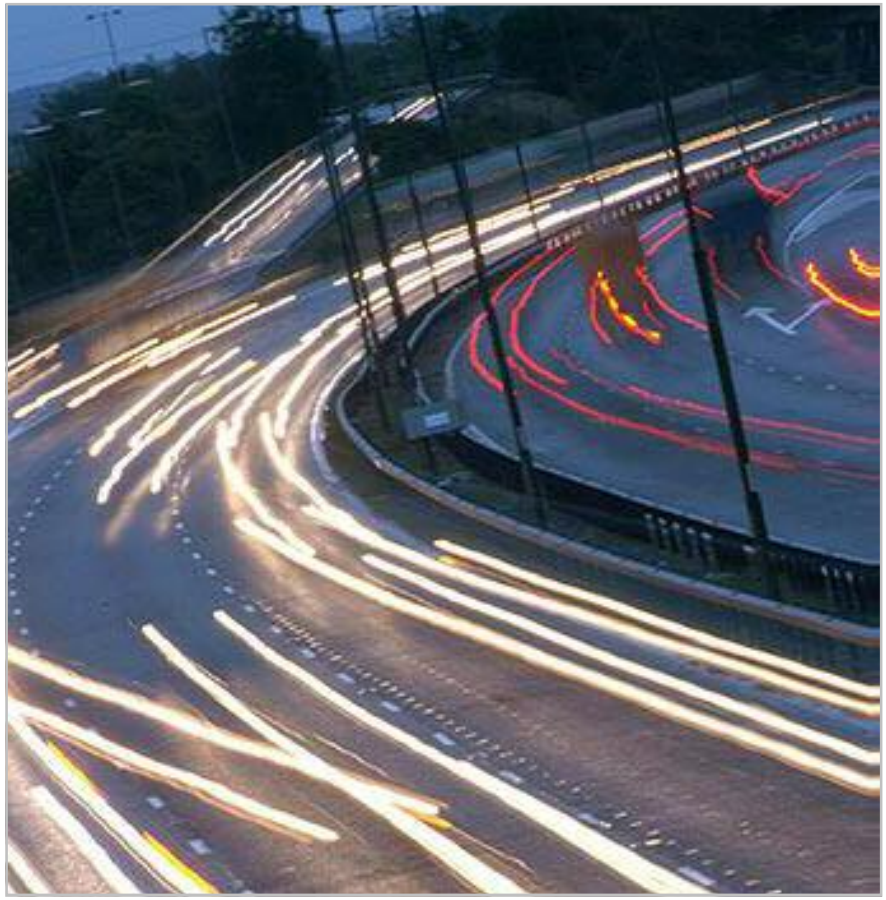
Accident analyses for bumper test area project

Prepared by Adam Barrow

Researcher – 11 September 2013

Front bumper analysis in pedestrian impacts

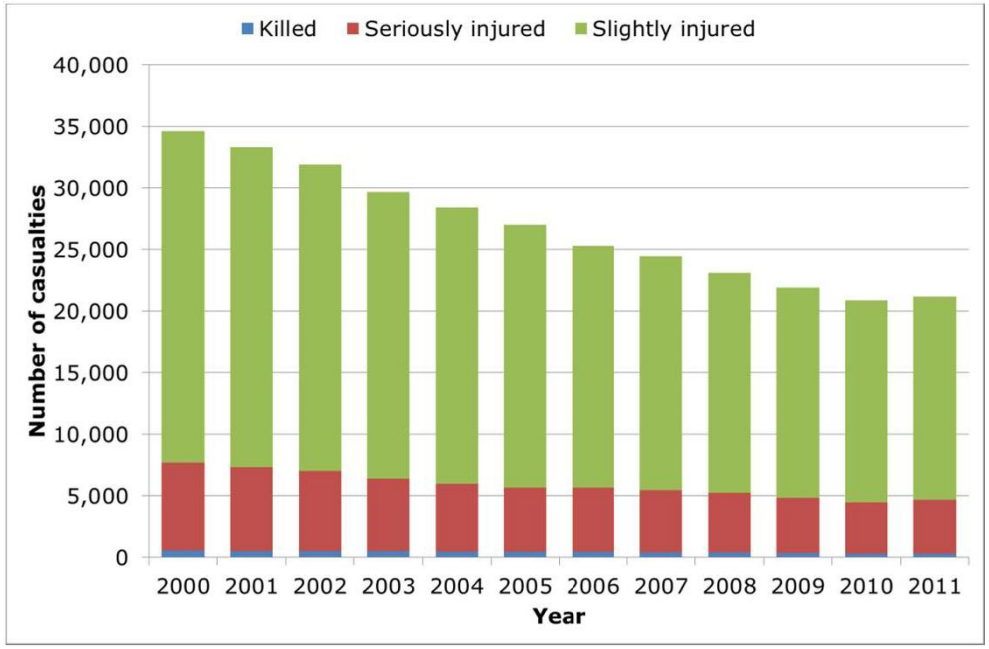
Statistics



- National accident datasets provide an indication of target population but no information on contact position of the pedestrian on the vehicle's bumper
- In-depth accident databases cases can be used to understand the accident situation in more detail, including:
  - Pedestrian contact point on the front bumper
  - Differences in contact point distribution by:
    - Age
    - Sex
    - Movement of pedestrian
    - Vehicle characterisics

National Pedestrian Impact Statistics – UK (STATS19)

Pedestrians hit by cars by severity and year



- Pedestrian casualties account for approx. 12-13% of all road accident casualties in the UK each year
  - Pedestrians hit by cars account for 80% of these
- Number of pedestrian casualties has declined (except for a slight increase in 2011)
- Approx. 22% of pedestrian casualties each year are killed or seriously injured

National Pedestrian Impact Statistics – UK (STATS19)

Pedestrians hit by cars by severity and age of casualty (2000-11)

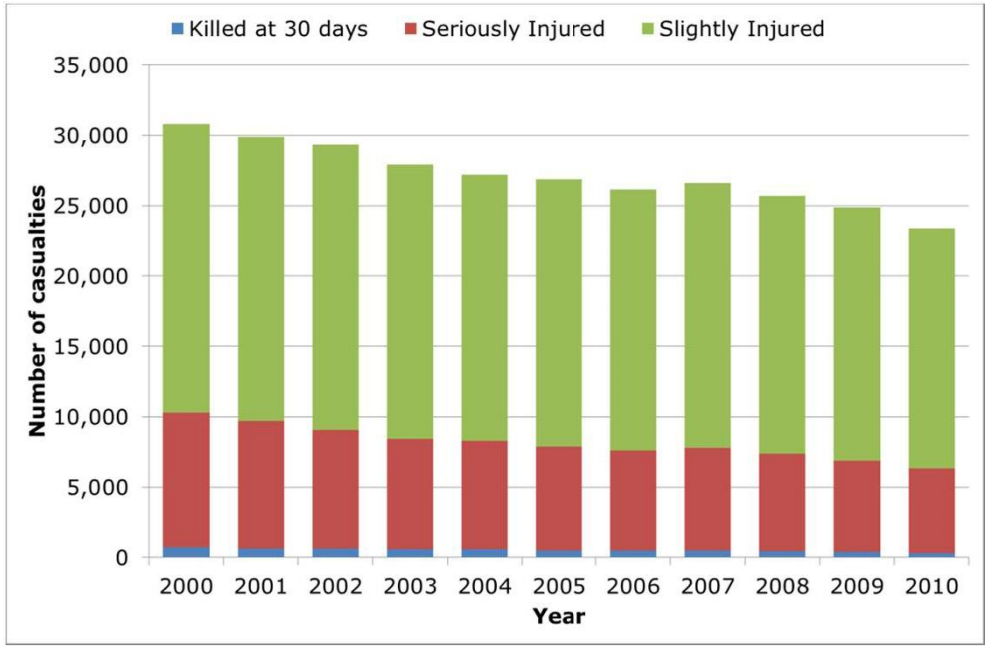
Casualty age	Killed	Seriously injured	Slightly injured	Total	% killed or seriously injured
0-15	578	22,810	95,248	118,636	20%
16-24	789	10,757	44,868	56,414	20%
25-39	841	9,792	40,544	51,177	21%
40-59	988	9,005	33,540	43,533	23%
60-79	1,158	7,851	20,707	29,716	30%
80+	952	3,893	7,678	12,523	39%
Unknown	24	1,149	8,683	9,856	12%
Total	**5,330**	**65,257**	**251,268**	**321,855**	**22%**

- 58% of pedestrians hit were male
- Biggest proportion of pedestrians ≤ 15 years (37%)
- Relatively few casualties ≥ 80 years
  - But these casualties have the highest proportion of killed or seriously injured casualties

- 58% of pedestrians were struck by the **front** of the car as the first point of impact
- Higher proportion in KSI casualties
  - 80% of killed
  - 63% of seriously injured

National Pedestrian Impact Statistics – Germany (CARE)

Pedestrians in accidents involving a car by severity and year



- Pedestrian casualties account for approx. 8% of all road accident casualties in Germany each year
  - Pedestrians in accidents involving cars account for just under 80% of these
- Number of pedestrian casualties has declined (except for a slight increase in 2007)
- Between 29% and 33% of pedestrian casualties each year are killed or seriously injured

National Pedestrian Impact Statistics – Germany (CARE)

Pedestrians in accidents involving a car by severity and age of casualty (2000-10)

Casualty age	Killed	Seriously injured	Slightly injured	Total	% killed or seriously injured
0-15	380	26,470	63,745	90,595	30%
16-24	570	9,113	32,291	41,974	23%
25-39	630	8,332	33,726	42,688	21%
40-59	1,166	13,870	40,013	55,049	27%
60-79	1,822	18,096	29,773	49,691	40%
80+	1,255	7,758	8,311	17,324	52%
Unknown	5	106	1,269	1,380	8%
Total	**5,828**	**83,745**	**209,128**	**298,701**	**30%**

- 52% of pedestrians were male
- Biggest proportion of pedestrians ≤ 15 years (30%)
- Relatively few casualties ≥ 80 years
  - But over half of these casualties were killed or seriously injured

- No information avaliable on first point of impact on the vehicle

Accident databases

UK & Germany

- Information on 4,700 accidents in the UK from 2000-2010
- 2 teams in distinct areas of the country
  - Vehicle Saftey Research Centre (VSRC), Leicestershire
  - TRL, Berkshire
- TRL analysis, not opinion of the UK DfT

- 23,444 reconstructed accidents in Germany from 1999-2013
- 2 teams in distinct areas of the country
  - Hanover Medical School, Hanover
  - Technical University, Dresden

Accident databases

UK & Germany

OTS

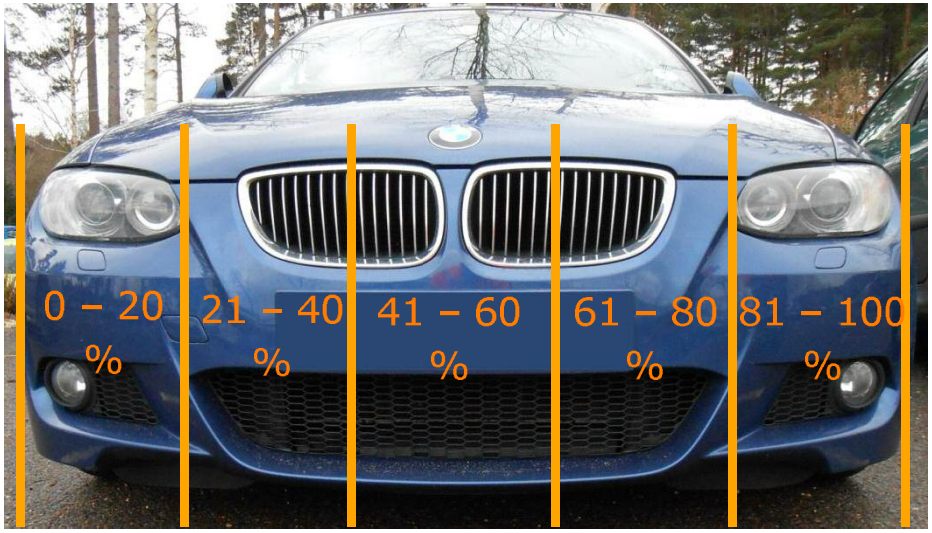
- Sample areas are broadly representative of national statistics except:
  - VSRC – slightly higher proportion of pedestrian impacts – URBAN area
  - TRL – slighlty higher proportion of car occupant impacts – RURAL area
- Biased towards severe accidents
  - 53% pedestrian KSI compared to 22%
  - But 23% MAIS 3+ which is close
  - Bias could be important if a bumper region particularly safe or dangerous
- **Sample = 116 pedestrians**

GIDAS

- The sample is representative of German national statistics and is unbiased as:
  - Sample areas accurately represent German topography
  - Large sample size
  - A prescribed statisitcal sampling plan was used
- **Sample = 758 pedestrians**

Accident databases

Method



- The front bumper is divided into 5 equal segments and displayed as a percentage of full width of the vehicle
  - Not just test area
- GIDAS provides greater accuracy and divided the bumper into 10 segments – (but for some comparisons with OTS these have been reduced back to 5)
- Both datasets use 0% as Right side of vehicle and 100% Left side
  - So offside (O/S) and nearside (N/S) are opposite
- Pedestrian **contact position** on the bumper is determined with:
  - Recorded measurements on scene
  - Pedestrian and vehicle paths
  - Photographs of evidence on the vehicle

In-depth accident analysis

Dataset analysis

- Initial overview of pedestrian contact position in the datasets:
- First 'null' hypothesis:

There is equal probability of a pedestrian being struck across the full width of the bumper

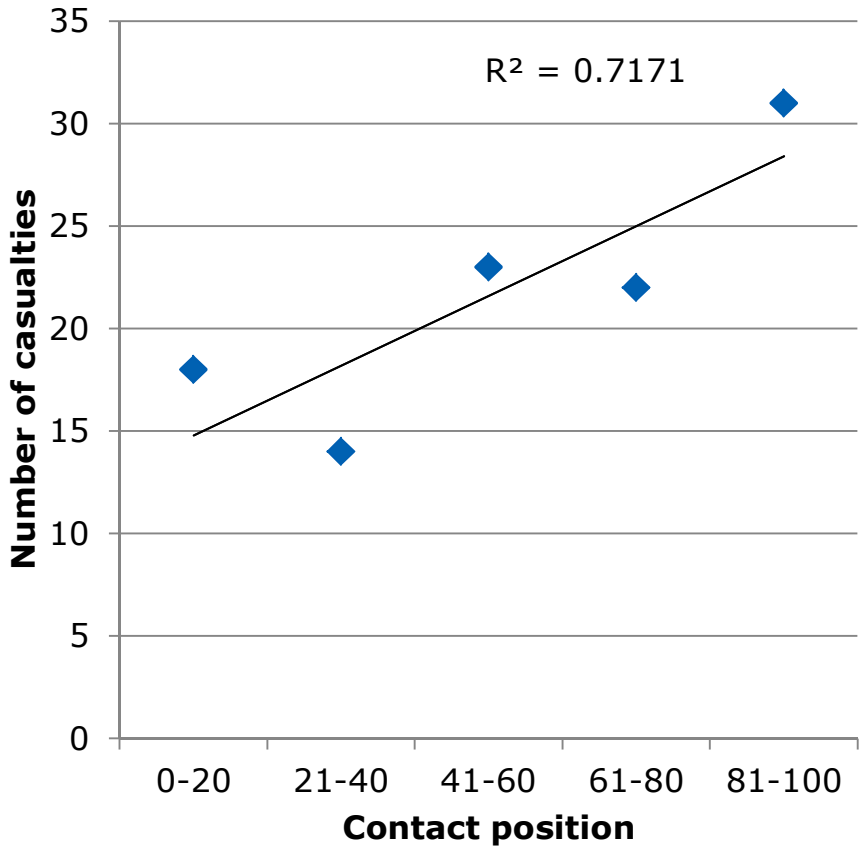
- Chi-squared goodness-of-fit test
  - Tests for a difference between the number of casualties struck in each of the contact positions and the theoretical number if the distribution was uniform across the bumper
- Second hypothesis:

If distribution of contact positions is not uniform, then the relationship is linear

- Regression line
  - Arises from the fact that pedestrians are more likely to be hit crossing from the N/S

In-depth accident analysis

Casualties by contact position



OTS

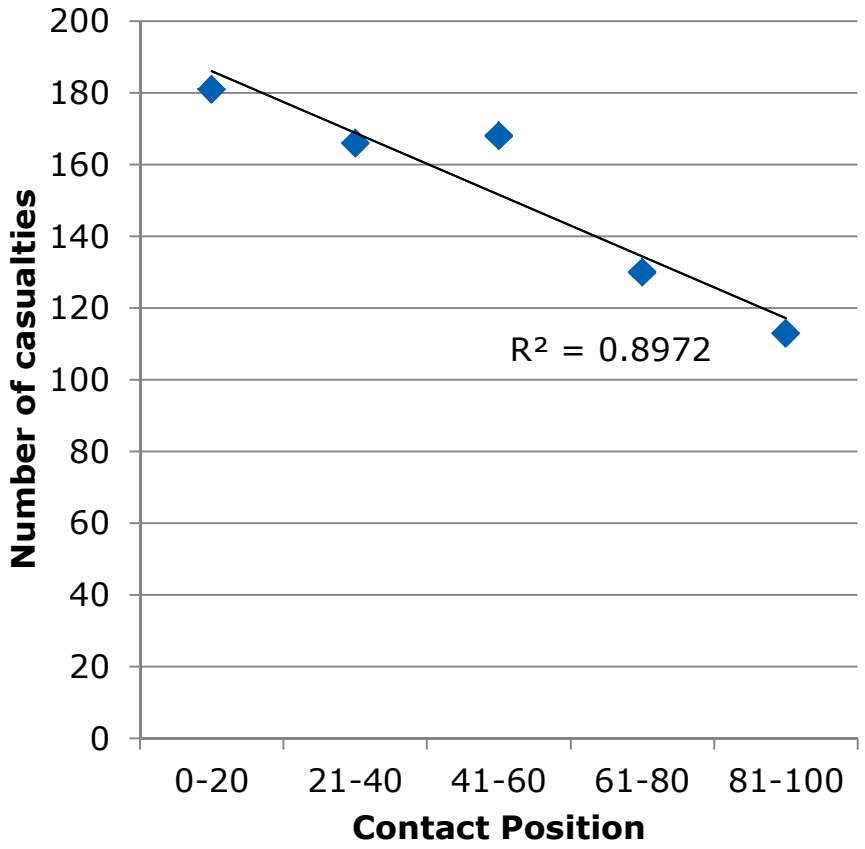
- Chi squared test of goodness of fit:
  - p=0.11
- Distribution of casualties across the bumper contact posistion is not significantly different from a uniform distribution
- Very low numbers in the test

- More pedestrians struck to the nearside
- R^2 value shows that bumper contact position accounts for 71% of variability in number of casualties across the bumper.
- The relationship is approx. linear

In-depth accident analysis

German In-Depth Accident Study

Casualties by contact position



GIDAS

- Chi squared test of goodness of fit:
  - $p<0.05$
- Distribution of casualties across the bumper contact posistion is significantly different from a uniform distribution

- More pedestrians struck to the nearside
- When 10 categories are used $R^2=0.34$, but when grouped into 5 approximately 90% of the variablity in number of casualties is explained by contact position
- Relationship is approx. linear

In-depth accident analysis

Dataset analysis

- More in-depth analysis of pedestrian and vehicle factors:
- OTS and GIDAS provide a range of information on the pedestrians and vehicles involved:
- Each variable is examined to determine if there is a difference in the distribution across bumper contact position
  - E.g. are females more commonly hit on the N/S of the vehicle than males
- Chi-squared test of independence
  - Tests for difference in the distribution of 2 categories across bumper contact position
- Low sample sizes in some categories of variables prevent statistical analysis – instead analysis of the raw numbers is done

In-depth accident analysis

Casualties by pedestrian gender

Contact position	Gender			Total casualties
	Female	Male	Unknown	
0-20	8	10	0	18
20-40	4	10	0	14
40-60	12	10	1	23
60-80	8	14	0	22
80-100	12	17	2	31
Unknown	2	6	0	8
Total	**46**	**67**	**3**	**116**

OTS

- Chi squared test of independence for gender:
  - $p<0.10$
- Distribution of female casualties across the bumper contact position is significantly different from the distribution of male casulaties
- At 90% confidence interval

In-depth accident analysis

German In-Depth Accident Study

Casualties by pedestrian gender

Contact position	Gender		Total casualties
	Female	Male	
0-10	28	37	65
10-20	58	58	116
20-30	47	54	101
30-40	35	30	65
40-50	43	42	85
50-60	38	45	83
60-70	26	28	54
70-80	43	33	76
80-90	26	36	62
90-100	19	32	51
Total	**363**	**395**	**758**

GIDAS

- Chi squared test of independence for gender:
  - $p<0.05$
- Distribution of female casualties across the bumper contact position is significantly different from the distribution of male casulaties

In-depth accident analysis

Casualties by pedestrian age

OTS

- Kruskall-Wallis test to compare age distribution of casualties across bumper contact position
  - p>0.10 (p=0.59)
- Age distribution across the bumper not significant
- No difference in the age of casualties by bumper contact position

GIDAS

- Only summary data were provided for GIDAS so no test could be performed

In-depth accident analysis

Casualties by pedestrian movement prior to impact

Contact position	Pedestrian movement				Total casualties
	In path	N/S	O/S	Unknown	
0-20	0	5	13	0	18
20-40	1	7	5	1	14
40-60	2	13	8	0	23
60-80	1	15	5	1	22
80-100	5	18	6	2	31
Unknown	1	4	3	0	8
Total	**10**	**62**	**40**	**4**	**116**

OTS

- Chi squared test of independence between pedestrians approaching from N/S vs O/S only:
  - $p<0.05$
- Distribution of casualties approaching from the N/S by contact position is significantly different to the distribution approaching from the O/S
- Sample size for categories "In path" and "Unknown" too small for analysis and have been excluded

In-depth accident analysis

Casualties by pedestrian movement prior to impact

Contact position	Pedestrian movement			Total casualties
	N/S	O/S	Other	
0-10	44	10	11	65
10-20	69	30	17	116
20-30	52	28	21	101
30-40	33	25	7	65
40-50	34	41	10	85
50-60	45	32	6	83
60-70	28	21	5	54
70-80	27	40	9	76
80-90	17	30	15	62
90-100	8	34	9	51
Total	**358**	**290**	**110**	**758**

GIDAS

- Chi squared test of independence between pedestrians approaching from N/S vs O/S only:
  - $p<0.05$
- Distribution of casualties approaching from the N/S by contact position is significantly different to the distribution approaching from the O/S
- Sample size for other categories are too small for analysis and have been excluded

In-depth accident analysis

Casualties by vehicle age

OTS

- Kruskall-Wallis test to compare vehicle age distribution across bumper contact position
  - p>0.10 (p=0.60)
- Age distribution across the bumper not significant
- No difference in vehicle age by bumper contact position

GIDAS

- Only summary data were provided for GIDAS so no test could be performed

In-depth accident analysis

Casualties by collision speed

OTS

- OTS does not provide accurate enough collision speed for most pedestrian impacts so no test could be performed

GIDAS

- Only summary data were provided for GIDAS so no test could be performed

In-depth accident analysis

OTS and GIDAS Dataset summary

Contact Position	▪ OTS: casualty distribution was statistically uniform (but visibly skewed to the N/S) and approximately linear ▪ GIDAS: distribution was non-uniform (skewed to N/S) and approximately linear
Pedestrian Gender	▪ OTS: females have different distributions across the bumper contact positions than males ▪ GIDAS: females have different distributions across the bumper contact positions than males
Pedestrian Movement	▪ OTS: pedestrians approaching from the N/S have different distribution across the bumper contact positions than those from the O/S ▪ GIDAS: pedestrians approaching from the N/S have different distribution across the bumper contact positions than O/S
Vehicles age	▪ OTS: no significant effect from vehicle age ▪ GIDAS: unknown ▪ Where possible analyses were repeated excluding vehicles registered before 2000 – results were very similar to the full analyses

In-depth accident analysis

Conclusions in relation to injury risk across the bumper

- Increased risk of pedestrian contact to the N/S of the bumper is cancelled out by the linear relationship
  - The increased risk to the N/S is directly balanced by the reduced risk to the O/S
    - This assumes that the bumper and its sub-structures are symmetrical
- Gender differences resulted in different distribution of pedestrian impact across the bumper and may also influence injury risk (males are typically taller, etc.)
  - Difference in lower limb length and therefore contact point on the limb
  - Structural differences (e.g. in bone density and muscle density) may also influence injury risk

In-depth accident analysis

Injury risk

- The next part of the analysis aims to determine if there is a greater risk of injury at the outskirts of the bumper compared to the centre or if injury risk is also linear across the bumper.
- Sample numbers are too small to perform any analysis and so conclusions are drawn from the actual values displayed in the tables

Injury risk

Casualties by whole-body MAIS and contact position

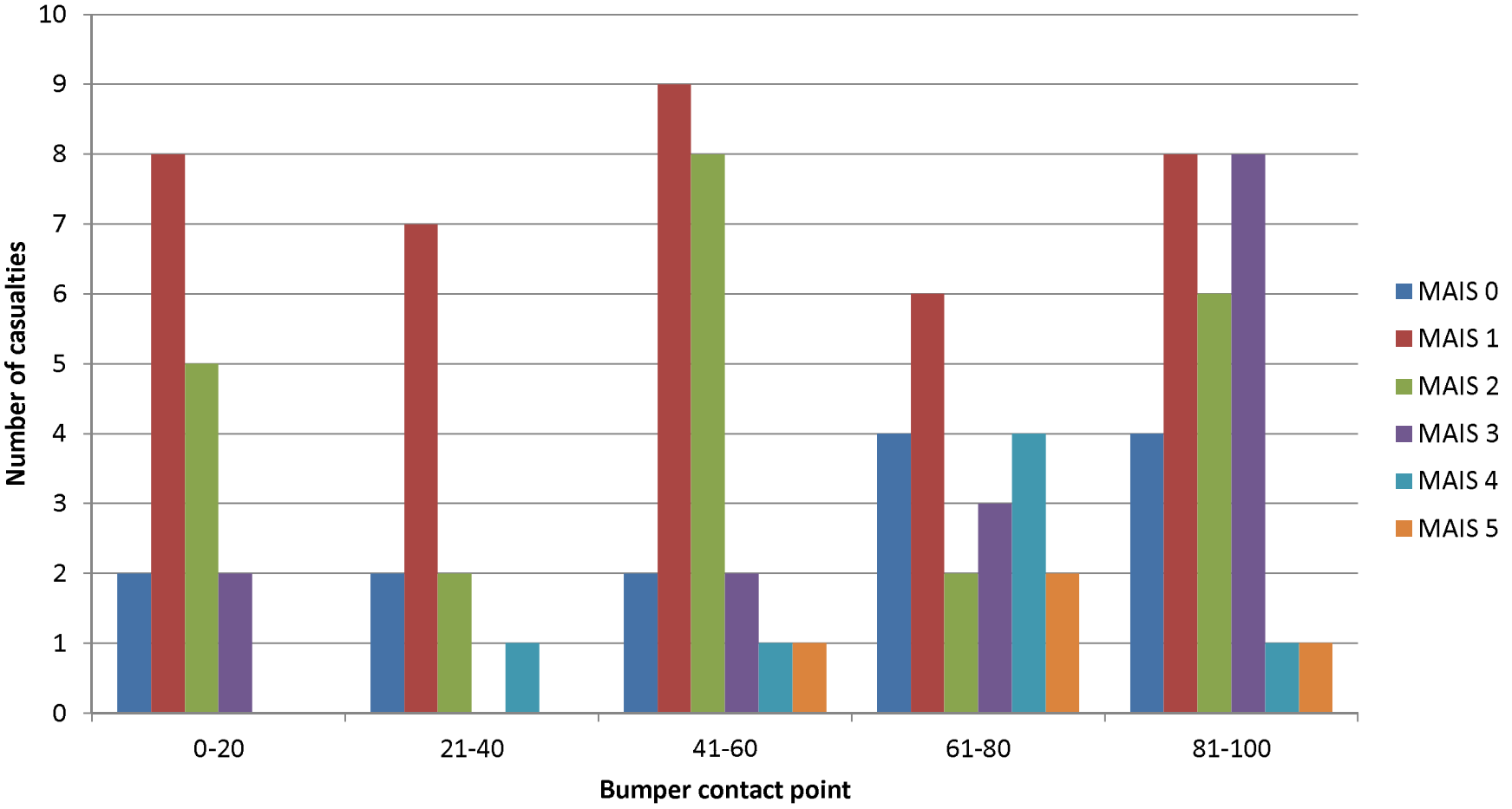
MAIS	Unknown	0-20	21-40	41-60	61-80	81-100	Total
0	3	2	2	2	4	4	17
1	3	8	7	9	6	8	41
2	1	5	2	8	2	6	24
3	1	2	0	2	3	8	16
4	0	0	1	1	4	1	7
5	0	0	0	1	2	1	4
6	0	0	0	0	0	0	0
9	0	1	2	0	1	3	7
Total	**8**	**18**	**14**	**23**	**22**	**31**	**116**

OTS

- MAIS 1 and 2 casualties appear to vary very little across bumper contact point
  - Peaking in the centre of the bumper
- Casualties with MAIS 3 are more frequent towards the N/S outskirts of the bumper
  - Highest possible MAIS for lower extremity is 3

Injury risk

Casualties by whole-body MAIS and contact position



Injury risk

Casualties by whole-body MAIS and contact position

GIDAS
German In-Depth Accident Study

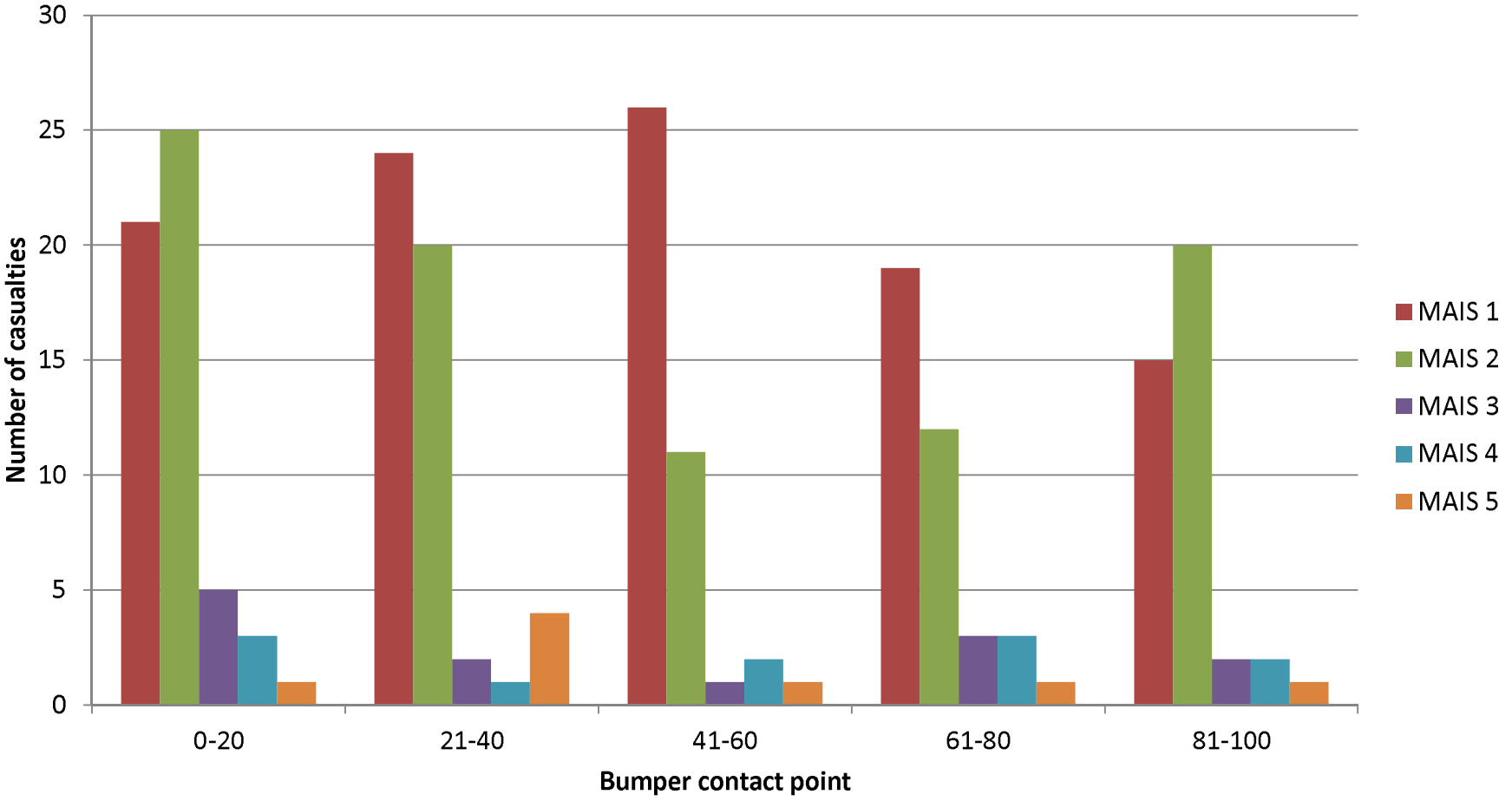
MAIS	0-20	21-40	41-60	61-80	81-100	Total
0	0	0	0	0	0	0
1	21	24	26	19	15	105
2	25	20	11	12	20	88
3	5	2	1	3	2	13
4	3	1	2	3	2	11
5	1	4	1	1	1	8
6	3	0	0	2	0	5
9	5	0	4	3	2	14
Total	**63**	**51**	**45**	**43**	**42**	**244**

GIDAS

- MAIS 1 casualties mostly contact the bumper in the centre
- MAIS 2 casualties are common at the outskirts of the bumper
- MAIS 3+ casualties are fairly consistent across the bumper
  - Small numbers of casualties

Injury risk

Casualties by whole-body MAIS and contact position



Injury risk

Casualties by body region and contact position – AIS 1 only

	Unknown	0-20	21-40	41-60	61-80	81-100	Total
whole leg	0	0	0	0	0	0	0
upper leg	0	0	0	0	0	0	0
knee	0	0	0	0	0	0	0
lower leg	0	0	1	0	0	0	1
ankle	0	0	0	0	0	0	0
foot	0	0	0	0	1	0	1
unknown or unclassifiable	5	13	14	20	28	33	113
Total	**5**	**13**	**15**	**20**	**29**	**33**	**115**

OTS

- Almost all are unknown or unclassifiable
- In OTS skin abrasions and contusions are not coded with a body region
- These types of injuries almost entirely account for the unknown/unclassifiable AIS 1 injuries
- Distribution of these injuries follows the skew to the N/S contact positions and is linear (R^2=0.97)

Injury risk

Casualties by body region and contact position – AIS 1 only

	0-20	21-40	41-60	61-80	81-100	Total
whole leg	0	0	0	0	0	0
upper leg	2	1	2	3	2	10
knee	12	13	9	14	5	53
lower leg	14	13	9	9	7	52
ankle	2	2	0	1	1	6
foot	5	2	1	3	0	11
unknown or unclassifiable	2	0	3	2	0	7
excluded (hip or pelvis)	0	0	0	1	1	2
Total	**37**	**31**	**24**	**33**	**16**	**141**

GIDAS

German In-Depth Accident Study

GIDAS

- Primarily knee and lower leg injuries
- Both body regions have a greater number of injuries at the N/S following the distribution of pedestrian contact position

Injury risk

Casualties by body region and contact position – AIS 2 only

	Unknown	0-20	21-40	41-60	61-80	81-100	Total
whole leg	0	0	0	0	0	0	0
upper leg	0	0	0	0	0	0	0
knee	0	3	0	1	1	2	7
lower leg	1	2	5	11	4	7	30
ankle	0	0	0	1	0	0	1
foot	0	0	0	0	0	4	4
unknown or unclassifiable	0	0	0	3	0	1	4
Total	**1**	**5**	**5**	**16**	**5**	**14**	**46**

OTS

- AIS 2 injuries are primarily lower leg injuries with some knee injuries
- Most lower leg injuries occur in the middle segment of the bumper

Injury risk

Casualties by body region and contact position – AIS 2 only

	0-20	21-40	41-60	61-80	81-100	Total
whole leg	1	0	0	0	0	1
upper leg	0	0	0	0	0	0
knee	3	2	2	3	3	13
lower leg	16	21	10	10	7	64
ankle	0	0	0	0	0	0
foot	0	0	0	1	0	1
unknown or unclassifiable	0	0	0	0	1	1
excluded (hip or pelvis)	0	0	0	0	0	0
Total	**20**	**23**	**12**	**14**	**11**	**80**

GIDAS

German In-Depth Accident Study

GIDAS

- Most AIS 2 injuries are also lower leg with some knee injuries
- Knee injuries are fairly consistent across the bumper
- Lower leg injuries are skewed towards the N/S

Injury risk

Casualties by body region and contact position – AIS 3+ only

	Unknown	0-20	21-40	41-60	61-80	81-100	Total
whole leg	0	0	0	0	0	0	0
upper leg	0	1	0	1	3	4	9
knee	0	0	0	0	1	0	1
lower leg	0	1	1	0	0	0	2
ankle	0	0	0	0	0	0	0
foot	0	0	0	0	0	0	0
unknown or unclassifiable	0	0	0	0	0	0	0
Total	**0**	**2**	**1**	**1**	**4**	**4**	**12**

OTS

- All upper leg injuries are AIS 3 or above
- With the most injuries occurring on the N/S

Injury risk

Casualties by body region and contact position – AIS 3+ only

	0-20	21-40	41-60	61-80	81-100	Total
whole leg	0	0	0	0	0	0
upper leg	1	1	1	1	0	4
knee	0	0	0	0	0	0
lower leg	5	0	4	6	2	17
ankle	0	0	0	0	0	0
foot	0	0	0	0	0	0
unknown or unclassifiable	0	0	0	0	0	0
excluded (hip or pelvis)	0	0	0	0	0	0
Total	**6**	**1**	**5**	**7**	**2**	**21**

GIDAS

- AIS 3+ injuries primarily occur in the lower and upper leg
- Distribution of these injuries is fairly consistent across the bumper contact positions

Injury risk

Summary of bumper injury risk

Sample size	▪ Not really large enough numbers to draw strong conclusions ▪ Can still be indicative of the injury risks associated with the outskirts of the bumper
Correlation with whole-body MAIS	▪ In both datasets, lower extremity AIS injury distributions across the bumper contact positions mirror the whole-body MAIS distribution for that dataset
OTS	▪ AIS 1 injuries have not been assigned any body regions ▪ AIS 2 injuries are mainly lower leg and some knee injuries with even distribution across the bumper ▪ AIS 3+ injuries are mostly upper leg and at the N/S of the bumper
GIDAS	▪ AIS 1 injuries are mainly lower leg and more common to the N/S ▪ AIS 2 injuries are mainly lower leg and more common to the N/S ▪ AIS 3+ injuries are lower and upper leg and fairly even across the bumper

Injury risk

Conclusions

- Frequency of contact
  - Distribution varies from nearside to offside
  - If this is linear progression then, assuming vehicle symmetry, no point more or less likely to be struck
  - Note some influence of pedestrian gender, etc.

- Bumper injury risk
  - As ever, small numbers inhibit potential for analysis
  - Some injuries/severity of injuries seem to have peak around edges of vehicle front
  - Sometimes inconsistent trends between OTS and GIDAS
  - No evidence that extremities of bumper are 'safe'