Preliminary Benefits Methodology in Front-Front Vehicle Compatibility

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Objective

Prepare an analysis to examine the structure in the CDS data on the front-front compatibility problem and evaluate preliminary benefits estimates.

Compatibility metrics: mass, frontal stiffness, and frontal height/override.

Mass and structural disparities contribute to high injury rates.

Approach: investigate structural matching as a way to lower injury rates.

Preliminary methodology: Divide applicable data into discrete similar sets and evaluate injury rates.

2

1

Frontal Stiffness

K_w400 Equivalent stiffness to generate the same energy of crushing frontal structure to 400mm.

$$K_w 400 = \frac{2\int_{25mm}^{400mm} F(x)dx}{(400mm)^2 - (25mm)^2}$$

3

Definition of Crash Data Study Group CDS Data Years 1996-2005

All CDS: 45,409 Cases (80,299 Vehicles)

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Two Vehicle: 24,765 Cases (49,530 Vehicles)

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Body Type Restriction (Vehicles Either Car or LTV): 22,155 Cases (44,310 Vehicles)

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Crash Type Restriction (Both Vehicles with Frontal Damage, Non-Rollover, Highest ΔV from vehicle-to-vehicle) [includes Offset, Full Frontal, Override]: 3,532 Cases (7,064 Vehicles)

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Structural Data Restriction (Both Vehicles with Known Kw400, Mass): 1,604 Cases (3,208 Vehicles)

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Lighter Vehicle in Crash: 1,604 Cases [When equal mass, lower Kw400 vehicle used]

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Towed Lighter Vehicle with MY1996+ and Belted Driver: 431 Cases

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After Removing Cases with Lateral ΔV known to be >15kph: 397 Cases

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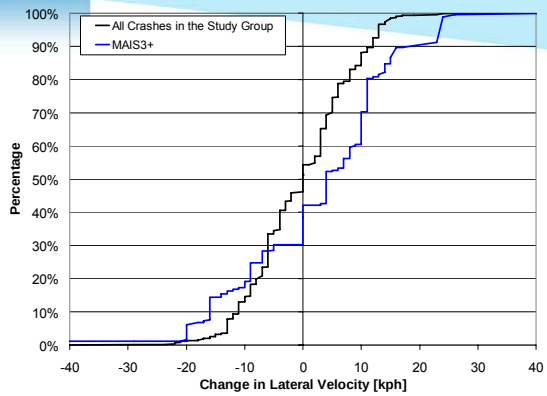
After Removing Cases with Known Override or Underride: 369 Cases

4

Cumulative $\Delta V_{lateral}$ Distribution



N=431

High $\Delta V_{lateral}$ can contribute to injuries independent of frontal compatibility (from case review).

$\Delta V_{lateral}$ was restricted to capture primarily collinear crashes. (Reduces N to 397)

CDS DATA YEARS 1996-2005 – TWO VEHICLE CRASHES – VEHICLE ADJUSTED WEIGHT
DRIVER OF LIGHTER VEHICLE – LIGHTER VEHICLE MODEL YEAR 1996+
LIGHTER VEHICLE TOWED - GENERAL AREA OF DAMAGE = FRONT (BOTH VEHICLES)

5

Override/Underride

PRELIMINARY

	Unweighted Cases	Percentage	Weighted Cases	Percentage
No Override	369	92.9%	111147	96.1%
Underride	24	6.0%	3756	3.2%
Override	4	1.0%	754	0.7%

"No override" is the dominant result.

Only cases with no known override were considered.

MAGNITUDE OF KNOWN $\Delta V_{lateral}$ RESTRICTED TO NO MORE THAN 15 kph
VEHICLE ADJUSTED WEIGHT - CDS DATA YEARS 1996-2005 – TWO VEHICLE CRASHES
DRIVER OF LIGHTER VEHICLE – LIGHTER VEHICLE MODEL YEAR 1996+
LIGHTER VEHICLE TOWED - GENERAL AREA OF DAMAGE = FRONT (BOTH VEHICLES)

6

Data Set Restrictions and Case Counts

Subject Vehicle

- Contains occupant whose injuries we consider
- Model Year 1996+
- Towed (Partner vehicle might not be towed)
- Lighter of the two vehicles
- No known override/underride
- Low $\Delta V_{lateral}$ (-15 kph $\leq \Delta V_{lateral} \leq$ 15 kph)

Subject Occupant

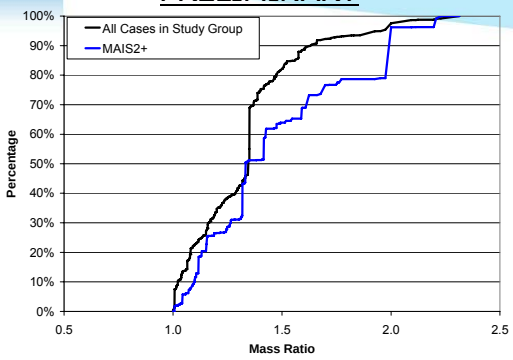
- Driver
- Belted

Crash Pair	**Car Lighter**	**LTV Lighter**	Total
Car-Car	**186**	**0**	186
Car-LTV	**138**	**16**	154
LTV-LTV	**0**	**29**	29
Total	324	45	369

7

Cumulative Mass Ratio Distribution

PRELIMINARY



N = 369

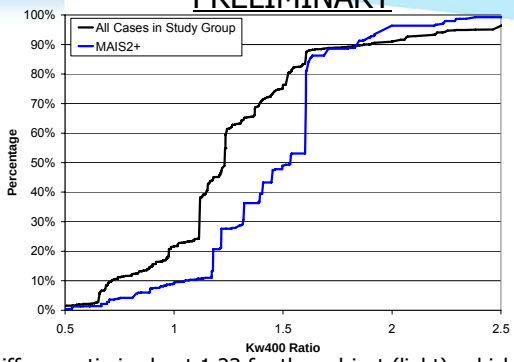
The median of the mass ratio is about 1.35 for the subject (light) vehicle.

MAGNITUDE OF KNOWN $\Delta V_{lateral}$ RESTRICTED TO NO MORE THAN 15 kph
VEHICLE ADJUSTED WEIGHTS - CDS DATA YEARS 1996-2005 – TWO VEHICLE CRASHES
DRIVER OF LIGHTER VEHICLE – LIGHTER VEHICLE MODEL YEAR 1996+
LIGHTER VEHICLE TOWED - GENERAL AREA OF DAMAGE = FRONT (BOTH VEHICLES)

8

Cumulative Stiffness Ratio Distribution

PRELIMINARY



N = 369

The median of stiffness ratio is about 1.23 for the subject (light) vehicles.
Thus, the lighter vehicle typically faces a vehicle that is 35% heavier and 23% stiffer.
Injuries increase as these ratios increase.

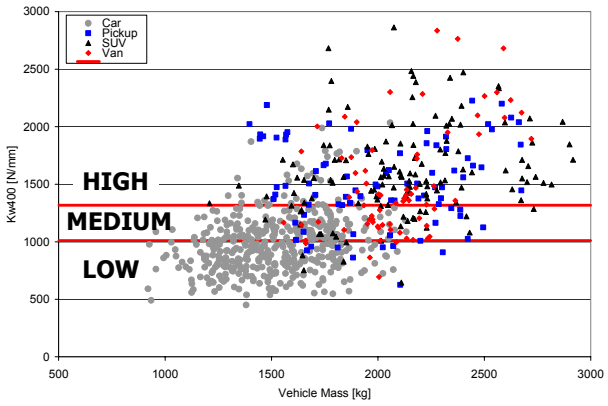
The median of stiffness ratio is about 1.53 for the subset of MAIS2+ cases.

MAGNITUDE OF KNOWN $\Delta V_{lateral}$ RESTRICTED TO NO MORE THAN 15 kph
VEHICLE ADJUSTED WEIGHTS - CDS DATA YEARS 1996-2005 – TWO VEHICLE CRASHES
DRIVER OF LIGHTER VEHICLE – LIGHTER VEHICLE MODEL YEAR 1996+
LIGHTER VEHICLE TOWED - GENERAL AREA OF DAMAGE = FRONT (BOTH VEHICLES)

9

Data for Choosing a Stiffness Matching Zone

PRELIMINARY



The Kw400 range should be feasible for virtually all vehicle masses.

10

Lighter Vehicles Injury Outcomes (MAIS2+) 369 Unweighted Cases

N = 369

PRELIMINARY

			Partner (Heavy) Vehicle		
			High Kw400	Medium Kw400	Low Kw400
Subject (Light) Vehicle	High Kw400	Injured	5	2	2
		All	20	18	14
	Medium Kw400	Injured	10	11	6
		All	33	35	26
	Low Kw400	Injured	19	16	25
		All	65	67	91

The case counts were quite low for the high stiffness subject vehicles and some medium stiffness subjects.

TRIAL AND ERROR MEDIUM RANGE FOR Kw400: 1010 N/mm – 1318 N/mm

CDS DATA YEARS 1996-2005 – TWO VEHICLE CRASHES – NO KNOWN OVERRIDE/UNDERRIDE
BELTED DRIVER OF LIGHTER VEHICLE – LIGHTER VEHICLE MODEL YEAR 1996+
LIGHTER VEHICLE TOWED - GENERAL AREA OF DAMAGE = FRONT (BOTH VEHICLES)
MAGNITUDE OF KNOWN $\Delta V_{lateral}$ RESTRICTED TO NO MORE THAN 15 kph

11

Lighter Vehicles Injury Outcomes (MAIS2+) Weighted Data

N = 369

PRELIMINARY

			Partner (Heavy) Vehicle		
			High Kw400	Medium Kw400	Low Kw400
Subject (Light) Vehicle	High Kw400	Injured	939	90	122
		All	7628	2958	3518
			12.3%	**3.0%**	**3.5%**
	Medium Kw400	Injured	3490	266	121
		All	18433	10132	2360
			18.9%	**2.6%**	**5.1%**
	Low Kw400	Injured	4883	2795	980
		All	17862	22206	26049
			27.3%	**12.6%**	**3.8%**

MEDIUM Kw400 RANGE (OPTIMIZED BY TRIAL AND ERROR): 1010 N/mm – 1318 N/mm

CDS DATA YEARS 1996-2005 – TWO VEHICLE CRASHES – NO KNOWN OVERRIDE/UNDERRIDE
BELTED DRIVER OF LIGHTER VEHICLE – LIGHTER VEHICLE MODEL YEAR 1996+
LIGHTER VEHICLE TOWED - GENERAL AREA OF DAMAGE = FRONT (BOTH VEHICLES)
VEHICLE ADJUSTED WEIGHT FACTORS
MAGNITUDE OF KNOWN $\Delta V_{lateral}$ RESTRICTED TO NO MORE THAN 15 kph

12

Next steps

Extend analyses to MAIS 3+ and fatalities.

Use constrained continuous (e.g., maximum likelihood) methods to examine several factors at once and optimize the feasible matching zones based on injury reduction.

Examine other datasets (e.g., Heavier Vehicles, Passengers, Unrestrained occupants)