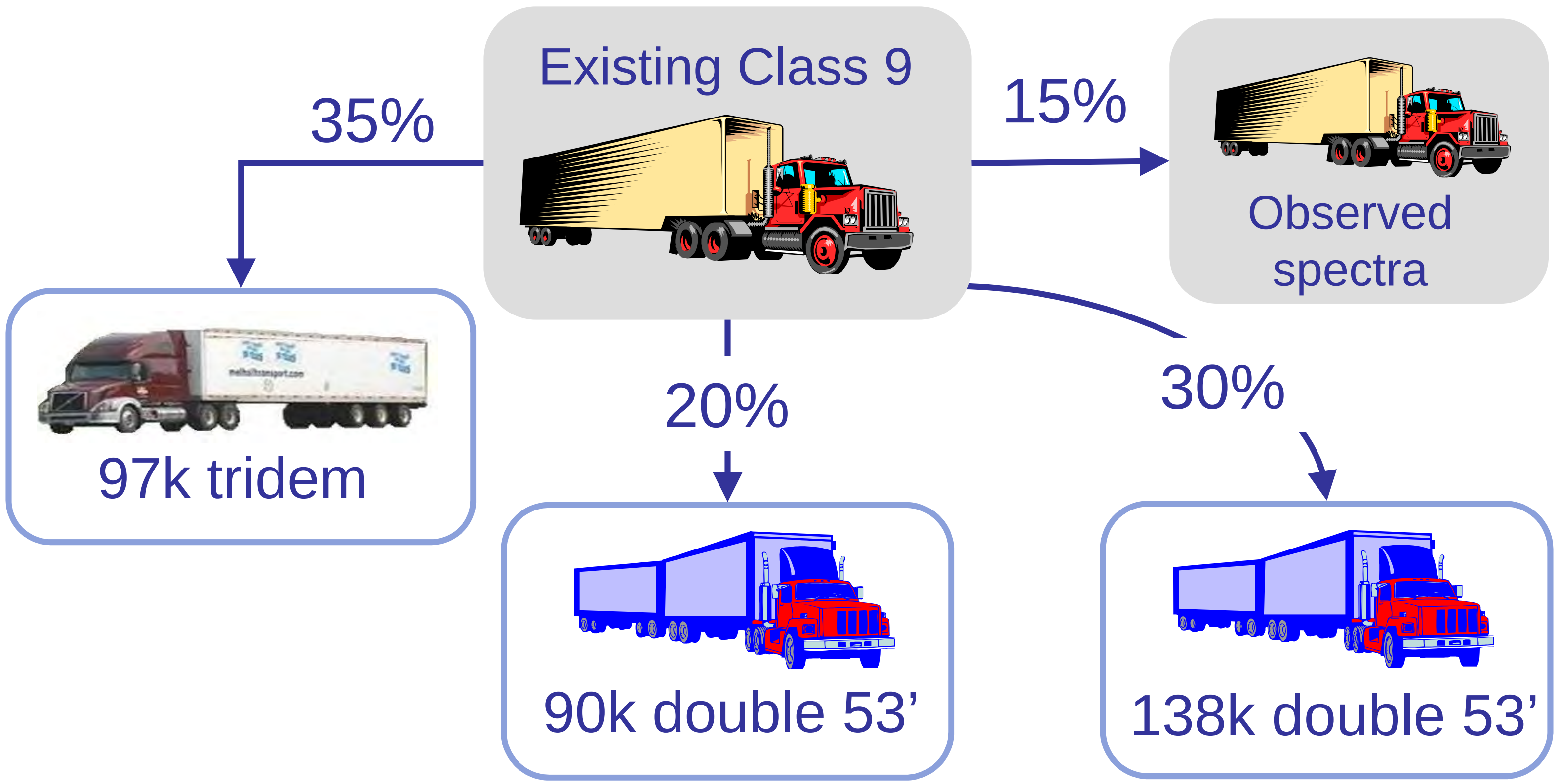
LCV Scenario



Total cargo remains unchanged

What does the LCV scenario entail?

Tandem & single weight limits =

Single and tandem axle repetitions ↓

Number of overweight single axles ↓

Number of overweight tandem axles ↓

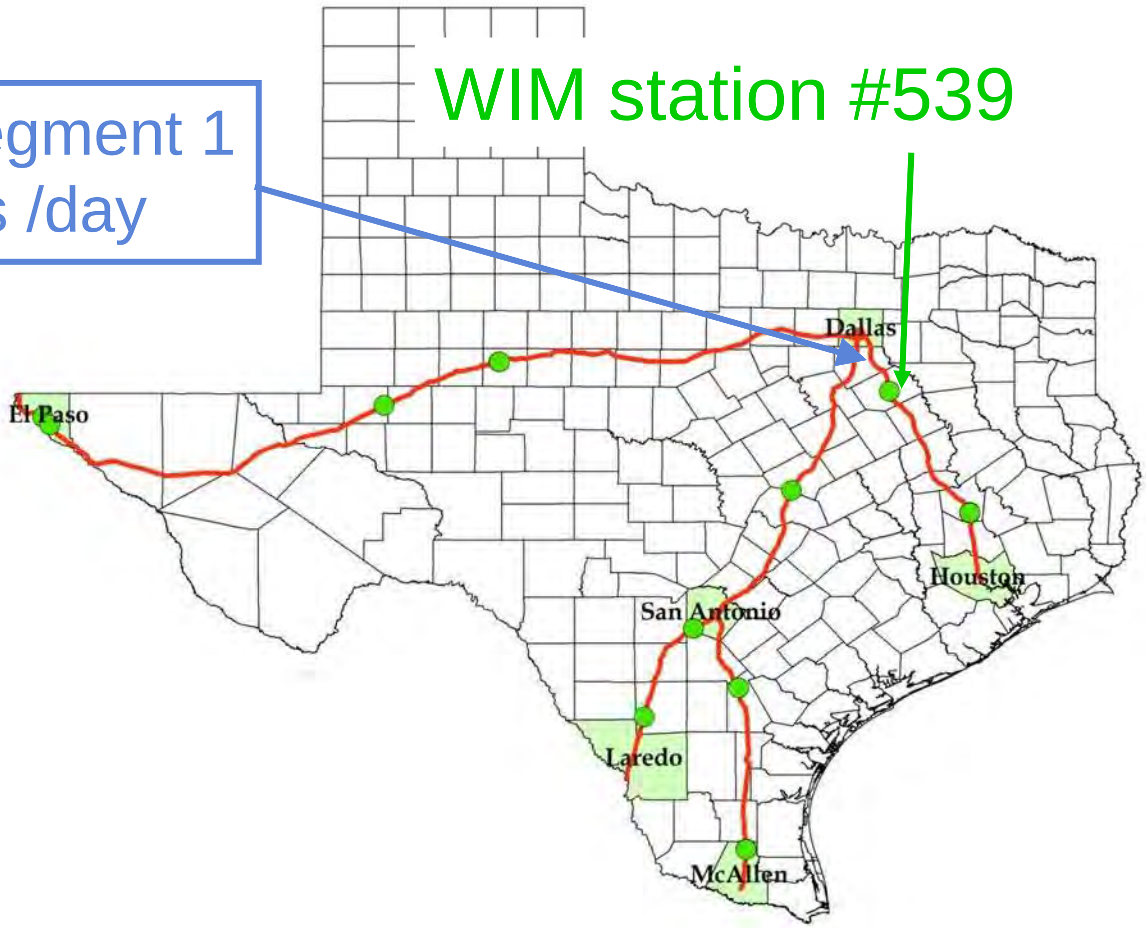
Tridem axle weight ↑

Heavy tridem repetitions ↑

Example

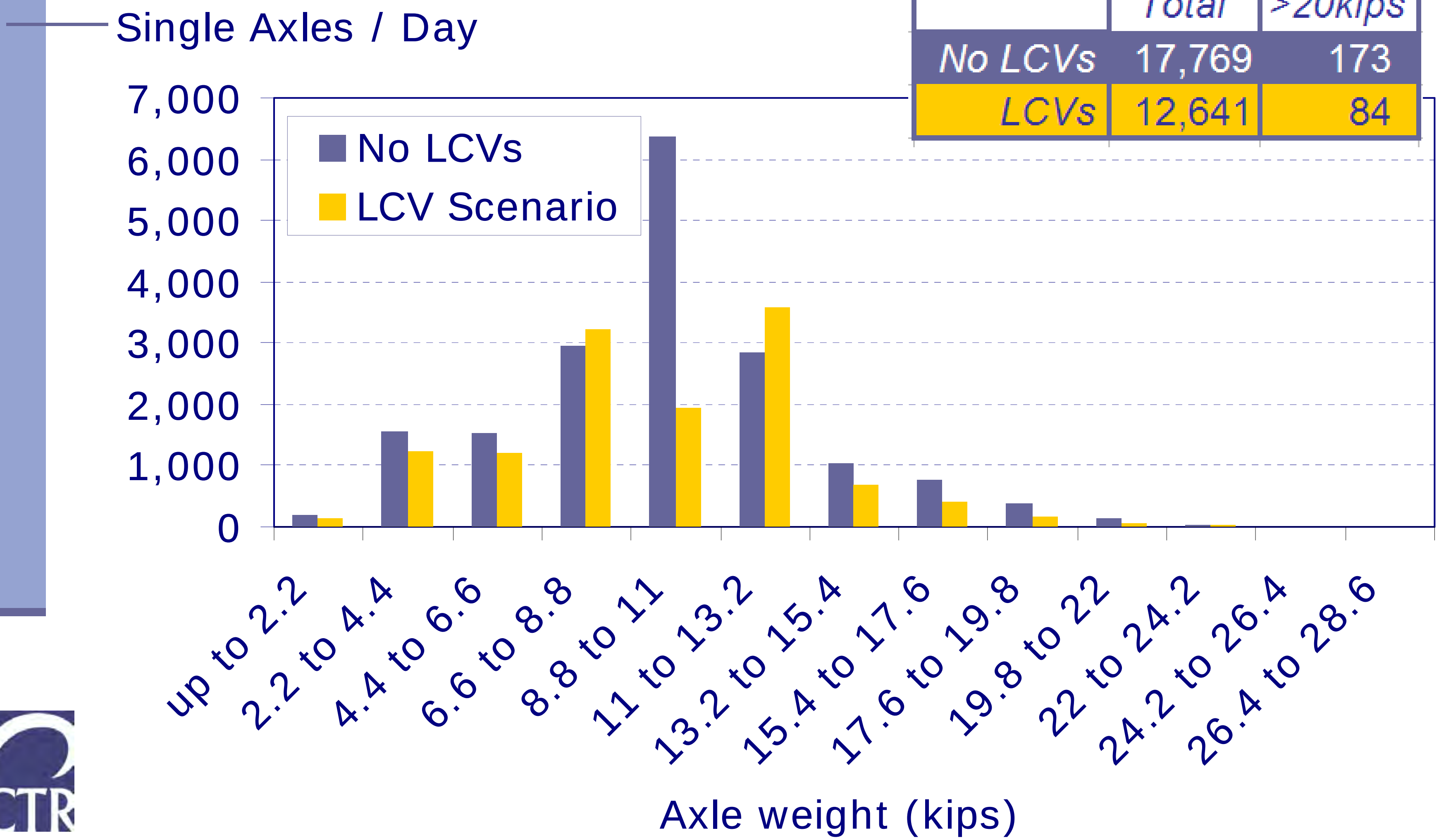
IH45 analysis segment 1
13,600 trucks /day

WIM station #539



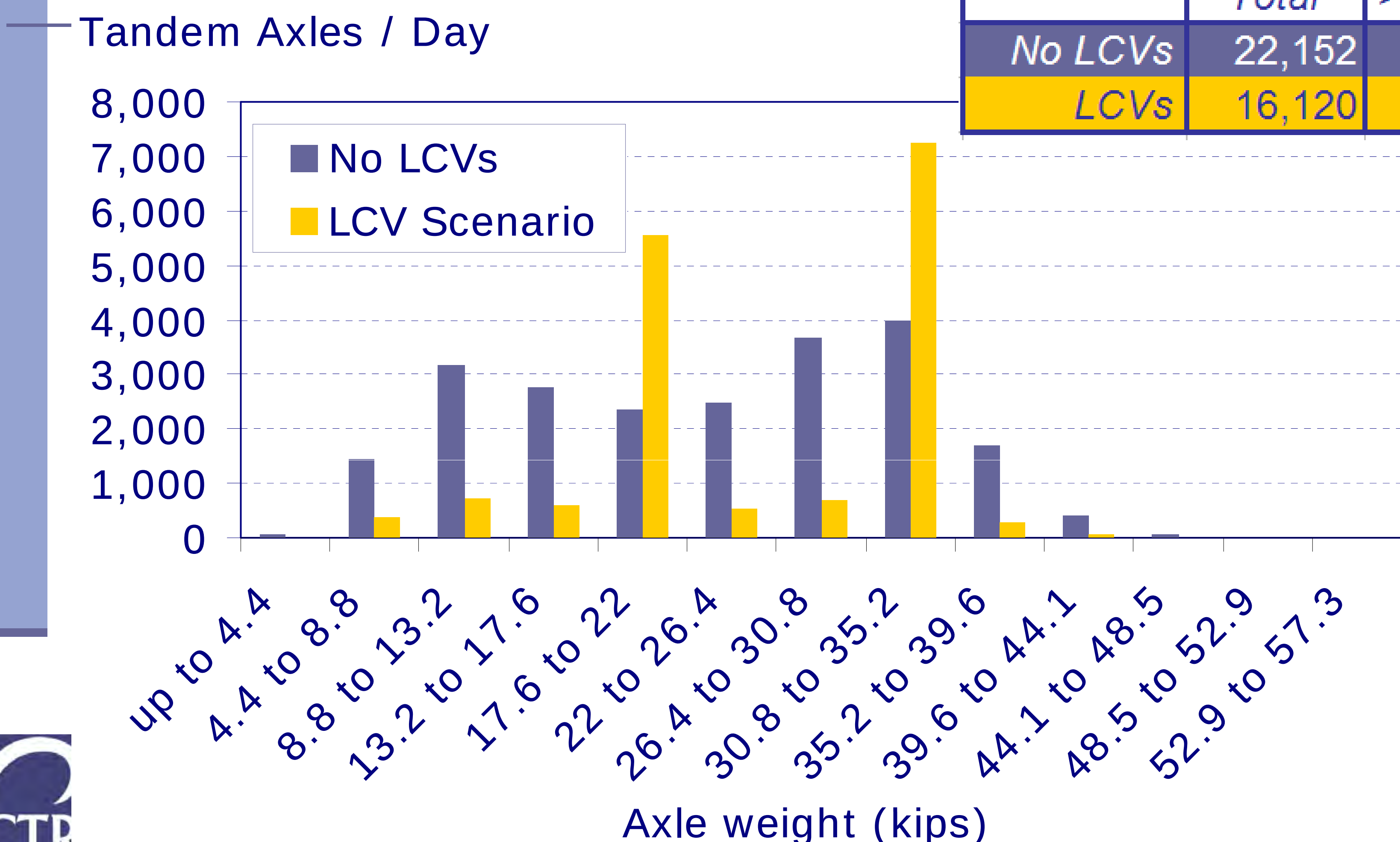
Single axles

Scenario	Axles/Day	
	Total	>20kips
No LCVs	17,769	173
LCVs	12,641	84



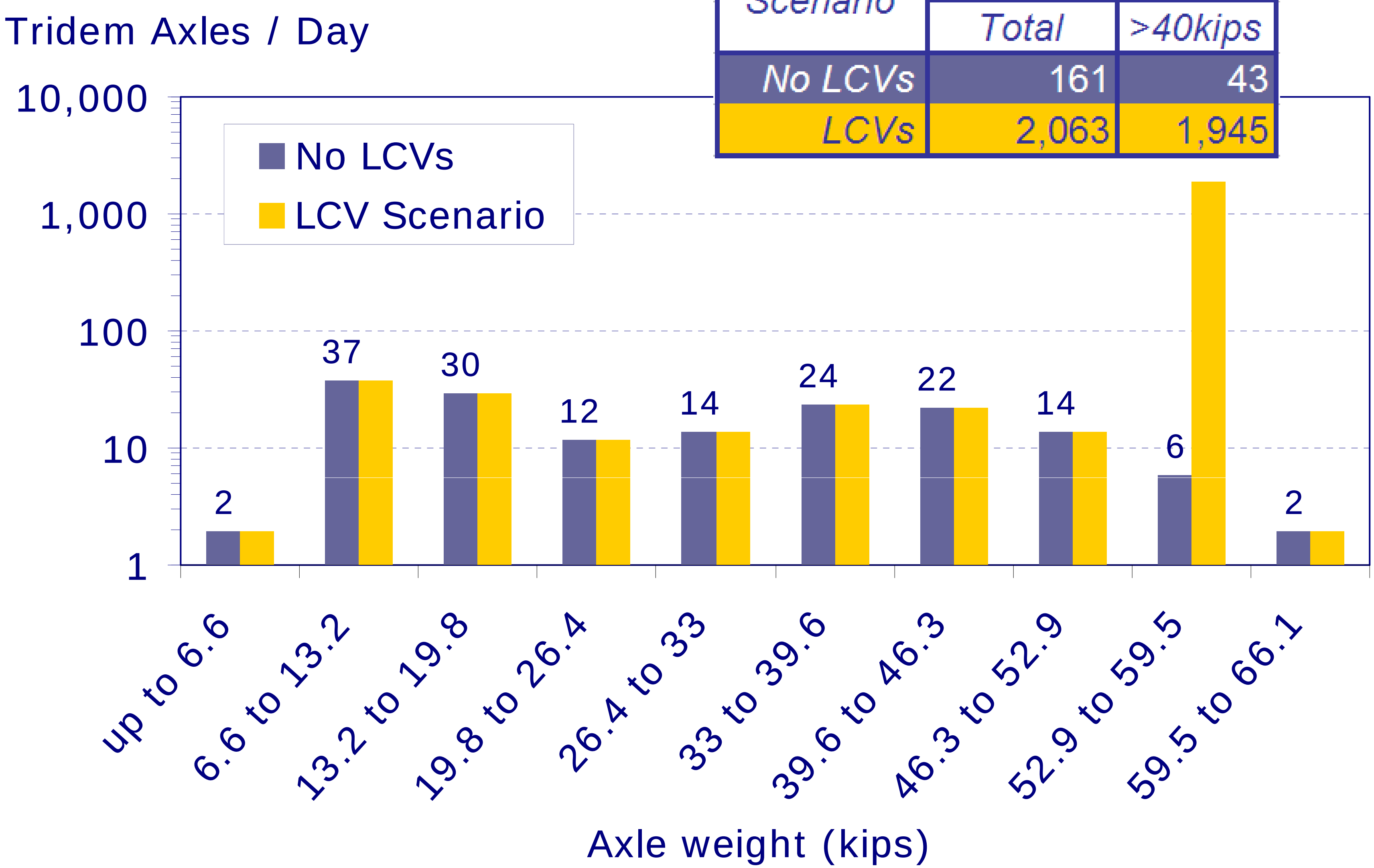
Tandem axles

Scenario	Axles/day	
	Total	*>34kips*
No LCVs	22,152	2,200
LCVs	16,120	385



Tridem axles

Scenario	Axles/day	
	Total	*>40kips*
No LCVs	161	43
LCVs	2,063	1,945



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Measures of LCV Impacts

Δ_{life} = Pvt. Life w/ LCV – Pvt. Life w/o LCV

$|\Delta life| \geq 1$ or Life<50yrs

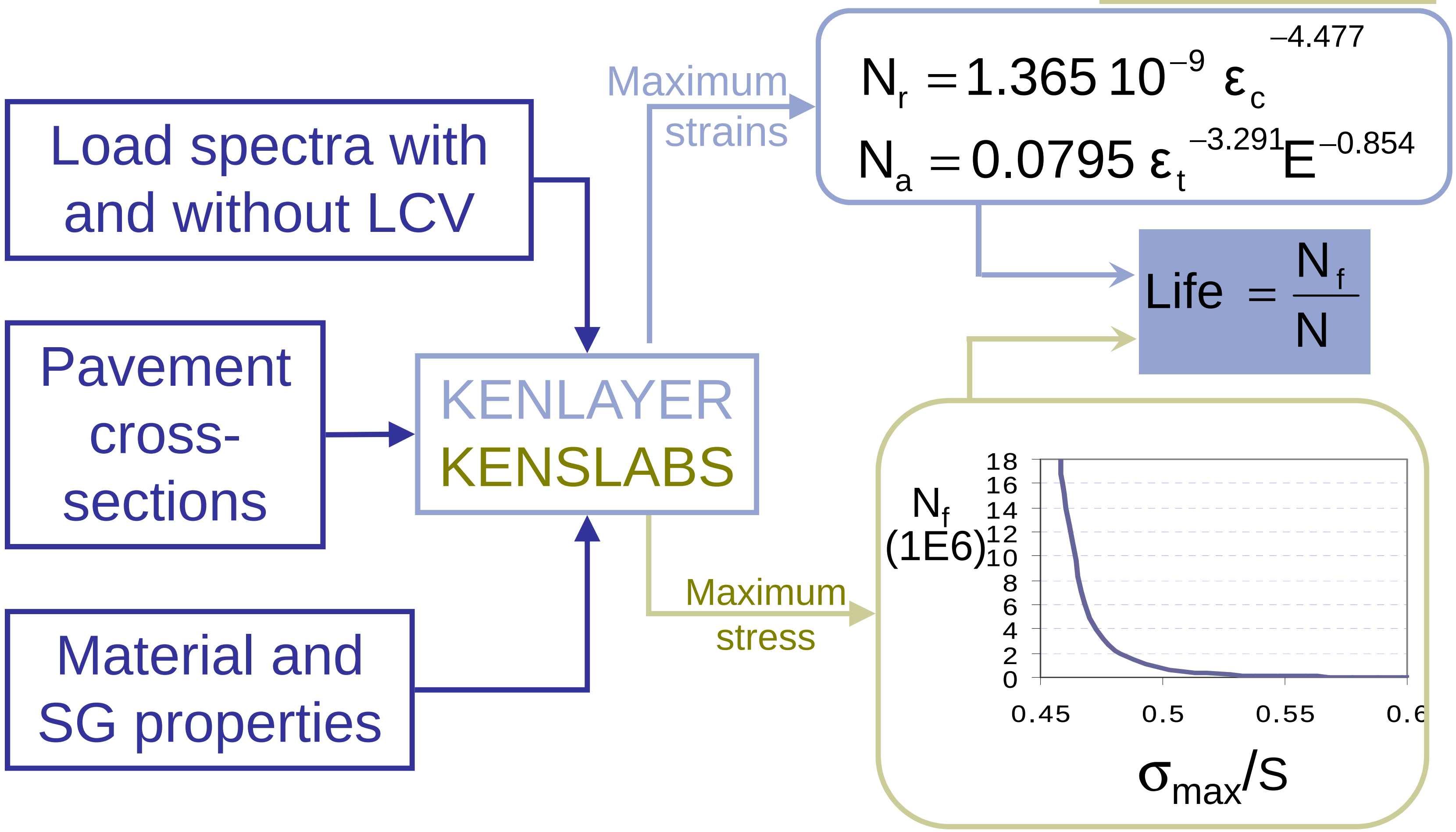
Δ_{cost} = Annual. cost w/ LCV – Annual. cost w/o LCV

$\Delta_{life}<1$ → $\Delta_{cost}>0$ → LCV scenario worse

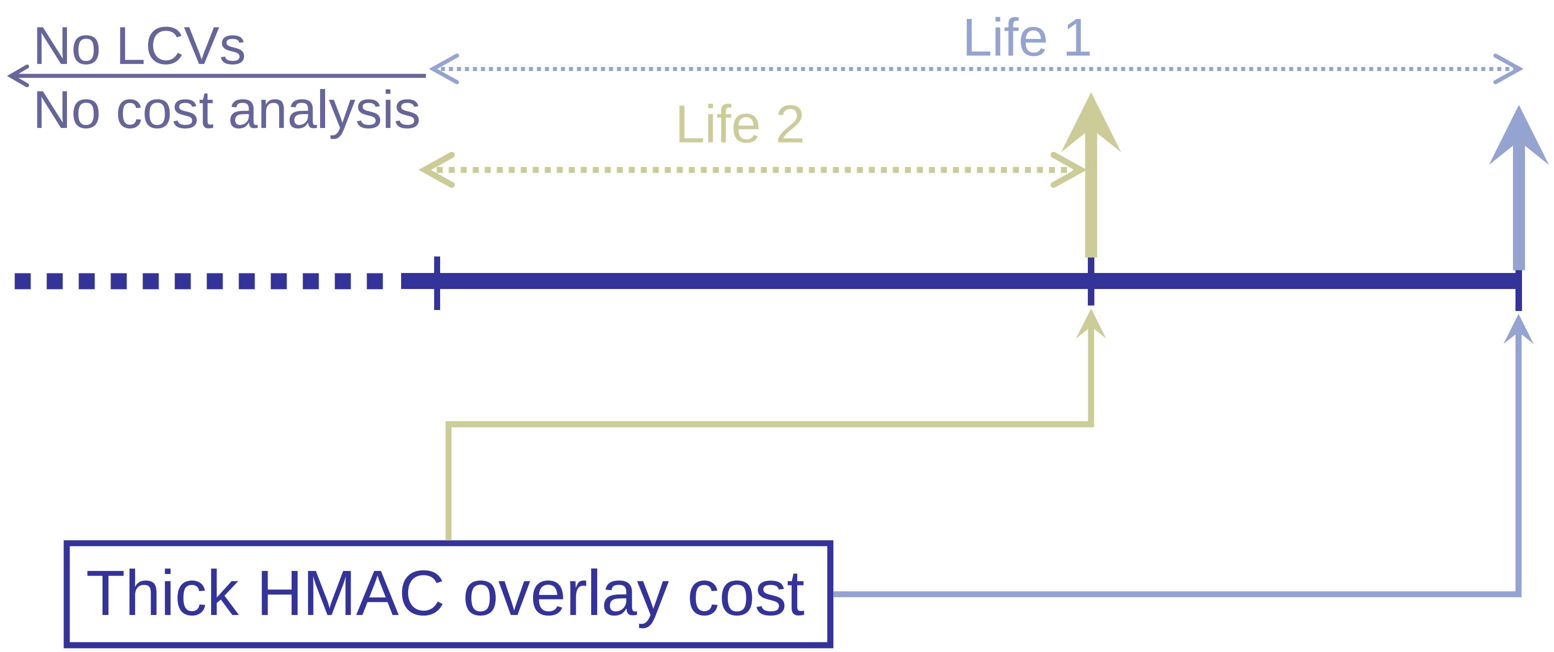
$\Delta_{life}>1$ → $\Delta_{cost}<0$ → LCV scenario better

How did we obtain Δ_{life}?

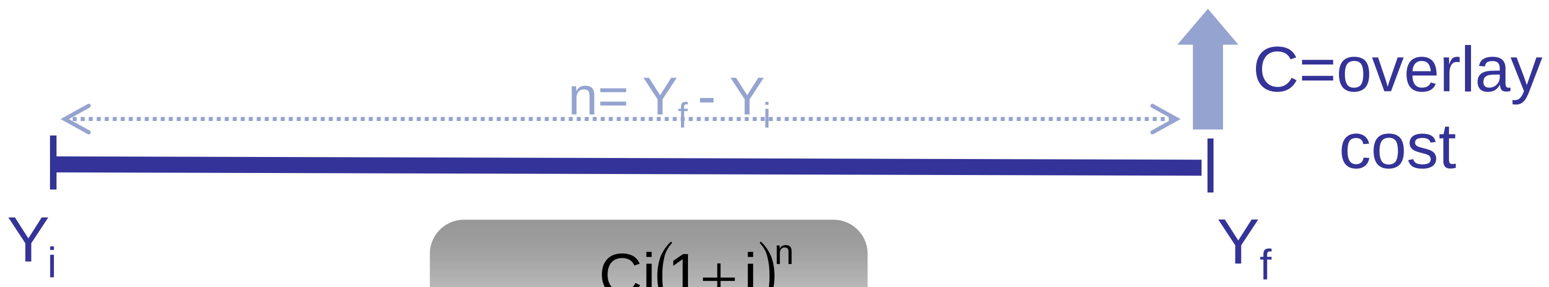
For the 152 analysis segments



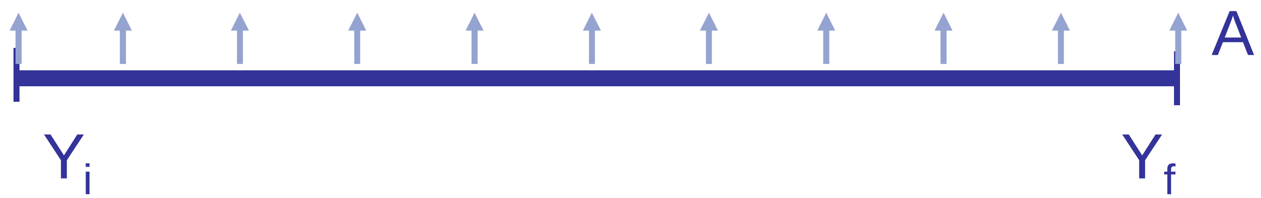
How did we obtain Δ_{cost}?



How did we annualize the costs?

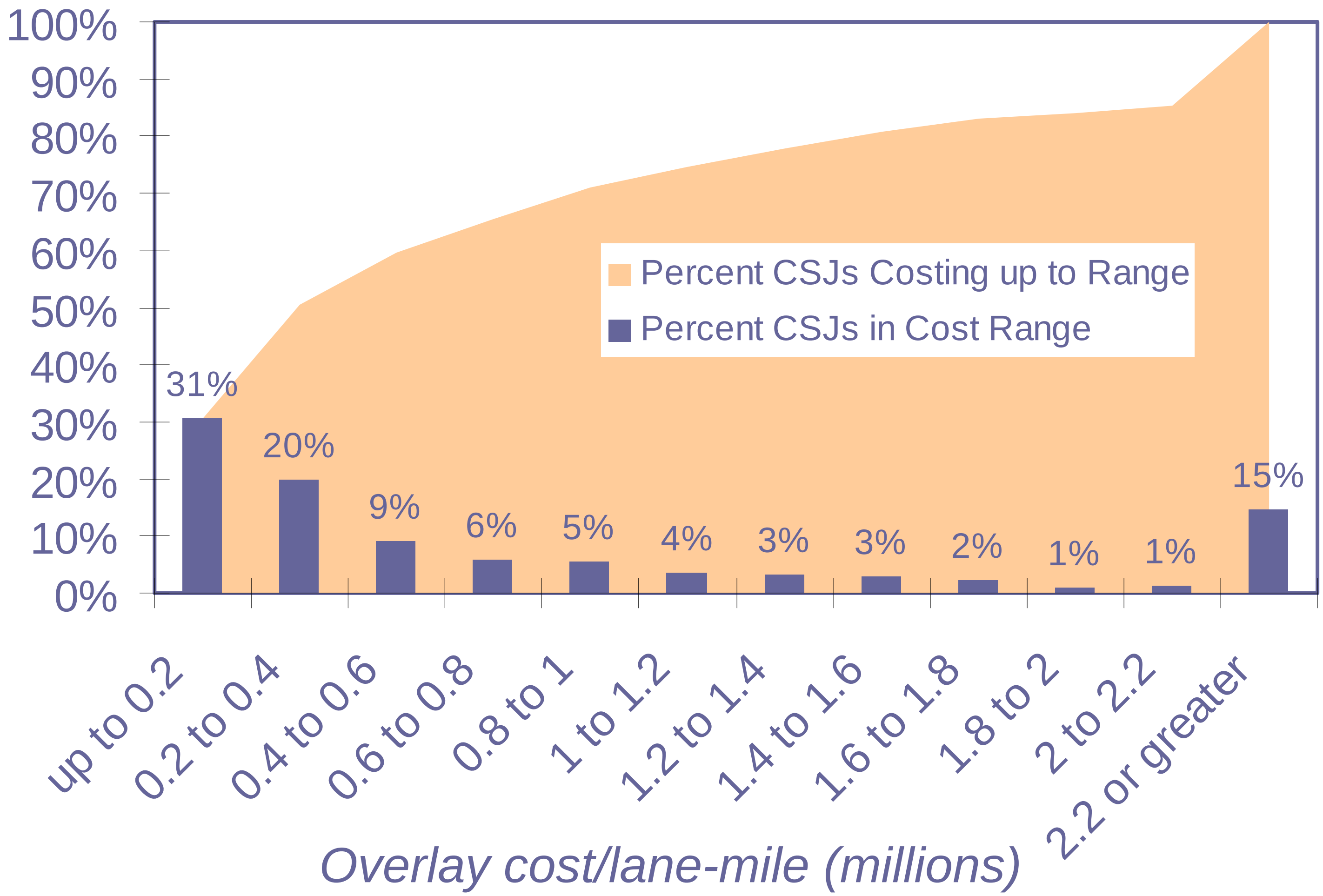


$$A = \frac{Ci(1+i)^n}{(1+i)^n - 1}$$



$$\Delta_{cost} = A_{w/LCV} - A_{wo/LCV}$$

What are the costs?



What costs did we use?

Percent Projects	Costing up to... ($1000/lane*mile)
50%	$390
50.5%	$400
60%	$607
75%	$1,219

Three cost scenarios

- $400 → 1
- $607 → 2
- $1,219 → 3

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Rigid Pavements

LCV scenario had no impact

- Overweight single axles had more impact on rigid pavement life than heavy tridems or heavy tandems.
- LCV scenario decreases overweight singles.
- Rigid pavement life very large without overweight singles.
- Stress ratios fall into fatigue equation region that is most sensitive to small variations in stresses.

Flexible Pavements

LCV scenario improved expected life in all corridors except San Antonio-McAllen

- In flexible pavements with 14” HMAC over strong bases and subbases, fatigue was due to rutting and LCVs decreased pavement life.
- In segments with overweight axles, LCV scenario improved pavement lives; generally, the thicker the HMAC layer the greater the Δ_{life}
- Heavy tridems appeared to do very little additional damage to the pavement.

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Results

	Length (mi)	Overlay Δ_{cost} ($millions/year)		
		$0.4m	$0.6m	$1.2m
Dallas El Paso	667	$(15.00)	$(22.77)	$(45.76)
Dallas Laredo	446	$(2.54)	$(3.85)	$(7.75)
Dallas Houston	261	$ -	$ -	$ -
San Antonio McAllen	243	$0.14	$0.22	$0.44
TOTAL	1,617	$(17.40)	$(26.40)	$(53.07)

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Why the differences?

	LCV Impact on Annual Overlay Costs	**Reasons**		
		% Rigid Pavement	*% Singles >20K*	*%Tandems >34K*
Dallas El Paso	decrease	52.3%	3.99%	31.29%
Dallas Laredo	decrease	19.8%	0.38%	6.85%
San Antonio McAllen	small increase	6.6%	0.28%	2.87%
Dallas Houston	(none)	100%		

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Dallas—Laredo

		Average Δ life	Lane miles	Overlay Cost (millions)		
				$0.4m	$0.6m	$1.2m
Dallas San Antonio	*Rigid*	*0*	413	$0	$0	$0
	Flexible	*-0.5*	1,180	$0.94	$1.43	$2.87
	Sub-total		1,594	$0.94	$1.43	$2.87
San Antonio Laredo	*Rigid*	*0*	29	$0	$0	$0
	Flexible	*2.6 ≥ 1*	447	($3.89)	($5.90)	($11.86)
	Flex 14" HMAC	*-3.6 ≤ -1*	159	$0.41	$0.62	$1.24
	Sub-total		635	($3.48)	($5.28)	($10.62)
Dallas Laredo Total			2,229	($2.54)	($3.85)	($7.75)

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Dallas—El Paso

HMAC	*Average Δlife (yrs)*	% Overweight	
		Singles	Tandem
12"	12.6	4%	31%
10"	6.0	4%	31%
9"	7.0	4%	31%
<8"	3.3	~0	~0

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Study Limitations

- Only one LCV scenario
- LCVs may not substitute overweight Class 9's
- Calculations limited to strains and stresses due to axle loads
- Pavement treatments limited to HMAC overlays
- Traffic data uncertainties and WIM data extrapolations
- Large variation in overlay unit price

Recommendations

- Best pavement type for future LCV corridors: CRCP
- If flexible, analysis suggests 8” as minimum HMAC thickness to prevent premature alligator cracking.
- Evaluate the Dallas-Houston corridor for possible LCV operations serving the Port of Houston.
- Evaluate other LCV scenarios before cost allocation.
- Develop sensitivity analysis combining load spectra variations and different LCV scenarios for cost alloction.

Thank you!

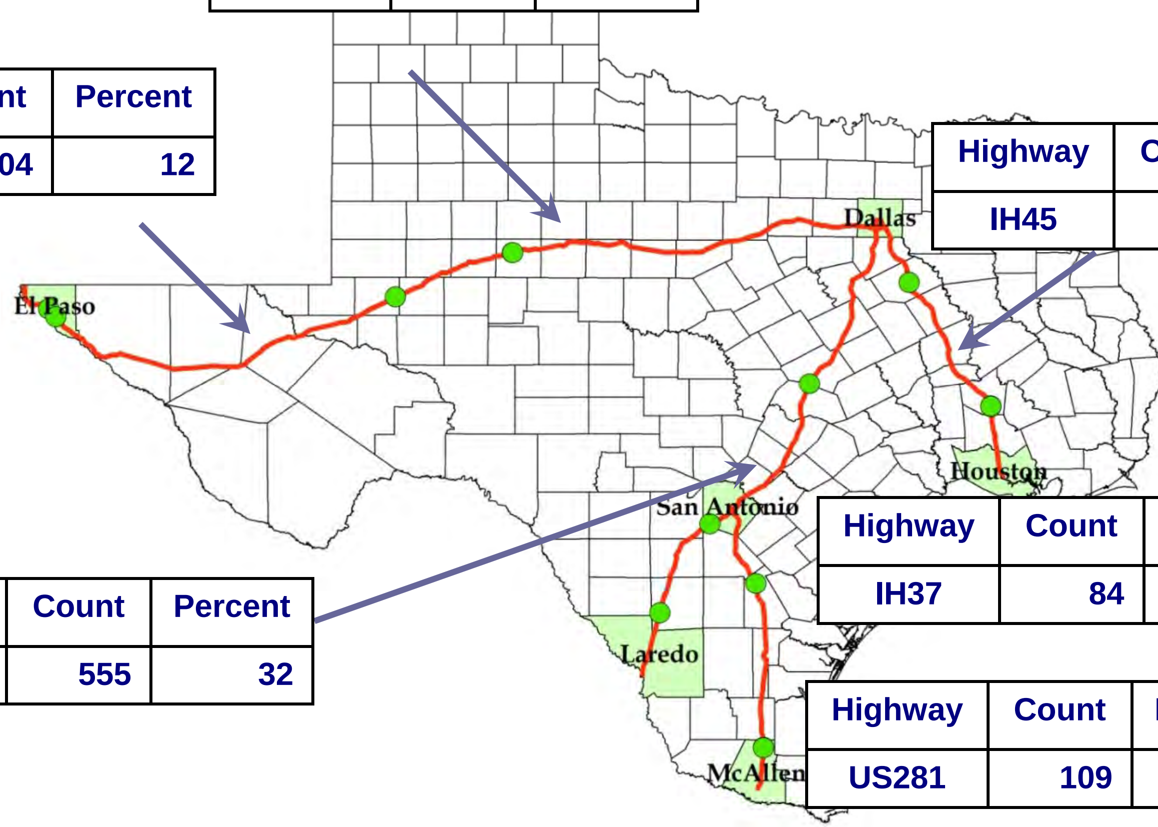
Bridge Analysis

Bridge Statistics (1713 Bridges)

Highway	Count	Percent
IH20	445	26

Highway	Count	Percent
IH10	204	12

Highway	Count	Percent
IH45	316	18

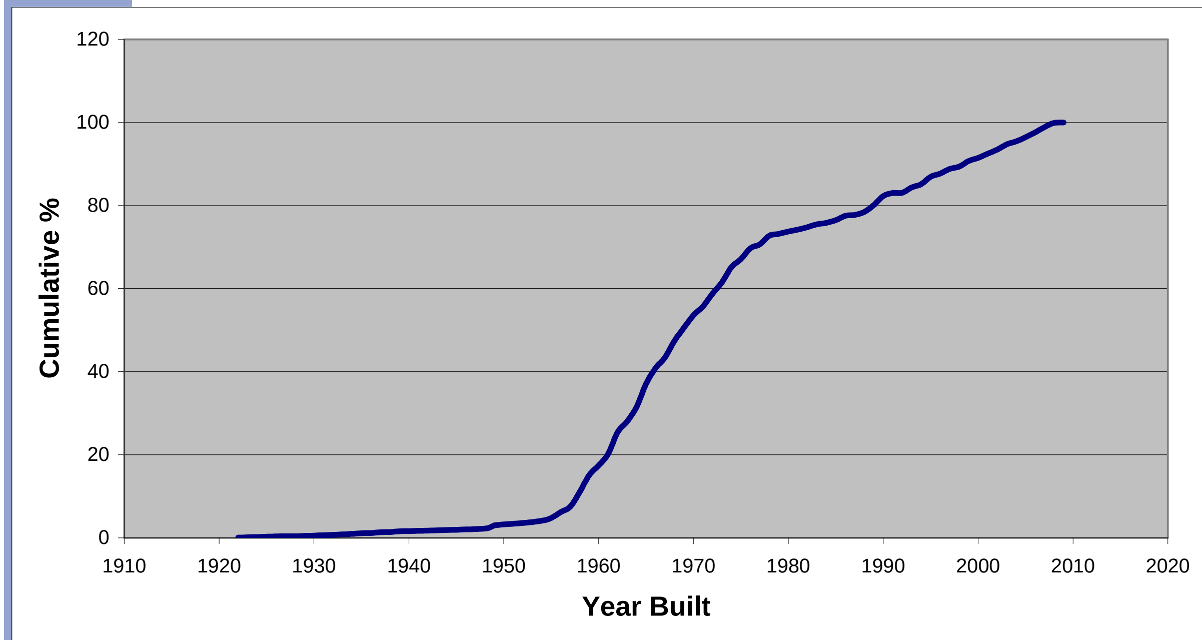


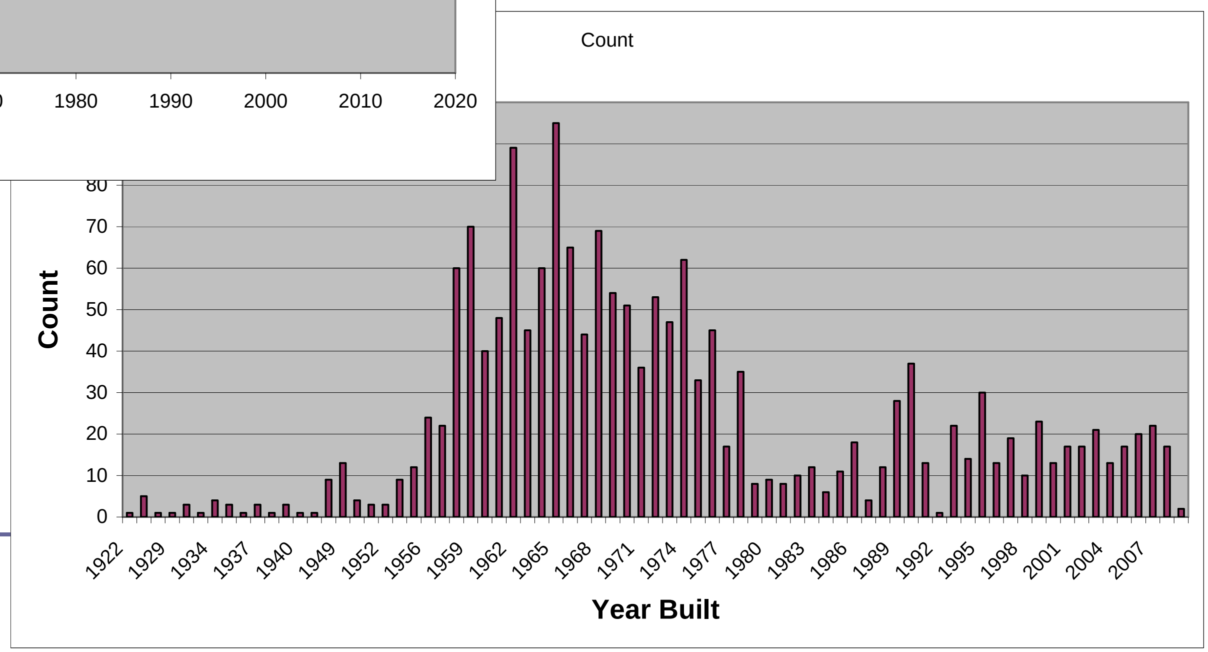
Highway	Count	Percent
IH37	84	5

Highway	Count	Percent
IH35	555	32

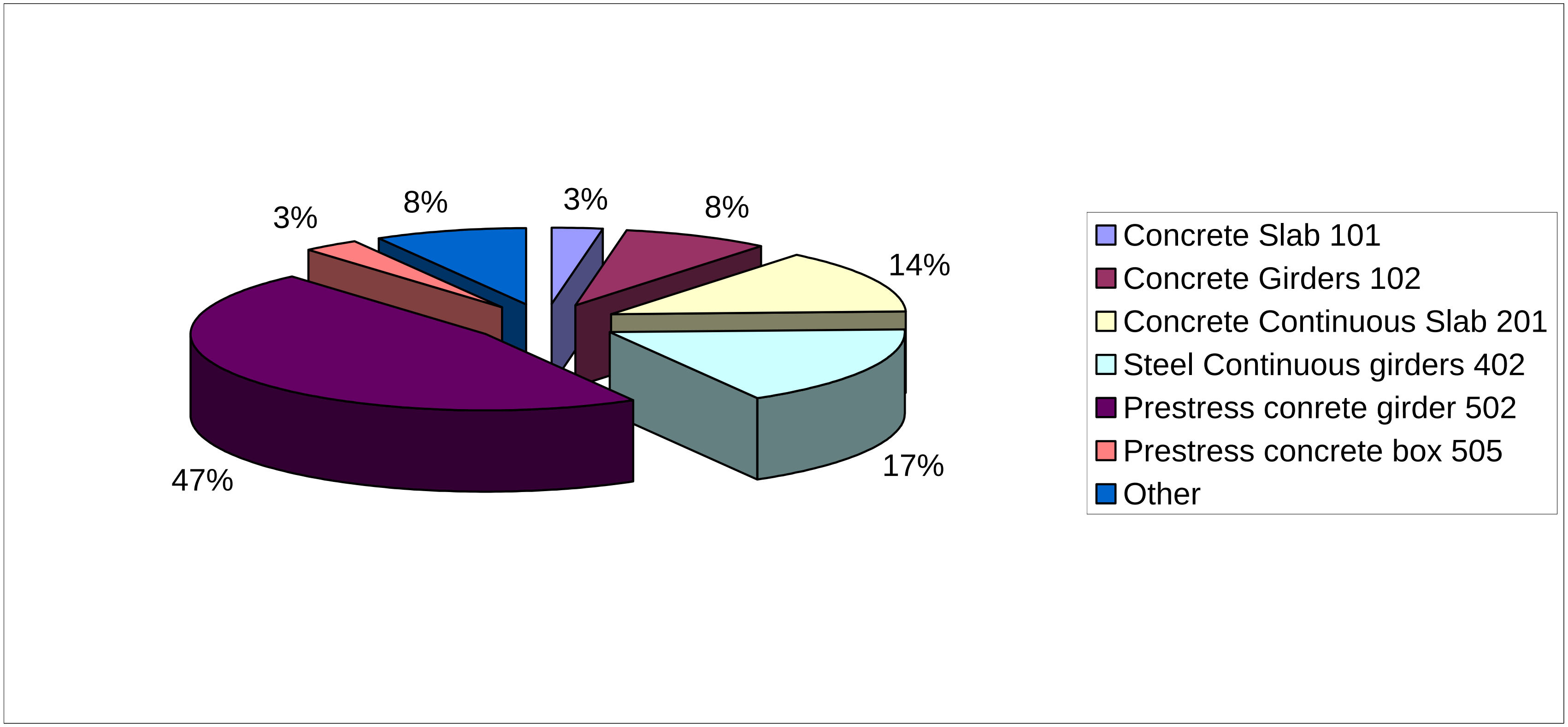
Highway	Count	Percent
US281	109	6

Bridge Statistics – Year built

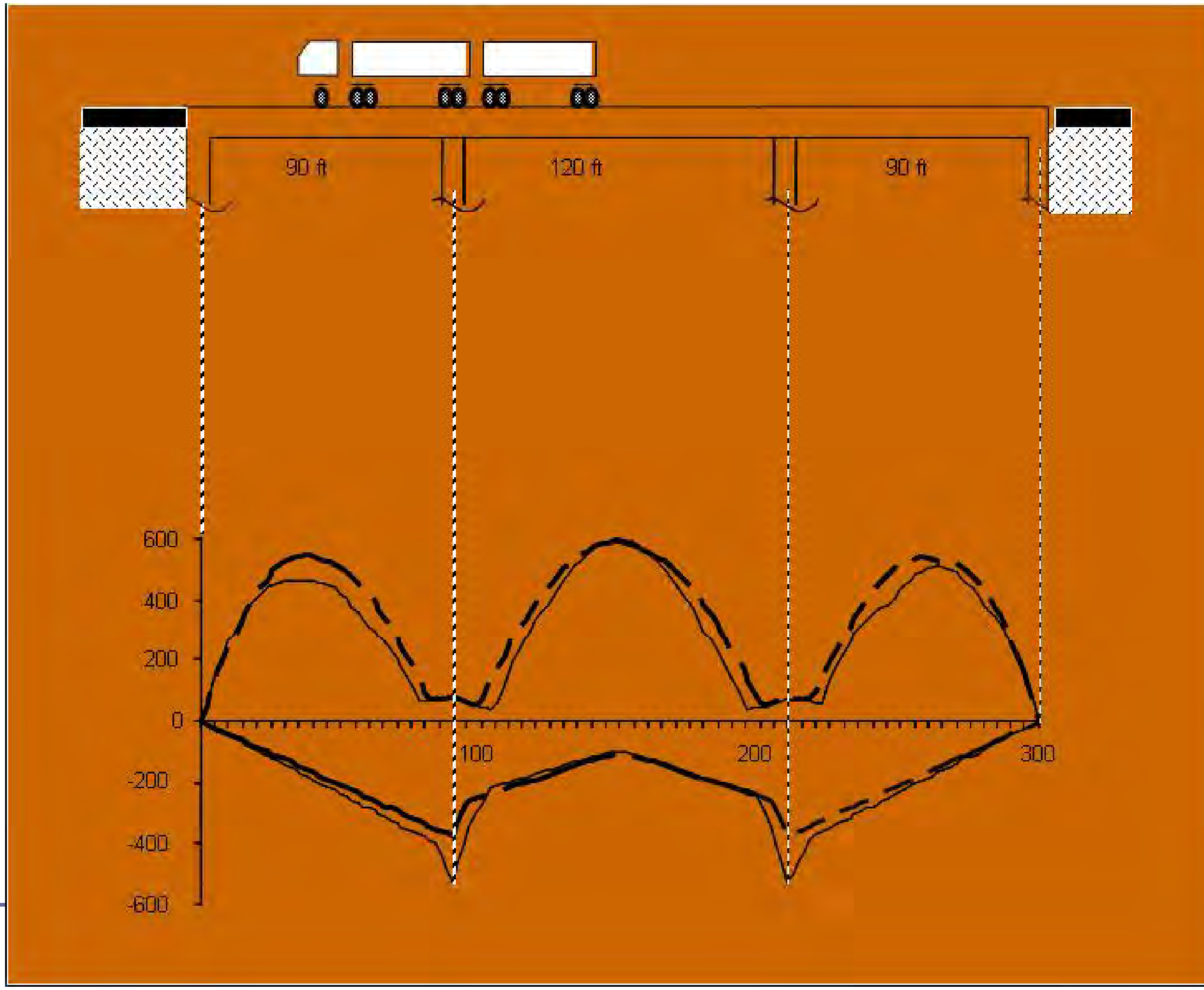




Bridge Statistics – Structure Type



Traditional Methodology
Live Load Bending Moments Proposed/Rating Ratios



Traditional Methodology- MOANSTR

M O A N S T R
Moment Analysis of Structures

BASIC Batch Processor Menu

(1) Enter or Edit Future Traffic Loads.

(2) Include Dead Load Moments?: NO

(3) Perform Batch Moment Analysis.

(4) Save or Load Future Traffic Loads.

(5) Moment Analysis Interrupt Criteria (% Overload): 50

(6) Enter Inventory Rating Multipliers.

Select a Number (1-6) or <ESC> to Return to BASIC

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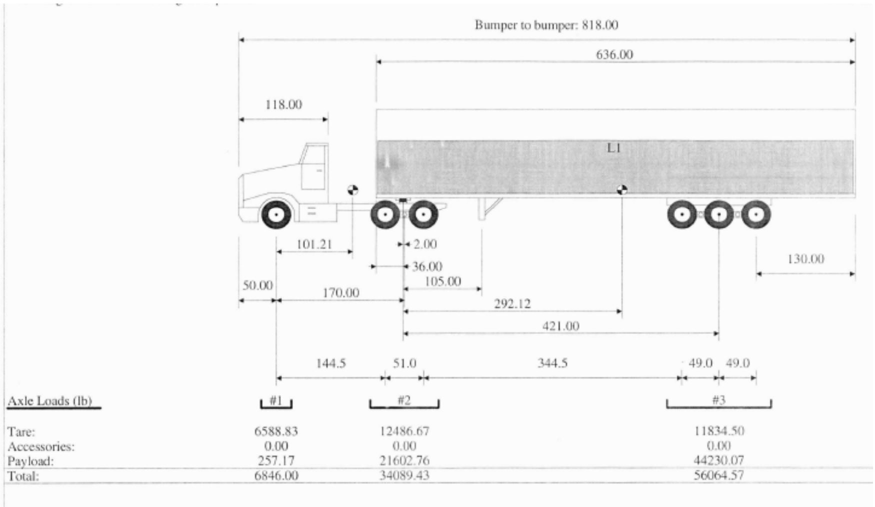
Live Load Moment Ratios

Inventory Rating

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 -34000.0000000000        -56065.0000000000                 1
ID #        M 0+        M 0-   MX.RAT +OR-      M 1+        M 1-   MX.RAT +OR-
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36960, 0.312E+07, 0.000E+00,1.000,N/A, 0.505E+07, 0.000E+00,1.617,(+),
36961, 0.312E+07, 0.000E+00,1.000,N/A, 0.505E+07, 0.000E+00,1.617,(+),
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```

Axle	Axle Loads
Steering	6,846
Tractor	34,089
Trailer	56,065
TOTAL	97,000

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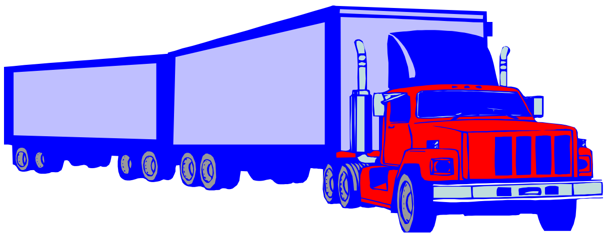
Case Study Configurations- 97K Tridem

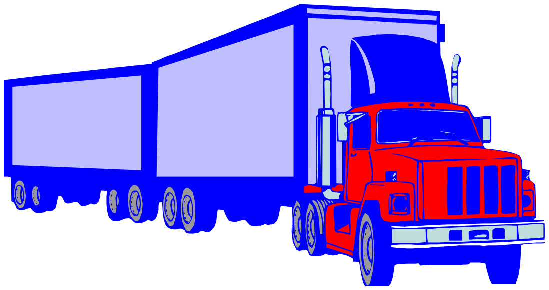
97k tridem

- Axle Spacing: 14ft 35ft
- Axle Loads: 7K 34K 56K

Case Study Configurations- Double 53’



90k double 53’

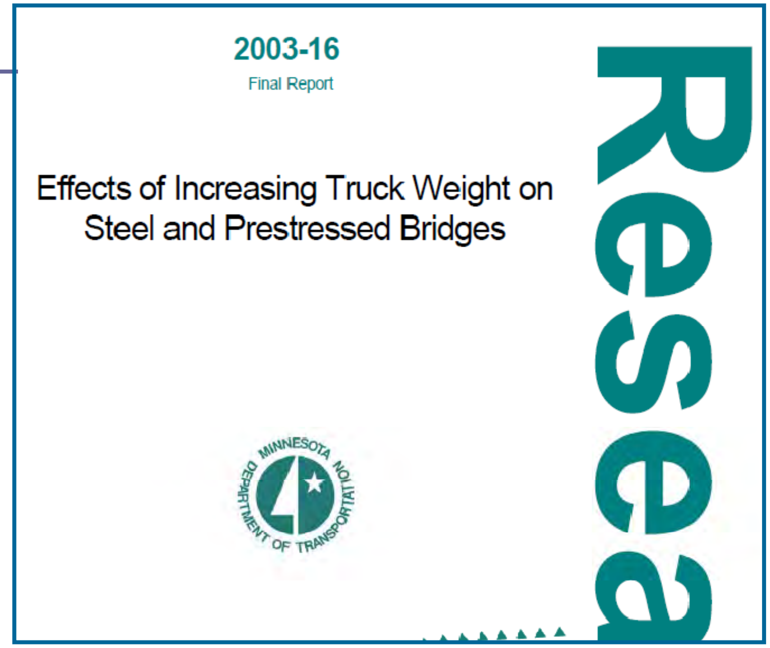


138k double 53’

- Axle Spacing: 18ft 41ft 19ft 41ft
- Axle Loads: 12K 31.5K 31.5K 31.5K 31.5K
- Axle Loads: 12K 19.5K 19.5K 19.5K 19.5K

Overstress Ratios from Literature

- Recent designs (80s) can support 20% weight increase.
- Older designs susceptible to 10% weight increases.


2003-16

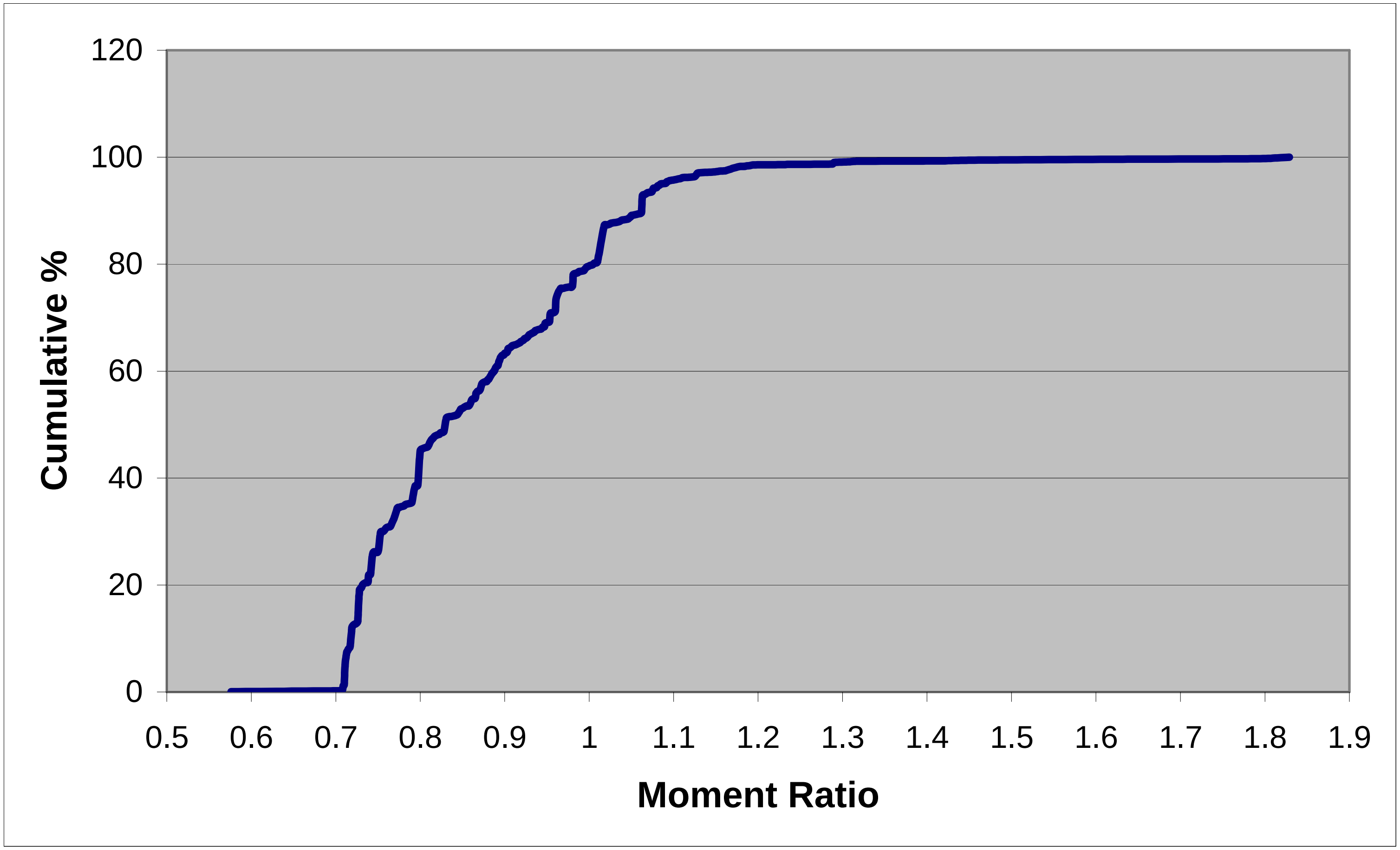
Final Report

Effects of Increasing Truck Weight on Steel and Prestressed Bridges

Resea

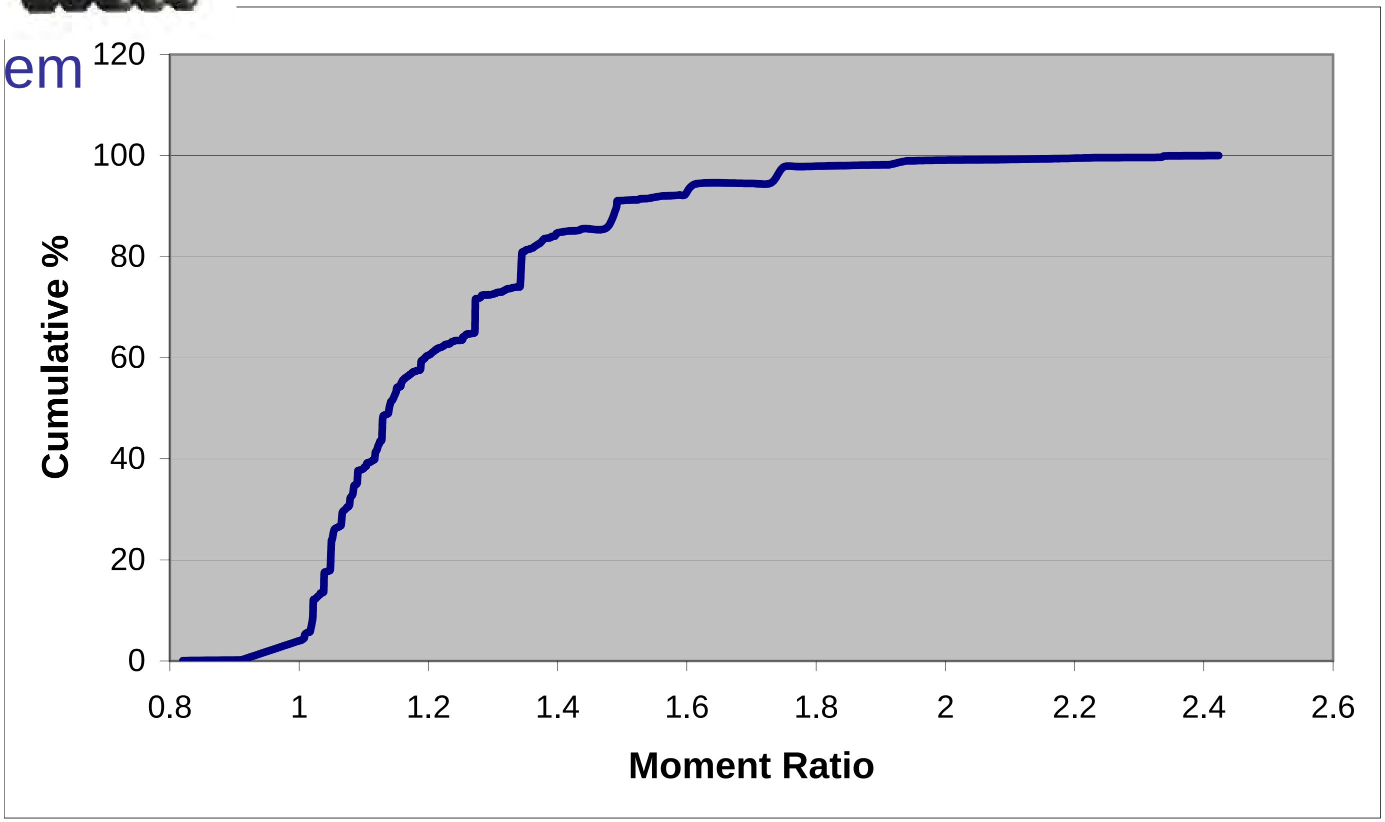
Essentially all prestressed girders, modern steel girders, and most bridge decks could tolerate a 20% increase in truck weight with no reduction in life. Unfortunately, most Minnesota steel girder bridges were designed before fatigue-design specifications were improved in the 1970’s and 1980’s. Typically, an increase in truck weight of 20% would lead to a reduction in the remaining life in these older steel bridges of up to 42% (a 10% increase would lead to a 25% reduction in fatigue life).

Moment Ratio Statistics All Routes Legal 18 Wheeler



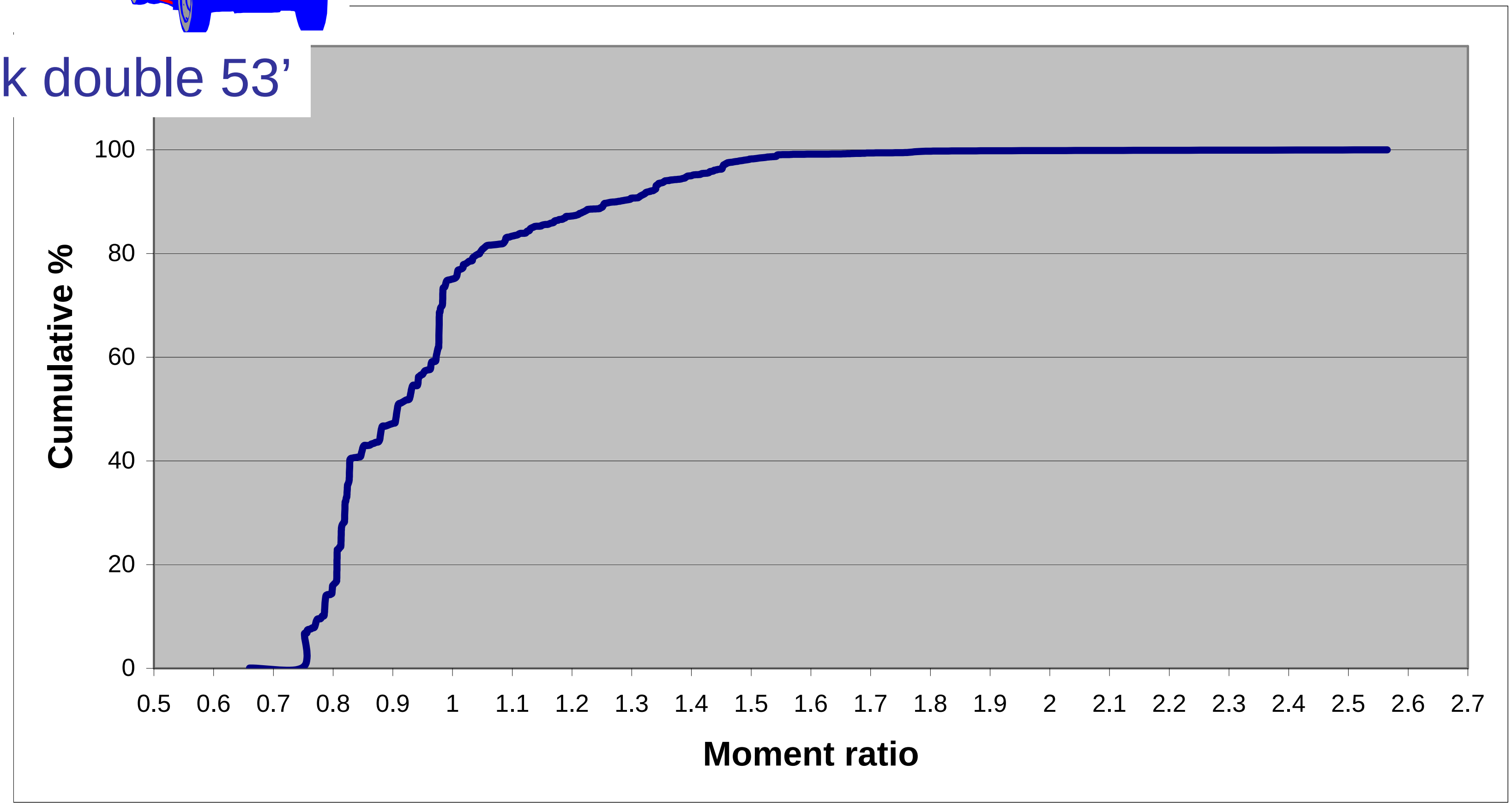
Moment Ratio Statistics All Routes 97K Tridem

97k tridem

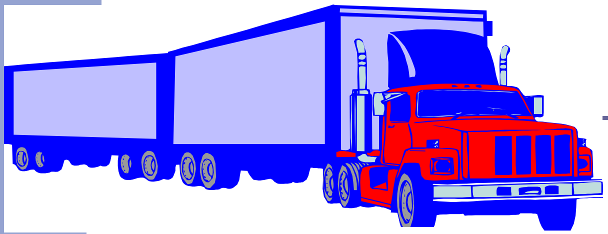


Moment Ratio Statistics All Routes
Double 53' Maxed out

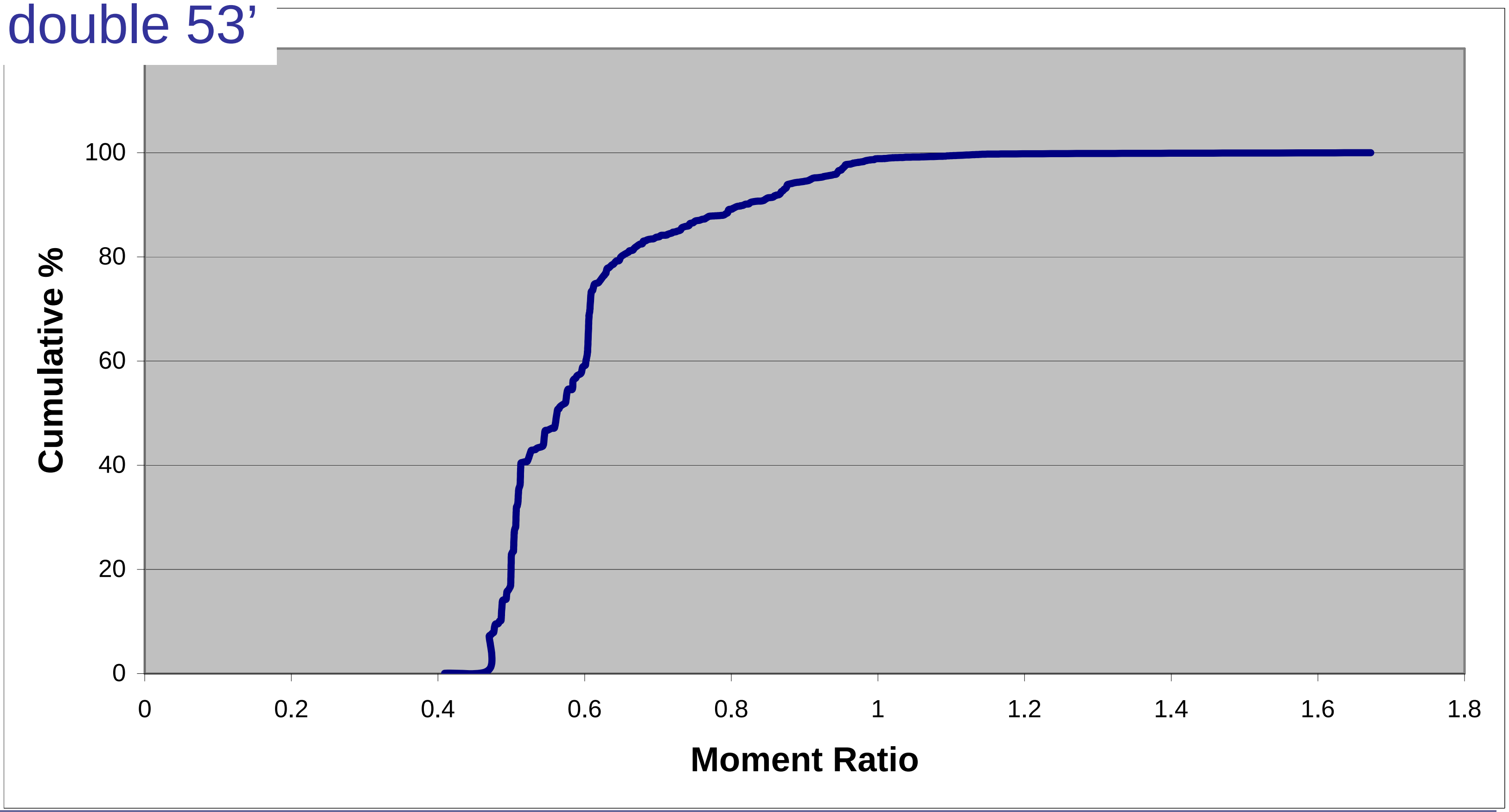
138k double 53'



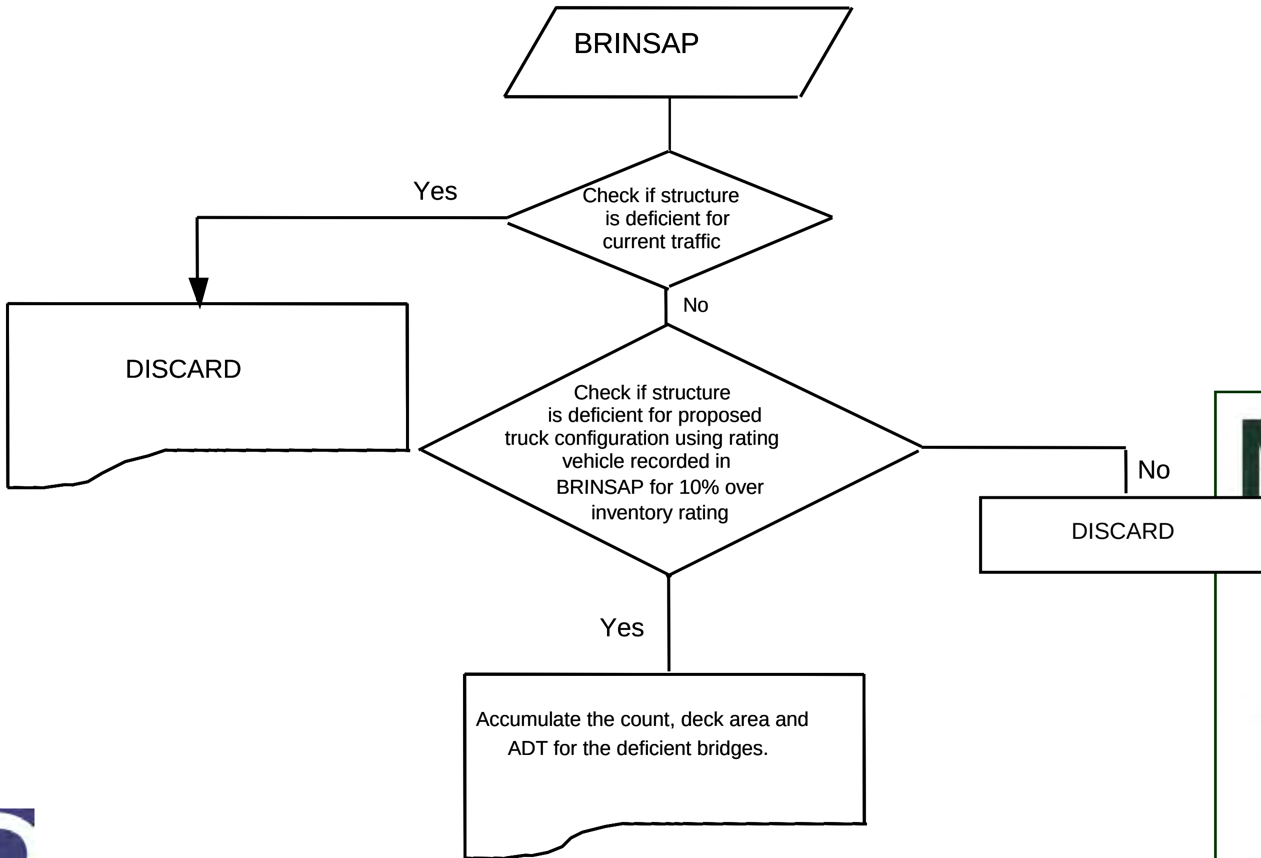
Moment Ratio Statistics All Routes Double 53' Cubed out



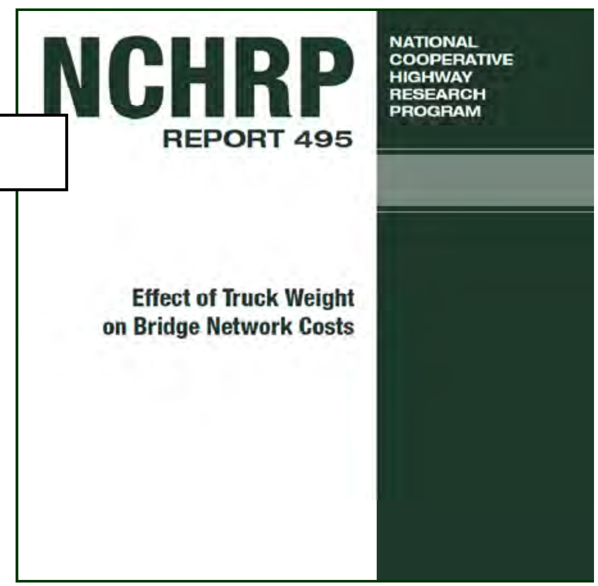
90k double 53'



Analysis Methodology



Supported by Level 1Analysis



Results 97K Tridem

97k tridem

1.1 Moment Ratio Criteria

Highway	Count	Area (sqft)	ADT	PV Cost $
IH10	145	1,092,520	3,822,520	207,578,743
IH20	255	2,694,798	3,657,001	512,011,639
IH35	289	7,097,868	10,091,459	1,348,594,958
IH45	89	1,954,679	4,962,040	371,388,953
IH37	42	793,428	1,258,670	150,751,358
US281	60	999,060	617,330	189,821,457
Total	880	14,632,353	24,409,020	2,780,147,108

1.2 Moment Ratio Criteria

Highway	Count	Area (sqft)	ADT	PV Cost $
IH10	126	836,570	3,300,400	158,948,357
IH20	189	1,274,125	1,886,420	242,083,712
IH35	183	2,938,770	6,130,009	558,366,357
IH45	47	643,122	1,324,970	122,193,237
IH37	14	137,679	433,460	26,158,972
US281	23	164,369	113,730	31,230,015
Total	582	5,994,635	13,188,989	1,138,980,650

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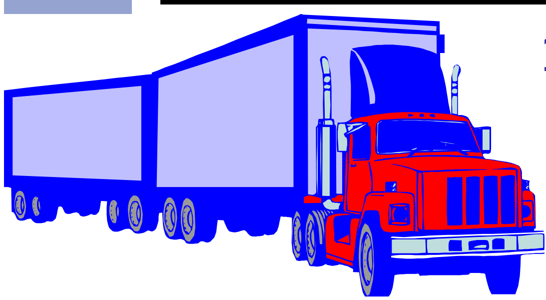
Results Double 53’ Maxed Out

1.1 Moment Ratio Criteria

Highway	Count	Area (sqft)	ADT	PV Cost $
IH10	7	148,468	427,660	28,208,844
IH20	35	487,417	728,060	92,609,192
IH35	116	4,632,500	4,904,869	880,174,981
IH37	30	642,587	1,053,110	122,091,568
IH45	13	312,459	989,500	59,367,134
Total	201	6,223,430	8,103,199	1,182,451,719



1.2 Moment Ratio Criteria

138k double 53’

Highway	Count	Area (sqft)	ADT	PV Cost $
IH10	7	148,468	427,660	28,208,844
IH20	27	370,349	419,150	70,366,348
IH35	95	3,772,940	4,812,269	716,858,562
IH37	30	644,855	1,091,850	122,522,488
IH45	14	316,820	1,015,160	60,195,876
Total	173	5,253,432	7,766,089	998,152,118

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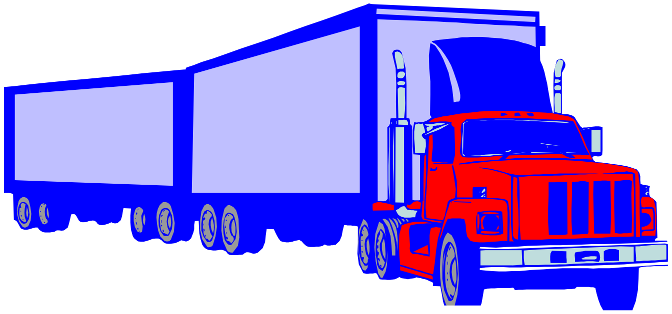
Results Double 53' Cubed Out



90k double 53'

NO IMPACT!

Results Mixing All Configurations

1.1 Moment Ratio Criteria

Highway	Count	Area (sqft)	ADT	PV Cost $
IH10	145	1,092,520	3,822,520	207,578,743
IH20	257	2,709,810	3,678,501	514,863,919
IH35	293	7,169,479	10,346,609	1,362,201,010
IH45	89	1,954,679	4,962,040	371,388,953
IH37	42	793,428	1,258,670	150,751,358
US281	60	999,060	617,330	189,821,457
Total	886	14,718,976	24,685,670	2,796,605,440

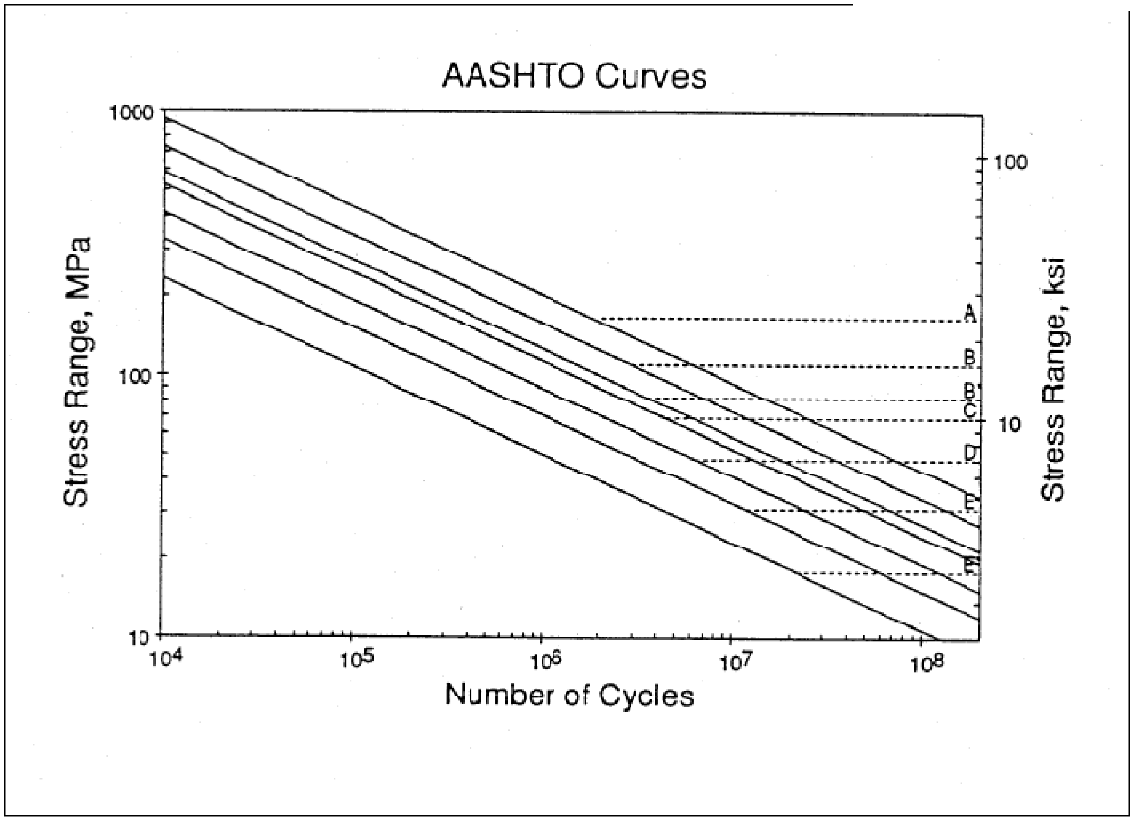
1.2 Moment Ratio Criteria

Highway	Count	Area (sqft)	ADT	PV Cost $
IH10	130	914,899	3,403,570	173,830,753
IH20	202	1,449,063	2,090,690	275,322,008
IH35	246	6,023,241	8,770,989	1,144,415,828
IH37	36	694,103	1,225,590	131,879,608
IH45	53	837,670	1,879,790	159,157,262
US281	23	164,369	113,730	31,230,015
Total	690	10,083,345	17,484,359	1,915,835,474

Using Fatigue Concepts

$NS^m = C$

Log N = C – m Log S



- N – number of cycles
- S – Stress Range
- m – Constant Material dependent
- C – Constant
- AASHTO specifies 75 year design life
- This achievable with inventory rating stress levels.

Using Fatigue Concepts

- Assuming no influence of load spectra (equal number of passages of the proposed load):

BRINSAP Bridge Type	m
Prestress conrete girder 502	3.5[2]
Prestress concrete box 505	3.5[2]

2. Altry, A.K., Arabbo, D.S., Crowin, E.B., Dexter, R.J. and French, C.E., (2003). “Effects of increasing truck weight on steel and prestressed bridges”, Mn/DOT final report (2003-16), Minnesota Department of Transportation

$$F' = F / \left(\frac{M_{AS}}{M_{BC}}\right)^m$$

- F’ Calculated bridge life due to proposed load
- F Current bridge life= 75-Bridge Age
- m material constant
- MAS/MBC Moment ratio from MOANSTR analysis

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Results Using Fatigue Concepts

97k tridem

Discount rate 5%

Hghway	Total # Bridges	# Bridges ratio > 1.4	# Bridges ratio <= 1.4	PV Cost Bridges ratio>1.4	PV Cost Bridges ratio <=1.4	Total PV	Total PV W/O Fatigue
IH10	145	93	52	95,652,327	49,340,578	144,992,905	207,578,743
IH20	255	29	225	29,743,816	188,538,999	218,282,815	512,011,639
IH35	289	39	250	73,419,591	369,055,608	442,475,199	1,348,594,958
IH45	89	8	81	7,345,514	109,020,049	116,365,563	371,388,953
IH37	42	0	42	-	51,468,909	51,468,909	150,751,358
US281	60	18	40	23,967,778	29,241,925	53,209,703	189,821,457
Totals	880	187	690	230,129,026	796,666,067	1,026,795,093	2,780,147,108

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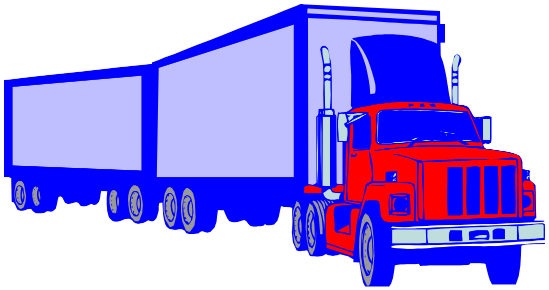
Results Using Fatigue Concepts



138k double 53'

Discount rate 5%

Hghway	Total # Bridges	# Bridges ratio > 1.4	# Bridges ratio <= 1.4	PV Cost Bridges ratio>1.4	PV Cost Bridges ratio <=1.4	Total PV	Total PV W/O Fatigue
IH10	7	2	5	4,089,408	12,510,994	16,600,402	28,208,844
IH20	35	5	30	19,798,798	31,217,358	51,016,156	92,609,192
IH35	116	33	83	477,864,573	139,248,361	617,112,934	880,174,981
IH37	30	5	25	15,094,987	51,400,797	66,495,784	122,091,568
IH45	13	6	7	19,991,515	22,200,123	42,191,638	59,367,134
Totals	201	51	150	536,839,281	256,577,633	793,416,914	1,182,451,719

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Conclusions and Recommendations

- 97 K Tridem has significant bridge impacts
- Double 53’ maxed-out impacts are mostly due to negative moments
- Double 53’ cubed out has no bridge impacts
- Project developed new methodology based on fatigue that needs better calibration of *m* factors
- Fatigue approach demands WIM data to generate reliable load spectra.
- Bridges screened by the analysis can be evaluated using a more detailed manual methodology for the high ticket high ADT bridges.

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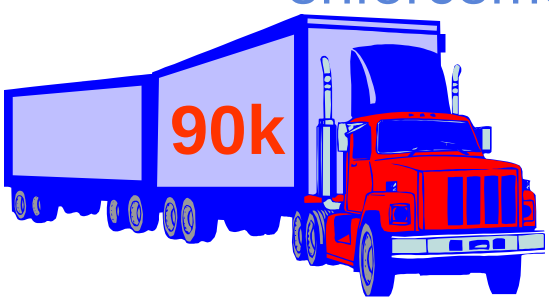
Combined recommendations

BRIDGES
AND
PAVEMENTS

Cubed-out double 53’

- FINDING: “cubed-out” double 53’ has no impacts on bridges or pavements.
  - Related recommendations
    - Strictly enforce the 19.5K tandem weight limit (to prevent bridge impacts).
    - Estimate and allocate the (external) cost of this enforcement in the candidate corridors.



and

- FINDING: “weighed-out” double 53’ and 97K tridem have impacts on bridges but not on pavements. 97K tridem bridge impacts are more significant.
  - Related recommendations
    - Develop cost-allocation / cost-recovery procedure of bridge costs.
    - Pavement cost reductions estimated in this study too sensitive to input data variations and are not accurate enough for cost allocation. Sensitivity analysis and additional traffic mix scenarios needed.

Cost/Benefit Tradeoffs

Rob Harrison
Jose Weissmann

- Truck size and weight regulations need both an economic (C-B) and financial analysis (FA)

- Integral but not central features of most previous TSW studies

- Case studies of key routes support more accurate and equitable C-B and FA work

- Cost Allocation

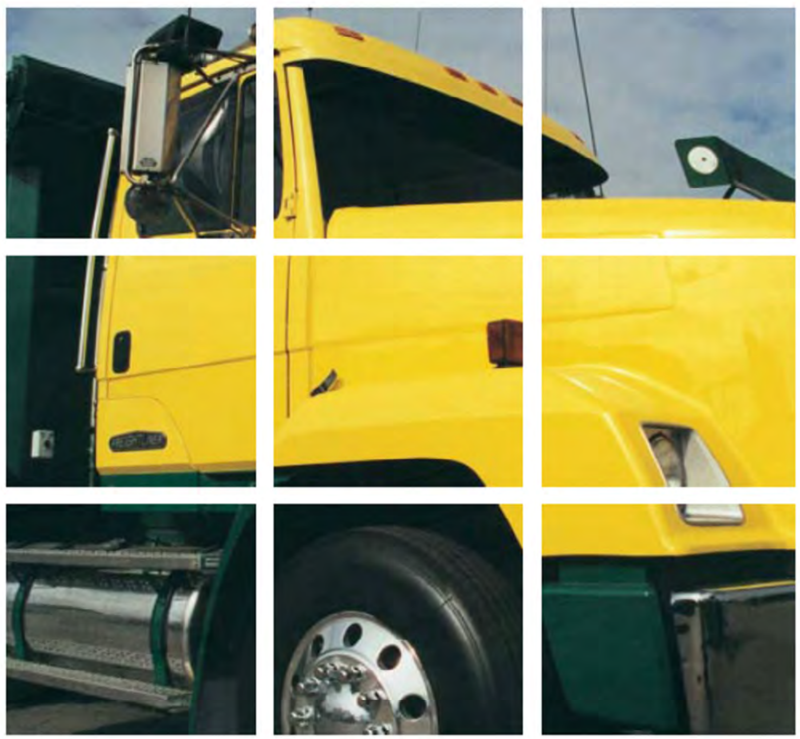
- Pilot-Test Contributions

- 0-6095 Final Report
  - Cost picture is emerging
  - Advisory panel members participation is critical—productivity
  - Multi-year pilot tests monitoring infrastructure and operating costs (R)
  - Develop a basic structure for the more refined C-B

- Take what others know—Australia and the EU

National Heavy Vehicle Accreditation Scheme (NHVAS)

- A guide for operators to the National Heavy Vehicle Accreditation Scheme (NHVAS).
- The NHVAS can help all operators whether they are big or small.



- Further Discussion