Ford Alliance Pedestrian Project

"Understanding the Pedestrian Injury Distribution and Mechanism"

Patrick Bowman, Carol Flannagan, & Jingwen Hu

University of Michigan Transportation Research Institute

MTQIP Collaborative Meeting

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Context

- Pedestrians make up 16% of all traffic fatalities[1]
- The number of pedestrian deaths rose 3% while all traffic fatalities declined by 2.4% in 2018[1]
- In Michigan, 14.9% of crash fatalities were pedestrians (145 total) in 2018[2]
- Vehicle technology (e.g., automatic braking, airbags, etc) to prevent injuries crashes has advanced for many crash types but less has been directed at preventing pedestrian injuries and deaths

[1] NHTSA "Pedestrian Safety" [https://www.nhtsa.gov/road-safety/pedestrian-safety]
[2] Michigan Traffic Crash Facts [www.MichiganTrafficCrashFacts.org]

Context

Two hopeful technologies for the future are:

1. Vehicle hood design to reduce injury
   - This is mandated in Europe, but not in the U.S.
   - More space between hood and engine plus even front-grille airbags have been developed
2. Pedestrian Automatic Emergency Braking
   - Beginning to be deployed in US and Europe
   - Only prevents some frontal pedestrian crashes and works best in daylight

Context

Technology development and benefits estimation requires data

- But, pedestrians are not included in current in-depth crash datasets that code injury and crash mechanisms
- The last pedestrian in-depth study was done in 1994 and vehicle designs have changed

Objective

The objective of this proposed study is to develop an improved method of understanding the pedestrian injury distribution and mechanism by collecting recent pedestrian injury cases and linking the police-reported crash data to the trauma data

- Linked cases will be reconstructed and used to impute vehicle speed and injury mechanism
- Linked cases will also be used to identify injury patterns

Overall Goal

Help Ford determine ways that pedestrian safety can be improved through vehicle design and technology

Crash Data

- Michigan State Police (MSP) crash records
  - Census of all police-reported crashes occurring on public roadways
  - 2013 – 2018 data years
- Inclusion Criteria
  - Pedestrian crashes on public roadways only
  - Included those crashes involving personal injury or property damage (> $1000)
- Exclusion Criteria
  - Passenger vehicles only
  - Single-vehicle crashes

Trauma Data

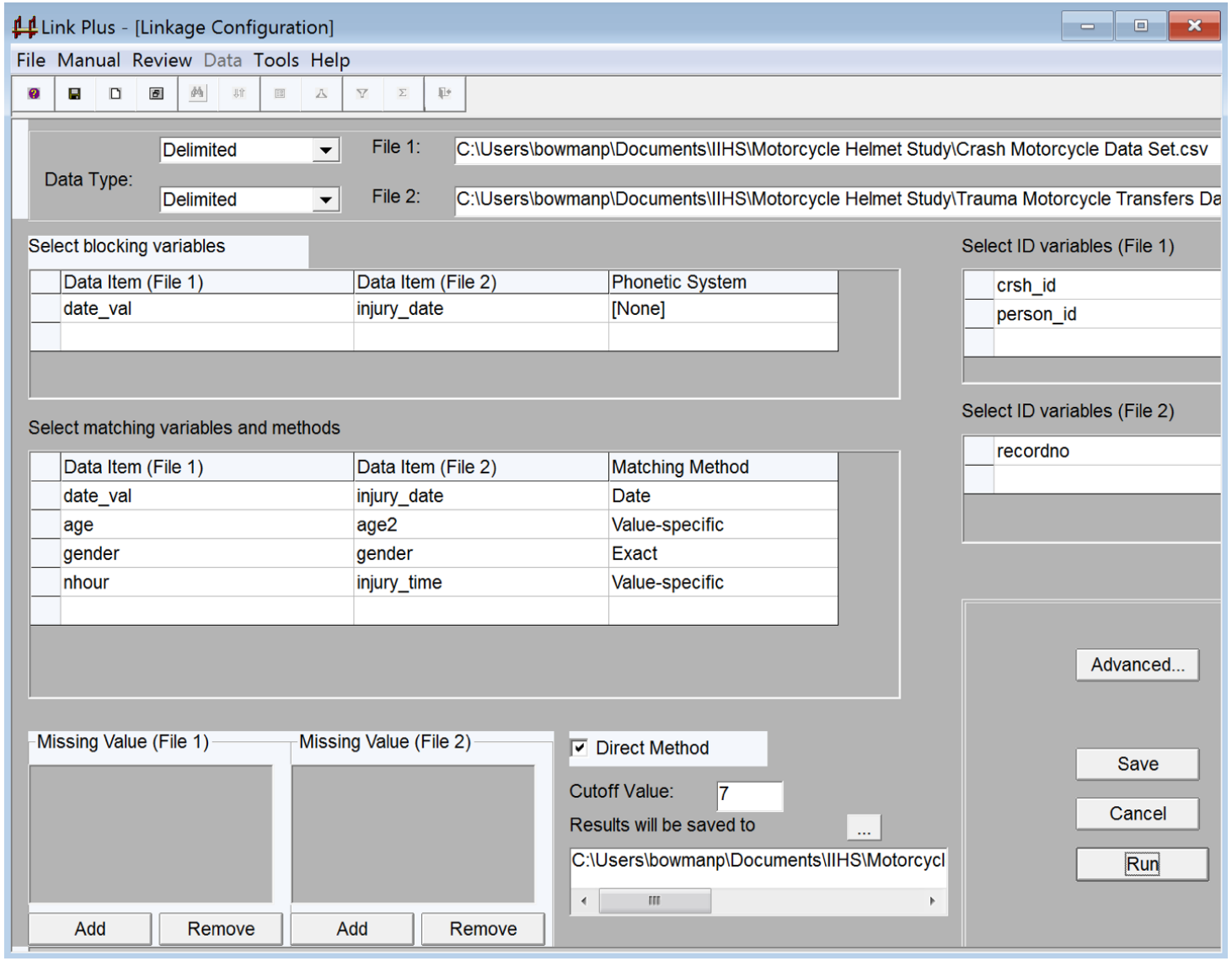
- Trauma data were linked to police-report data from Michigan
  - 822 linked total, 423 pedestrians used
  - 61.9% linkage rate
- Note that all cases in the sample have some serious injuries (because they are in the trauma dataset)
- Graphs show which injuries, *given that they are injured*
  - i.e., this isn't showing probability of injury given crash characteristics

Trauma data linkage

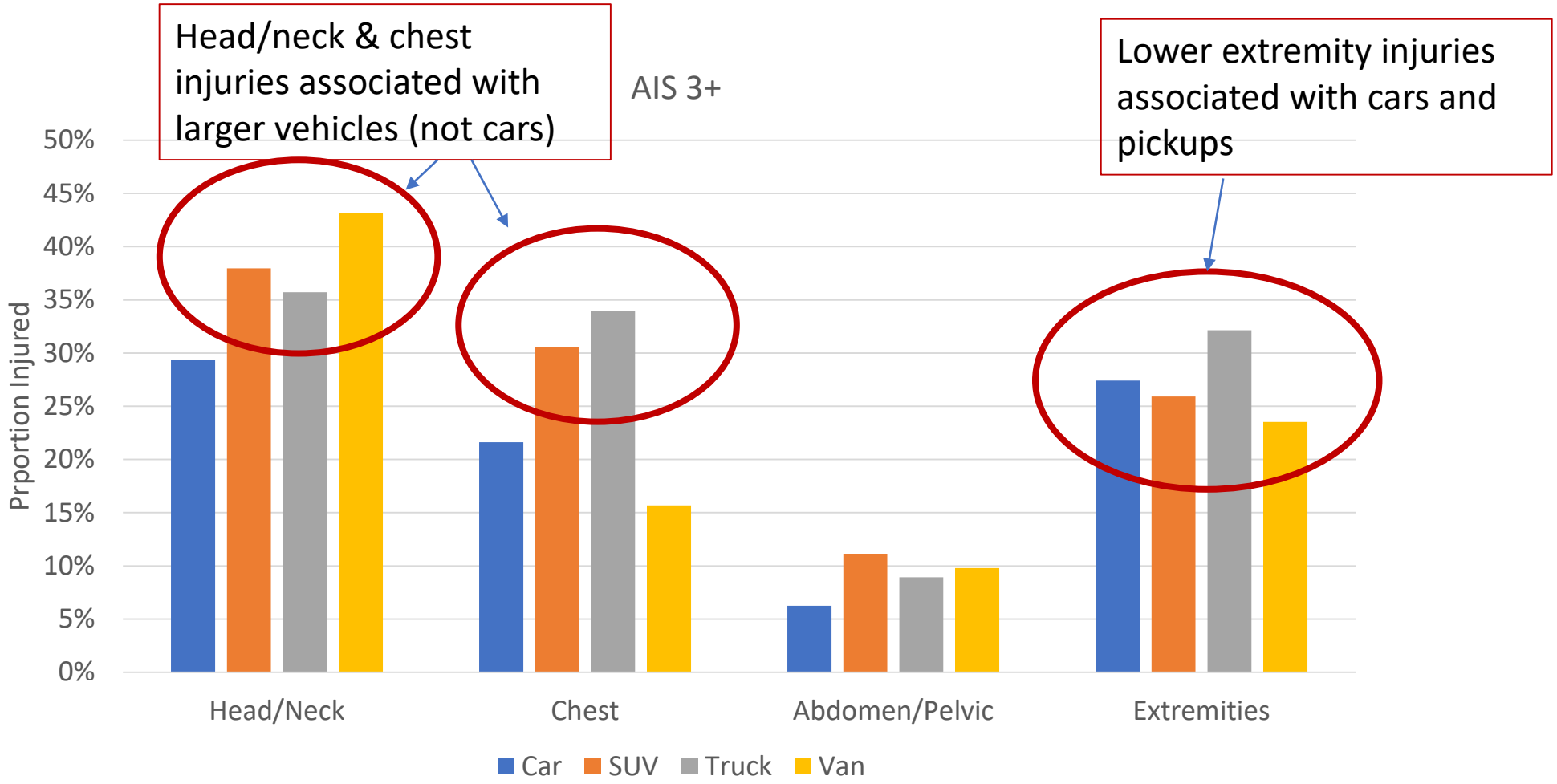
- Trauma data contain detailed breakdown of injuries for a large set of pedestrian crash events
- Linkage to crash data is done probabilistically based on date/time of event (or hospital admission), gender, and age
- Match score assesses the likelihood of a match being correct
  - $m = \frac{p(variables\ match | match\ is\ true)}{p(variables\ match | match\ is\ false)}$

Data Linkage

- Link Plus software
  - Free
  - Specify data formats
  - Matching method of date, value, or phonetically
  - Cutoff value
- Linkage variables
  - Gender
  - Age
  - Crash date [block]



Vehicle Type



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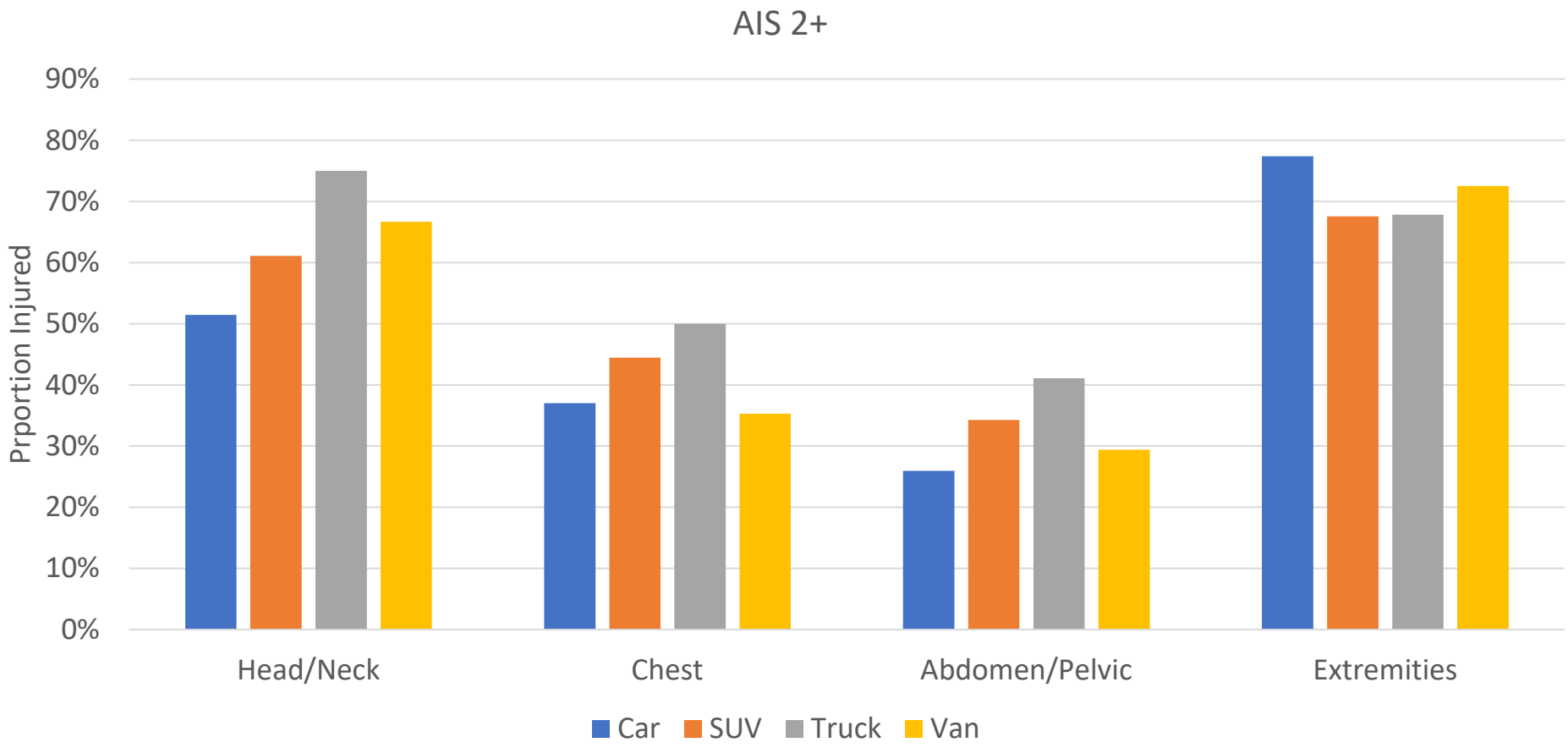
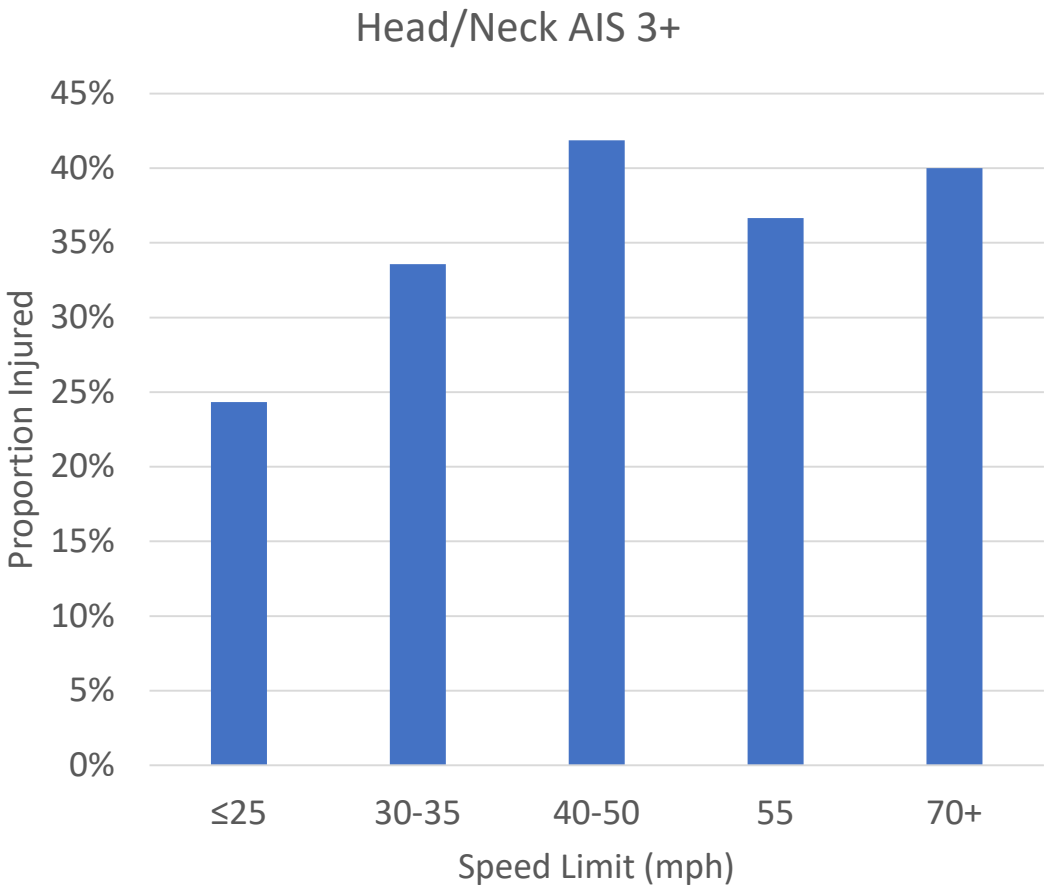
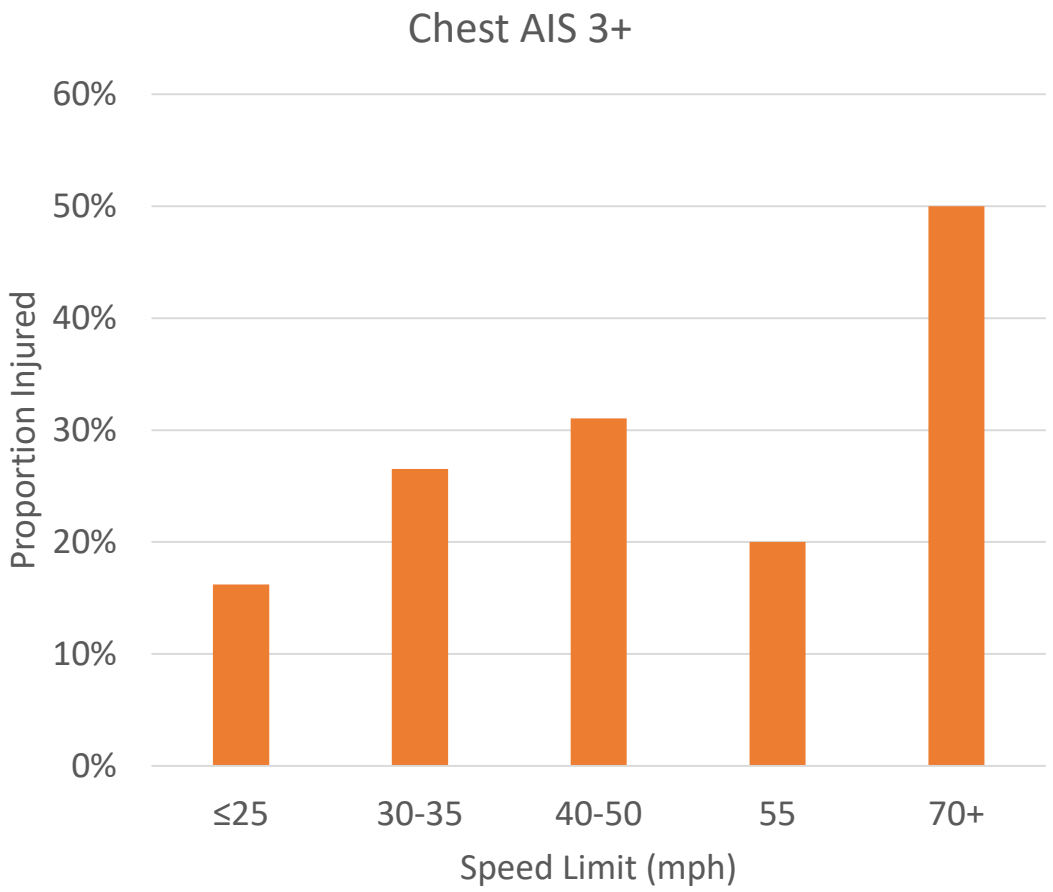


Speed Limit

- 64% of all pedestrian crashes in Michigan were on roads with speed limits ≤35 mph
- 38% of all fatal pedestrian crashes in Michigan were on roads with speed limits ≤35 mph
- 52% in our dataset were on roads with speed limits ≤35 mph
  - Our dataset falls in between all ped crashes and fatal ped crashes
  - Higher speed limits result in greater injury risk

Speed Limit


Head/Neck AIS 3+
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Proportion Injured
≤25
30-35
40-50
55
70+
Speed Limit (mph)


Chest AIS 3+
60%
50%
40%
30%
20%
10%
0%
Proportion Injured
≤25
30-35
40-50
55
70+
Speed Limit (mph)

Case selection for reconstructions

- We select cases from linked dataset with high match scores and good police-report narratives and diagrams for reconstruction
- Cases will be selected from a variety of scenarios and vehicle types (car, pickup, SUV/van)
- Ten cases selected to develop reconstruction process so far

Police Report data

Trauma data

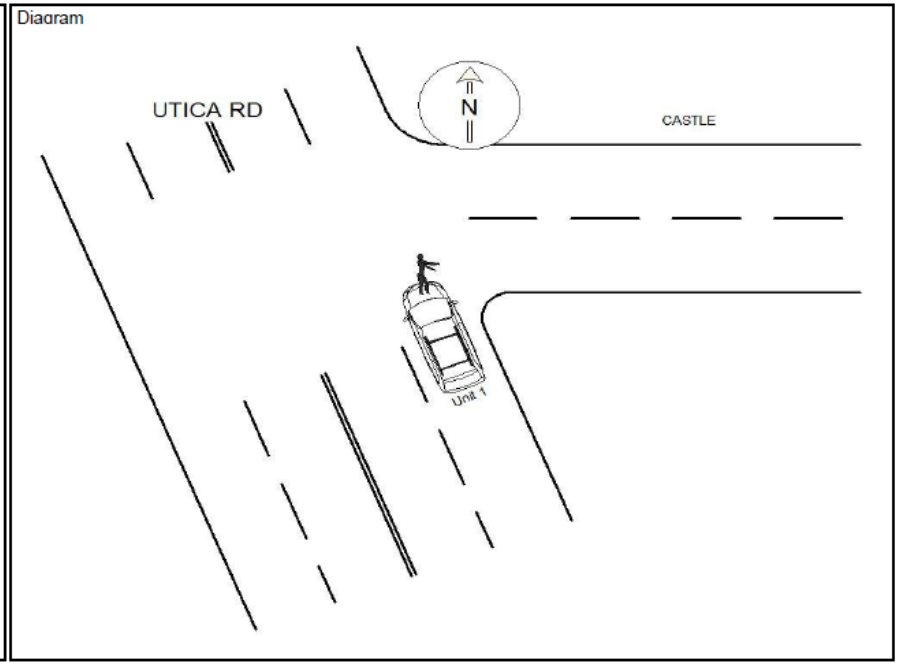
AIS Code	AIS Description
140629.3	cerebrum hematoma NFS
161011.5	diffuse axonal injury w LOC GT 24 hrs NFS
440604.2	diaphragm lac NFS
442205.3	hemopneumothorax NFS
510402.1	abdomen skin/subcutaneous/muscle contusion; hematoma
541826.4	liver lac - major; disruption LEQ 75% lobe; multiple; burst
542810.2	pancreas contusion; hematoma NFS
544226.4	spleen lac - major; disrpution; no hillar injury; devasculared GT 25%
710202.1	UE skin/subcutaneous/muscle abrasion
810202.1	LE skin/subcutaneous/muscle abrasion
854172.3	proximal tibia fx - complete articular; plateau; bicondylar - open
854272.3	tibia shaft fx - complex; comminuted; segmental - open
856151.2	pelvic ring fx - posterior arch intact; isolated fx
856161.3	pelvic ring fx - incomplete disruption of posterior arch NFS

Case Reconstructions – Case Selection

Record Number	Sex	Age	Height	Weight	AIS	AIS Description	Comments on accident	Pedestrian action	Vehicle Action	Posted Speed Limit	Vehicle	Similar Vehicle Model Available
9856					150202.3	Basilar fracture without CSF leak	Simple. Travelling at 25 MPH in their lane. Impact from right/center of vehicle	Crossing not at intersection	Going straight ahead	35		
19863					510202.1 772410.1 810202.1 853271.3	abdomen skin/subcutaneous/muscle abrasion carpal joint sprain LE skin/subcutaneous/muscle abrasion femur shaft fx - complex; comminuted; segmental	Running across street. Gets hit on the right side of body. Speed - 35	Crossing not at intersection	Going straight ahead	35		

Narrative

Diagram



Case Reconstructions – Preliminary Simulations

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Need to try a number of simulations to find one that fits injuries best

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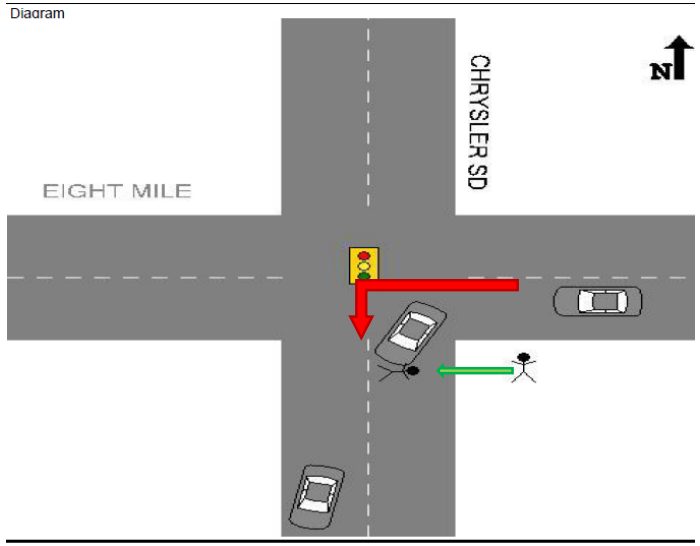
Select best match

	Vehicle Speed	Pedestrian Posture	Impact Location
Case 1	32kmph	Standing	Middle
Case 2	32kmph	Standing	Corner
Case 3	32kmph	Walking/Running (5mph)	Middle
Case 4	32kmph	Walking/Running (5mph)	Corner
Case 5	40 kmph	Standing	Middle
Case 6	40 kmph	Standing	Corner
Case 7	40 kmph	Walking/Running (5mph)	Middle
Case 8	40 kmph	Walking/Running (5mph)	Corner

	Tolerance	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
HIC15	700	715	1344	468	17	1419	1304	782	28
Sternum Res.Acc (g)	85g	25	17	20	20	27	17	21	20
Upper Torso Res. Acc (g)		38	20	22	16	42	22	21	17
Lower Torso Res. Acc (g)		23	24	24	22	36	34	34	23
Right Upper Leg Res. Acc (g)		65	89	141	119	77	97	160	204
Right Lower Leg Res. Acc (g)		188	169	163	185	278	290	328	220
Lower Torso Res. Force (N)	10 kN	1807	2369	3417	2215	3046	3172	1807	9576
Right Upper Leg Res. Force (N)	3-10 kN	4215	3101	3886	5706	7842	4970	5142	6178
Right Lower Leg Res. Force (N)	3-6 kN	2697	2378	2066	2049	4109	3593	3069	2884
Right Upper Leg Lateral Shear (N) (Y-axis)	3.9 kN	1244	1151	3214	5685	1308	1092	4056	6101
Right Lower Leg Lateral Shear (N) (Y-axis)	3.4 kN	1419	1489	1288	1935	1788	1686	1520	2303
Right Upper Leg Lateral Bending (Nm) X-axis	320 Nm	199	198	177	288	262	220	238	216
Right Lower Leg Lateral Bending (Nm) X-axis	200-400 Nm	63	75	58	29	61	24	63	42

Case 6 - Crash ID: 9601770



- Vehicle
  - Action– Turning left (Posted Speed Limit – 25MPH)
  - Vehicle Involved
- Pedestrian
  - Action - Crossing the road without a crosswalk
  - Pedestrian

140650.3	cerebrum hematoma - subdural NFS
140682.3	cerebrum pneumocephalus
140693.2	cerebrum subarachnoid hemorrhage NFS
150200.3	base skull fx NFS
441412.4	lung contusion - bilateral - major; 1+ lobes; increased A-a gradient
441450.4	lung lac - bilateral NFS
442202.2	pneumothorax NFS
442209.2	pneumomediastinum
510402.1	abdomen skin/subcutaneous/muscle contusion; hematoma
750621.2	clavicle shaft fx
750900.2	scapula fx NFS

Crash Conditions & Injury Measures – Crash ID: 9601770

Iteration	V Speed kph	Ped Speed mph	Impact location m	Ped orientation deg(radian)	Vehicle turning (deg/s)
1	40	-3	0 (center)	-90 (-1.57) - lateral	85
2	40	-3	0.8 (left corner)	-90 (-1.57) - lateral	85
3	40	-3	0.8 (left corner)	-63 (-1.1) - facing away from vehicle	85

HIC15	Sternum_acc g	Left Low Leg Bending Nm	Left Low Leg Force N	Left Low Leg Shear N	Left Up Leg Bending Nm	Left Up Leg Force N	Left Up Leg Shear N	Right Low Leg Bending Nm	Right Low Leg Force N	Right Low Leg Shear N	Right Up Leg Bending Nm	Right Up Leg Force N	Right Up Leg Shear N
700	**85 g**	**200-400 Nm**	**3-6 KN**	**3.4 KN**	**320 Nm**	**3-10 KN**	**3.9 KN**	**200-400 Nm**	**3-6 KN**	**3.4 KN**	**320 Nm**	**3-10 KN**	**3.9 KN**
862	97	119	3407	1030	53	5811	1667	127	3493	935	113	5573	3138
845	91	50	1708	938	48	4839	1560	112	4382	844	90	9427	8809
880	111	121	1807	964	99	3544	2311	123	3284	1053	121	5101	2313

Torso Low Lumbar Low Res Force N	Torso Low Lumbar Low Shear N
4862	4312
3629	3582
5872	5084

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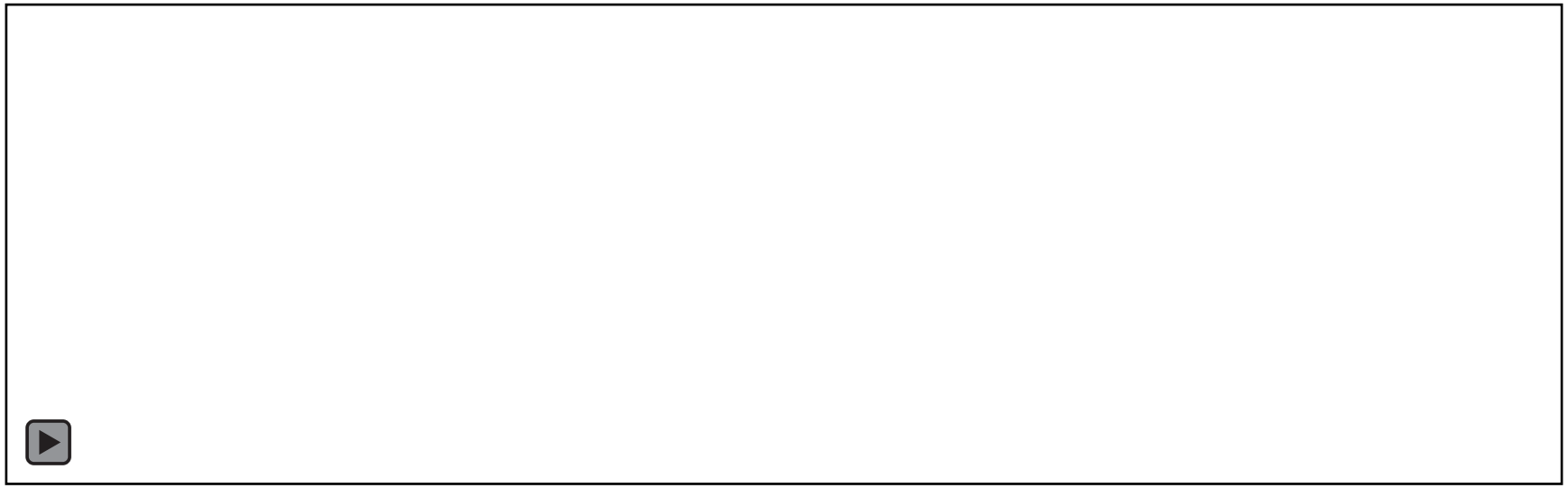
Crash Kinematics – Crash ID: 9601770



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700	**85 g**	**200-400 Nm**	**3-6 KN**	**3.4 KN**	**320 Nm**	**3-10 KN**	**3.9 KN**	**200-400 Nm**	**3-6 KN**	**3.4 KN**	**320 Nm**	**3-10 KN**	**3.9 KN**
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Reconstructed Crashes with Reduced Speed

S.No	Case	Description	Injury	Original Delta v	-20% Delta v		-40% Delta v		-60% Delta v	
1	1486041	Vehicle driving straight and pedestrian crossing street 2004 Ford Taurus Delta V=60kph	Head **(HIC)**	1373	1235	-10.04%	207	-84.91%	454	-66.93%
			Chest (Sternum Acc) **g**	63	49	-22.13%	139	121.21%	46	-26.06%
			Lumbar Low Force **N**	3887	5040	29.66%	2106	-45.83%	2106	-45.83%
			Lower Ex Bending **Nm**	75	93	24.14%	34	-54.80%	27	-64.29%
2	1496455	Vehicle driving straight and pedestrian standing in center lane (Lateral Impact) 2005 Ford Taurus Delta V=45kph	Head **(HIC)**	688	454	-34.04%	341	-50.37%	94	-86.30%
			Chest (Sternum Acc) **g**	38	70	82.41%	53	38.53%	18	-54.18%
			Lumbar Low Force **N**	9059	4255	-86.03%	2598	-71.33%	1265	-86.03%
			Lower Ex Bending **Nm**	399	338	-15.44%	263	-34.19%	239	-40.13%
3	9891219	Vehicle driving straight and pedestrian running across street 2005 Dodge Grand Caravan Delta V=40kph	Head **(HIC)**	856	383	-55.30%	52	-93.93%	9	-99.00%
			Chest (Sternum Acc) **g**	44	86	95.50%	29	-33.61%	29	-33.31%
			Lumbar Low Force **N**	8223	5772	-29.80%	4539	-44.80%	3185	-61.26%
			Lower Ex Bending **Nm**	109	92	-15.46%	114	4.00%	56	-48.86%
4	9989979	Vehicle driving straight and pedestrian crossing street (Fatal) 1998 Ford Explorer Delta V=56kph	Head **(HIC)**	1629	1694	4.04%	1008	-38.11%	437	-73.15%
			Chest (Sternum Acc) **g**	60	55	-7.43%	39	-34.60%	27	-55.42%
			Lumbar Low Force **N**	10056	9271	-7.81%	8646	-14.02%	4371	-56.54%
			Lower Ex Bending **Nm**	74	61	-17.86%	40	-46.13%	13	-82.97%
5	9739478	Vehicle driving straight and pedestrian crossing street (Lateral Impact) 2000 DODGE Grand Caravan Delta V=32kph	Head **(HIC)**	542	475	-12.37%	325	-39.93%	317	-41.46%
			Chest (Sternum Acc) **g**	61	74	20.98%	26	-57.11%	26	-57.48%
			Lumbar Low Force **N**	1728	2911	68.42%	1944	12.50%	1298	-24.91%
			Lower Ex Bending **Nm**	204	184	-10.06%	144	-29.42%	106	-47.89%
6	9601770	Vehicle driving straight and pedestrian crossing street 2009 DODGE Grand Caravan Delta V=40kph	Head **(HIC)**	880	674	-23.43%	448	-49.11%	100	-88.62%
			Chest (Sternum Acc) **g**	111	101	-8.87%	31	-72.39%	28	-75.05%
			Lumbar Low Force **N**	5872	4683	-20.25%	2526	-56.98%	986	-83.20%
			Lower Ex Bending **Nm**	121	87	-28.32%	97	-20.36%	85	-29.96%

How Do We Use This Information?

- Once models with injury mechanisms are created, we can simulate the benefit of better hood design and other vehicle countermeasures
- These simulations are not possible without accurate injury data (MTQIP)
- Project finalized at the end of May, with results to Ford

Thank You for Providing Us with Data!

Patrick Bowman

Statistician

bowmanp@umich.edu