Developments in the Risk of Crash Involvement and Injury to Car Occupants by Model Year Using Vehicle Specific Exposure Data

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Abstract Crash test based consumer information systems, such as EuroNCAP or US NCAP, have indicated a substantial reduction in the risk of serious injury to car occupants since the mid-1990s. In parallel with these improving experimental results, there has been a steady reduction in the total numbers of car occupants seriously or fatally injured and it has been generally assumed that improved crash protection accounts for much of the reductions observed societally. Nevertheless, there has been very little analysis of the relationship between experimental results and any real reductions in casualties because of the influence of confounding effects of other parameters including the exposure to risk of different categories of vehicle and the underlying trends in mobility. This paper uses UK national accident data and recently available exposure data to evaluate the developments of risk of fatal or serious injury in parallel with the risks of crash involvement.

Keywords Crashworthiness, EuroNCAP, indicators, risk

I. INTRODUCTION

The first biomechanically-based crashworthiness requirements in Europe were introduced in 1996 when Directive 96/27/EC [1] concerning side impact protection was introduced. This was shortly followed by Directive 96/79/EC [2] which addressed frontal crash protection. The EuroNCAP consumer information system was then launched in 1997 using similar crash tests to the regulatory conditions but rewarding better performance beyond the legal limits. By 2010, as shown in Figure 1, car occupant fatalities in GB had reduced to 31% of their 1990 value and much of this has been attributed to improvements in car occupant protection.

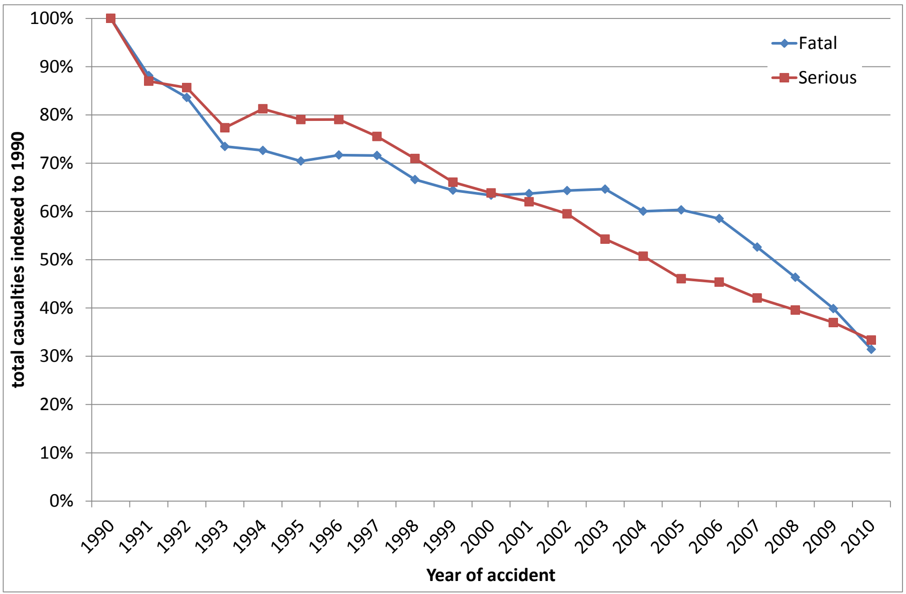

Fig 1. Reduction in GB traffic casualties

While some researchers have identified a link between better EuroNCAP performance and reduced injury rates, there has been little research that assesses changes in car crashworthiness and relates them to changes in the risks of crash involvement. The numbers of relevant cars available in accident databases and the lack of reliable exposure data have been obstacles, particularly with the need to eliminate other factors that may affect

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injury or crash risks such as driver age, driving style or the changes in vehicle mass.

Previous research has been conducted to investigate the relationship between the EuroNCAP crashworthiness ratings and safety outcomes. Lie and Tingvall [3] showed a strong relationship between EuroNCAP test scores and injury risk at a population level although not for individual models. Fails and Minton [4] compared EuroNCAP modifiers to real-world collisions while Newstead et al [5] compared EuroNCAP to real-world based rating scales finding only modest levels of association. Segui Gomez et al [6] examined the relationship between EuroNCAP scores and injuries to specific body regions without finding significant associations.

This paper aims to add to the body of knowledge concerning the development of crash and injury risks in the car fleet since the EU crashworthiness requirements were introduced in 1996 using macroscopic accident and exposure data.

II. METHODS

A. Developments in crashworthiness

The GB national accident data, "STATS 19", were analysed to calculate the numbers of crashes involving cars. The data are a census of all injury collisions that are reported to the police each year and are used at both a national and local level for road safety purposes. It is known that some categories of casualties such as pedestrian or cyclist are under-reported, particularly those sustaining slight injuries. However, the total car occupant casualties are considered reliable.

The STATS 19 data for the accident years 2008-2010 were used to estimate the development of crashworthiness for vehicles manufactured since 1990. The accident years were chosen to provide sufficient fatally or seriously injured casualties to be available for subsequent logistic regression analysis while minimising the influence of other road safety measures. In particular, the risk of serious or fatal injury is likely to be influenced by reductions in travel speed. While there has been a small decline in average speeds on roads in the UK since 1990, there were no reductions observed in official data in the years 2008-2010. The STATS 19 data analysed also include the year of manufacture and registration for use on the road of the vehicle which are matched from the national vehicle registration records together with other details of the vehicle. For this analysis the year of manufacture was used. Vehicles selected for inclusion in the model were manufactured in 1990 or later and were in collision with other cars in order to reflect the conditions of the regulatory and EuroNCAP test conditions. Table 1 summarises the STATS 19 data that were used to model crashworthiness.

To evaluate the developments in crashworthiness a logistic regression model was developed to link the odds of a fatal or serious injury to vehicle and driver factors.

B. Developments in rates of crash involvement

The rate of crash involvement is defined as $\frac{\text{number of collisions in a year}}{\text{distance travelled in the same year}}$.

Useful measures of exposure are not normally available and alternative methods such as induced exposure must be used to estimate crash involvement risk. However, new data of the distance travelled by each car in GB have become available. In the UK cars aged three years old or more are required to be tested annually to ensure they conform to roadworthiness requirements. The mileage observed on the vehicle odometer is recorded together with other details of the test outcomes and these data have recently been made available for analysis. It is not possible to relate the test data of an individual vehicle with the accident record of the same vehicle as a result of privacy considerations, however, individual makes and models and year of manufacture are available. It is therefore possible to calculate the distance travelled in a year for all cars of a specified make and model and in 2011 the total distance travelled by all vehicles was 3,322,400,698,105km .

Table 1. Most severely injured car occupant – crash years 2008 - 2010

Year of manufacture	Fatal	Serious	Slight	No injury	Total
1990	6	47	527	430	1010
1991	16	58	663	620	1357
1992	11	92	1000	927	2030
1993	18	180	1968	1571	3737
1994	24	258	3018	2502	5802
1995	34	368	4580	3578	8560
1996	45	463	6744	5110	12362
1997	73	612	9123	6968	16776
1998	70	734	11012	8492	20308
1999	71	804	12980	9661	23516
2000	73	890	14550	10294	25807
2001	62	911	15745	11441	28159
2002	80	923	16353	11932	29288
2003	76	917	15916	11457	28366
2004	63	809	14845	11380	27097
2005	58	753	13708	10915	25434
2006	48	695	12845	10261	23849
2007	46	760	13579	10937	25322
2008	30	609	10999	8515	20153
2009	14	353	5745	4481	10593
2010	8	124	2170	1652	3954
Total	926	11360	188070	143124	343480

There are 139,591 make and model combinations recorded in the roadworthiness data and many of these are of vehicles that are not cars or are currently on the road in small numbers. To simplify analysis a selection of car models was made to include all cars that had been manufactured in the period 1996-2011 and where there were at least 100,000 cars registered. This resulted in a group of 36 models of car that are listed in Table 2 together with the mean distance travelled. The relevant accident totals were also derived from the STATS 19 data for 2011 and these are also shown.

Details of the annual mileage covered by each car were entered at one of the many thousands of roadworthiness testing sites while the data on the make and model of car were entered onto a separate national vehicle registration system and later merged. With over 30,000,000 vehicle records nationally there were inevitably some administrative errors; for example, a model of car being recorded with a manufacture year before it was officially produced. Such errors were identified and the relevant records removed from the analysis. A more frequent limitation involved the effect of the age of a vehicle where typically the average annual mileage was observed to reduce after a certain age as illustrated in Fig 2. It can be observed that the group of Audi A4 vehicles manufactured in 1997 had the same cumulative distance travelled as those in 1998. This occurred as a result of the vehicles with higher distance travelled becoming no longer suitable for use on the road and thus being removed from the fleet for recycling. This meant that the estimates of average annual distance travelled were assumed to be in error for older vehicles although there was considerable variation in the characteristics between models. The data for the average distance travelled by each model of car were therefore limited for analysis to those years where there was a clear increasing trend and taking account of the size of the sample of each model within a year.

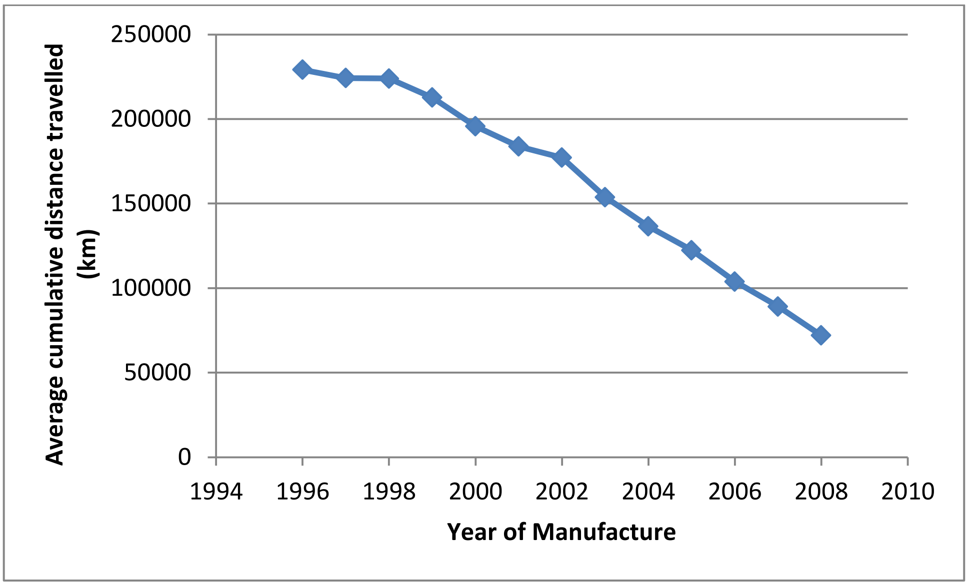

Fig 2. Cumulative distance travelled by year of manufacture: Audi A4

A further limitation of the exposure data resulted from the requirement that annual roadworthiness tests were only required once a car was three years old or greater so these years were aggregated for the subsequent analysis.

III. RESULTS

A. Crash involvement rates

The crash involvement rates of the selected models of cars were calculated from the total numbers that were involved in a crash of any type together with the total distance travelled in the year preceding the roadworthiness inspection. The results are shown in Figure 3 for each of the car sizes.

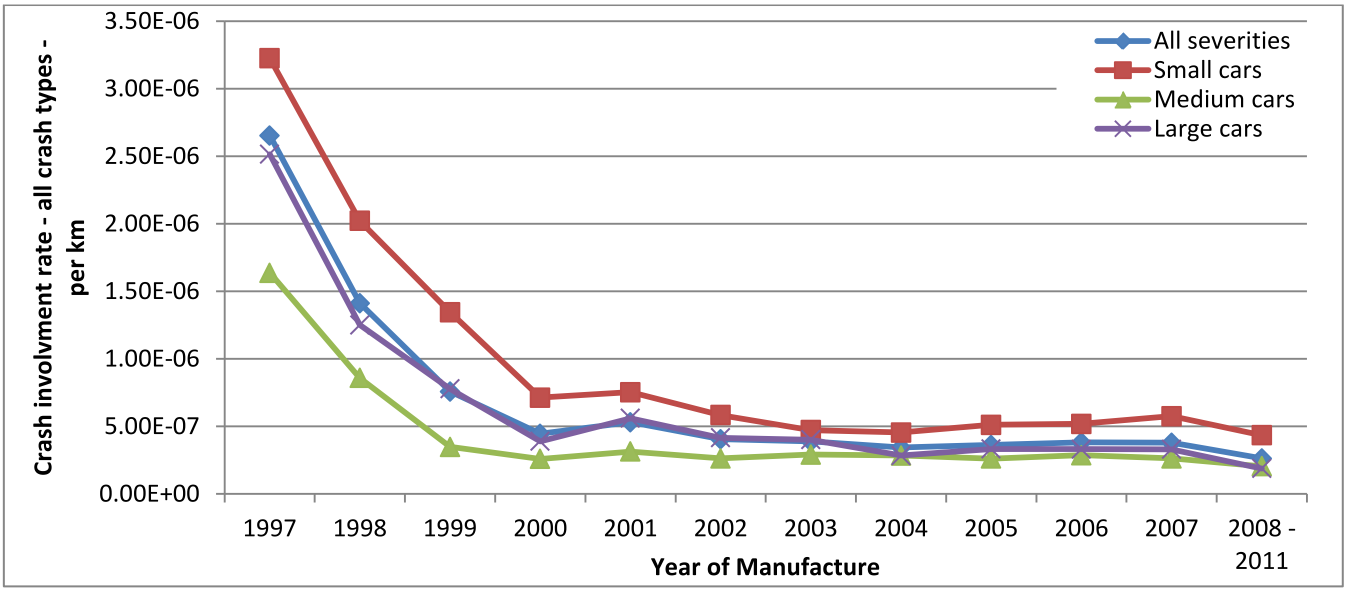

Fig 3. Crash involvement rate per km travelled – calendar year 2011

Figure 3 shows that small cars experienced the highest crash involvement rates in each of the years of manufacture. Small cars made in the period 2008-2011 had a rate that was 2.1 times greater than medium size cars and 2.3 times greater than large cars. The figure shows that crash involvement rates of all car sizes reduced compared to cars assembled in 1997 but most of this reduction took place in cars manufactured before 2000. Nevertheless the reduction in crash involvement risk of cars built in the period 2008-2011 is 36% lower than those built in 2000. Figure 4 compares the relative rates of crash involvement between car sizes for those made in 2008-2011 while figure 5 shows the reduction in rates from 2000.

Table 2. Summary details of selected models

Car model	car size	total km in year to 2010 - 2011	total crashes in 2011
AUDI A3	S	20,127,944,619	1236
AUDI A4	M	38,821,174,637	1435
CITROEN BERLINGO	S	19,533,415,458	932
CITROEN C3	S	10,502,027,381	954
CITROEN SAXO	S	20,058,259,272	1034
CITROEN XSARA	M	38,966,396,610	1443
FORD FIESTA	S	95,555,383,069	5697
FORD FOCUS	M	131,843,888,216	4018
FORD GALAXY	L	18,007,966,773	748
FORD KA	S	17,823,732,696	1765
FORD MONDEO	L	90,818,283,571	2454
HONDA ACCORD	L	17,337,563,693	626
HONDA JAZZ	S	9,161,684,026	920
MINI	S	15,846,056,190	1115
PEUGEOT 106	S	21,767,370,154	1183
PEUGEOT 206	S	65,130,870,274	3374
PEUGEOT 207	S	6,755,316,835	1284
PEUGEOT 306	M	32,258,999,307	849
PEUGEOT 307	M	34,187,422,157	1607
RENAULT CLIO	S	69,856,049,795	4793
RENAULT LAGUNA	L	24,303,213,272	599
RENAULT MEGANE	M	61,605,860,334	2902
ROVER 25	S	12,620,767,218	794
SEAT IBIZA	S	9,864,875,638	784
SKODA FABIA	S	13,472,462,002	908
SKODA OCTAVIA	M	16,333,407,776	1311
TOYOTA AVENSIS	L	23,780,566,934	1269
TOYOTA COROLLA	M	22,729,257,741	1166
TOYOTA YARIS	S	21,553,264,301	1666
VAUXHALL ASTRA	M	130,113,812,158	6191
VAUXHALL CORSA	S	97,748,392,885	7151
VAUXHALL VECTRA	L	66,593,599,176	2323
VAUXHALL ZAFIRA	L	40,556,850,454	1728
VOLKSWAGEN GOLF	M	98,430,413,232	3206
VOLKSWAGEN PASSAT	L	47,524,683,757	1836
VOLKSWAGEN POLO	S	46,843,919,370	2679
total km		1,508,435,150,979	73980
Total (all vehicles)		3.3224E+12	180616
% of all vehicles		45.4%	41.0%

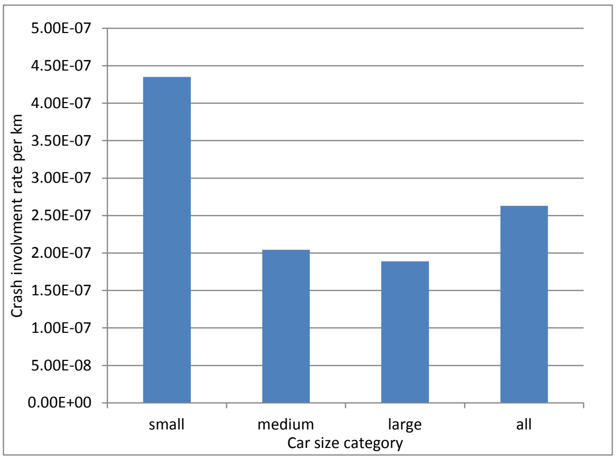

Fig 4. Comparison of crash involvement rates – cars built in 2008-2011

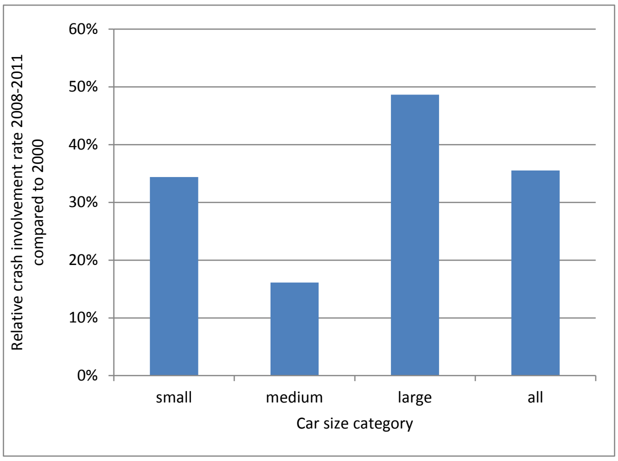

Fig 5. Relative crash involvement rates – 2008-2011 compared to 2000 cars

The reduction in crash involvement rates comparing cars manufactured in 2000 and 2008-2011 could also be a result of differences in driver characteristics which confound the results. It is believed that the younger drivers, who have higher crash involvement rates, may tend to drive older cars for economic reasons and this could influence the observed crash rates. To explain the changes in crash involvement rates and account for driver characteristics, a Generalised Linear Model (GLM) was developed with the following variables:

Dependent variable
- Total crashes

Independent variables
- Total vehicle km travelled in year
- Year of car manufacture
  1993 - 2010
- Driver sex
  - Male
  - Female*
- Driver age band
  - 0 - 5
  - 6 – 10
  - 11 - 15
  - 16 - 20
  - 21 - 25
  - 26 - 35
  - 36 - 45
  - 46 - 55
  - 56 - 65
  - 66 - 75
  - Over 75*
- Car size category
  - Large
  - Medium
  - Small*

***** Indicates the reference value for categorical variables in the model. These have a coefficient set to 1.

Since the GLM modelled the count of crashes a Poisson distribution was assumed together with a logarithm link function. Table 3 shows the significant variables and the parameter estimates for the GLM, all variables were significant at P<0.001. Only one interaction term, driver age x car size, was significant, also at P<0.001. Table 3 also shows the exponentiated value of the Coefficient, since a logarithmic link function was used for the model this value presents the multiplicative factor which can be used to estimate the effect of a change in each variable. For example the coefficient for year of manufacture is -0.012 and exp (-0.012) is 0.998 so an increase of one year in the year of manufacture corresponds to a crash involvement risk 0.988 of the previous year.

Table 3. GLM parameter estimates

Parameter Estimates					
			95% Wald Confidence Interval		
Parameter	Coefficient	Std. Error	Lower	Upper	Exp(B)
(Intercept)	24.921	2.4680	20.084	29.758	66543668250
Year of Manufacture	-.012	.0012	-.014	-.009	.988
Vehicle Kilometres travelled	2.437E-10	3.7058E-12	2.365E-10	2.510E-10	1.000
Driver sex=Male	.210	.0082	.194	.226	1.234
Driver age=16-20	1.540	.0306	1.481	1.600	4.667
Driver age=21-25	1.436	.0307	1.376	1.496	4.205
Driver age=26-35	1.407	.0307	1.347	1.467	4.084
Driver age=36-45	1.066	.0317	1.004	1.128	2.904
Driver age=46-55	.866	.0325	.803	.930	2.378
Driver age=56-65	.514	.0346	.446	.582	1.672
Driver age=66-75	.105	.0383	.030	.180	1.110
Car size=large	-.866	.0787	-1.020	-.711	.421
Car size=medium	-.320	.0513	-.421	-.220	.726
Driver age=16-20 and car size = large	-1.791	.1195	-2.025	-1.556	.167
Driver age=16-20 and car size = medium	-1.048	.0613	-1.168	-.928	.351
Driver age=21 - 25 and car size=large	-.693	.0893	-.868	-.518	.500
Driver age=21-25 and car size =medium	-.187	.0564	-.298	-.076	.829
Driver age=26-35 and car size = large	.443	.0822	.282	.604	1.557
Driver age=26-35 and car size = medium	.507	.0545	.400	.614	1.661
Driver age=36-45 and car size = large	.851	.0824	.689	1.012	2.341
Driver age=36-45 and car size = medium	.666	.0555	.558	.775	1.947
Driver age=46 - 55 and car size = large	.707	.0836	.544	.871	2.029
Driver age=46 - 55 and car size = medium	.542	.0568	.431	.653	1.720
Driver age=56 - 65 and car size =large	.570	.0868	.400	.740	1.768
Driver age=56 - 65 and car size =medium	.428	.0598	.311	.545	1.534
Driver age=66 - 75 and car size = large	.349	.0960	.161	.537	1.418
Driver age=66 - 75 and car size = medium	.208	.0662	.079	.338	1.232

Table 3 shows that, compared to female drivers, male drivers had a crash involvement rate 1.234 times greater. The youngest drivers had the highest crash involvement rates 4.667 times those of the oldest aged over 75. Large cars had the lowest crash risk, only 42% of that of the smallest cars while medium size cars had a risk 73% of smallest cars. Small cars had the highest crash risk with levels 2.4 times that of large cars and 1.4 times those of medium cars.

B. Crashworthiness development

National STATS 19 accident data classify injury severity into fatal, serious, slight or non-injury groups and the definitions are presented in Table 4. The serious group covers a relatively wide spectrum of injury severities and could include both a fracture to a finger and a casualty who dies 30 days or more after the crash. Nevertheless, the total casualties who were killed or seriously injured provide a useful indicator of long term trends in casualty severity.

Table 4. Injury severity definitions – UK national accident data

Injury severity	Definition	Examples
Fatal	Death within 30 days of the crash occurring	Excluding natural causes and suicide
Serious	Detention in hospital as an in-patient, either immediately or later	• Fracture • Internal injury • Severe cuts • Crushing • Burns • Concussion • Severe general shock requiring hospital treatment • Injuries to casualties who die 30 or more days after the accident from injuries sustained in that accident
Slight	Less severe injuries than the serious category	• Sprains, not necessarily requiring medical treatment • Neck whiplash injury • Bruises • Slight cuts • Slight shock requiring roadside attention
Non-injury	No reported injuries	

Figure 5 shows the decrease in the proportion of casualties sustaining fatal or serious injuries for the group of 343,480 collisions shown previously in table 1. The proportion of both groups showed a decrease when comparing cars manufactured in 1990 and cars manufactured in 2010. Casualties with serious injuries reduced by 43% comparing cars built in 1990 and 2010 while fatal injuries reduced by 66%. Figure 5 shows a large part of the reduction occurred in cars built in the early years of this period and cars built in 1996, the year the crashworthiness regulations were introduced, already had serious injury rates reduced by 24%.

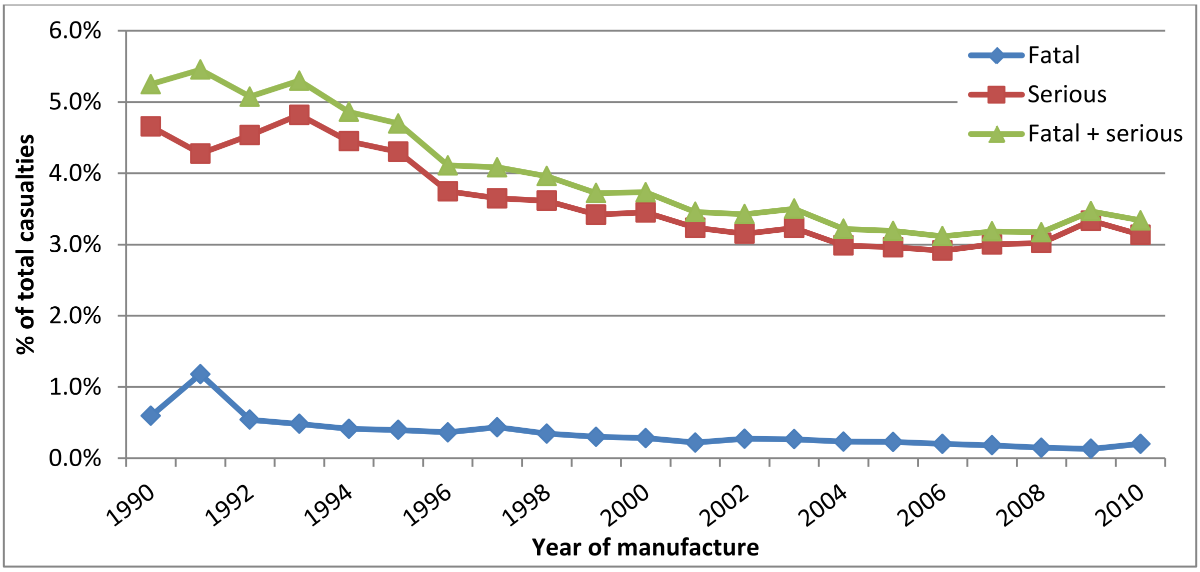

Fig 5. Fatal and seriously injured casualties as a % of total casualties with year of manufacture

As previously specified the accident year of the cases in Figure 5 was selected to be 2008-2010 as a compromise between maximising the total number of cars available for analysis while minimising potential confounding effects from other road safety measures. Driver and other vehicle factors were not inherently excluded however and it is probable that older cars may be driven by a different population of drivers than newer cars. Also, it is known that the typical mass of cars has increased which may affect impact severity and hence injury outcomes.

To control for these driver and vehicle factors a multinomial logistic regression model was developed to model injury risk and is shown in Table 5 below. Only car-to-car collisions were selected to most closely represent the conditions of EuroNCAP and the EU front and side impact Directives. The dependent variable was the highest severity of all occupants in the car. Explanatory scale variables included driver age, year of manufacture and gross weight of car. Year of accident was also entered to control for any further unaccounted changes in road safety conditions. Driver sex was entered as a categorical variable with female drivers as the contrast reference term.

A multinomial logistic regression model was developed to relate the severity of the most severely injured occupant of each car, classified as slight, serious or fatally injured, with a set of explanatory variables including driver age and sex, manufacture year, accident year and vehicle weight. The level of significance of an independent variable estimates the likelihood that it affects the outcome variable with relevant variables considered to have a significance of 5% or less. It can be seen that driver age and gross vehicle weight are highly significant predictors of the risk of fatality whereas the year of manufacture, driver sex and the year of accident were not. In particular, the significance of the year of manufacture as a predictor of fatality was 0,671 indicating no evidence of a relationship with fatality risk.

All of the predictor variables in the model showed highly significant relationships with risk of serious injury. The Odds Ratio for the year of manufacture indicated that for every unit increase the risk of a seriously injured casualty decreased by 2.6% after accounting for confounding effects. Driver age and sex were both significant predictors indicating the importance of adjusting for the factors.

Table 5. Crashworthiness model - car to car impacts

		Coefficient	Odds ratio (OR)	Sig.	95% Confidence Interval for OR Lower Bound	Upper Bound
fatal	Intercept	55.695		.878		
	driver age	.028	1.028	.000	1.012	1.044
	manufacture year	-.015	.985	.671	.921	1.054
	Vehicle weight.	-.002	.998	.000	.997	.998
	Accident year	-.015	.985	.937	.687	1.413
	Driver sex=Male	.416	1.516	.250	.746	3.080
serious	Intercept	-139.460		.104		
	driver age	.017	1.017	.000	1.013	1.021
	manufacture year	-.026	.974	.004	.958	.992
	Vehicle weight	-.001	.999	.000	.999	.999
	Accident year	.095	1.099	.029	1.010	1.197
	Driver sex=Male	-.442	.643	.000	.555	.744
slight	Intercept	-49.250		.111		
	driver age	.000	1.000	.672	.999	1.002
	manufacture year	-.001	.999	.772	.992	1.006
	Vehicle weight.	-.001	.999	.000	.999	1.000
	Accident year	.026	1.027	.092	.996	1.059
	Driver sex=Male	-.620	.538	.000	.509	.568

IV. DISCUSSION

Since 1996 there has been a considerable effort undertaken by car designers and engineers to improve the safety of vehicles on the road. Driven by regulation and by EuroNCAP the crash performance of current production cars is considerably higher than cars from the early 1990s. In parallel with the increasing safety levels of cars there has been an overall decline in traffic casualties which has been popularly attributed to car design. Nevertheless there have been few attempts to quantify the relationship, partly as a result of the potentially large influence of confounding factors including driver characteristics and the introduction of other road safety measures.

The research presented in this paper has analysed population data to quantify the relationship between the evolution of vehicle design and levels of crash involvement and crashworthiness. It has used two methods to minimise the influence of confounding factors by restricting the years of accident data analysed to limit changes in traffic patterns and by developing models to control for their effect. The analysis uses the year of manufacture of the cars as an indicator of the level of safety development of a car although, in reality, car design advances in steps with occasional large modifications, which may need re-homologation and more frequent facelifts. While an individual model may develop in steps, the analysis predicates that the combined effect of many models of car indicates an underlying more continuous development.

Previous research has examined the relationship between year of car manufacture and injury risk. Broughton [7] used GLM to evaluate the benefits of improved secondary safety for cars registered between 1988 and 2007 including registered vehicle years as a measure of exposure. He identified that the risk of death of drivers of cars registered for use on the road between 1996 and 1999 was 33% greater than for drivers of cars registered between 2000 and 2003. However, he did not explicitly include vehicle mass as a factor. The present analysis used induced exposure methods to show that the average reduction in serious injury risk for a unit increase in manufacturing year was 2.6% when controlling for confounding factors. This can be compared with the average 3.3% decline in total seriously injured casualties in car-to-car collisions over the accident years 1990-2010. The logistic regression model developed in this analysis inherently implies a progressive decrease in risk. However, the raw, unadjusted data indicate that risk of serious injury reduced by 40% from cars built in 1990 to 2010 but over half of this occurred before 1996 models. The 2008-2011 accident data show no evidence of a relationship between model year and risk of fatal injury. Partly this can be explained by the very broad definition of the serious injury category but these were also years when the UK saw a sharp reduction in car occupant fatalities from 1638 in 2008 to 1111 in 2010.

There has been little previous analysis of changes in crash involvement rates according to year of manufacture and other parameters. The recently available annual exposure data recorded at annual roadworthiness testing offers a new opportunity to evaluate crash involvement risks. The present paper is the first known where these data have been used for safety research purposes and the analysis has shown some of the potential of the data. The measures of exposure are based on the recorded mileage at tests undertaken in 2011 and the average distance travelled for selected models of cars has been combined with the total numbers of crashes by manufacture year to estimate crash involvement rates. The prevalence of older or higher mileage cars leaving the fleet at the end of life limits the range of manufacture years that can be included for analysis. The data do suggest though that in 2011 there was a sharp decrease in crash involvement rates for cars manufactured between 1997 and 2000. More recent models showed a decrease of crash involvement rates of 41% of cars manufactured after 2000. The GLM fitted to the data indicates that the measures of exposure as well as other driver and vehicle parameters are all highly significant indicators of crash involvement risk; however, the magnitude of the effect of manufacture year is much smaller than the other parameters. The development of crash risk with manufacture year may be contrasted with the increasing focus on vehicle based crash avoidance measures. There is little systematic data on the availability within the selected car models of systems such as ESC or Brake Assist although the progressive introduction of these systems may have influenced the crash involvement rates.

The crash involvement data also indicate differences between classes of car. Small cars have a crash involvement rate that is typically 1.4 times the rate of medium cars and 2.4 times that of large cars according to the classification used. This pattern is consistent across the range of years of manufacture examined. This contradicts the work of Evans [8] who estimated that a car of 900Kg mass had a 28% lower risk of crash involvement compared to one of mass 1800Kg and suggested that drivers of smaller cars adopted more cautious driving styles as a result of the perceived lower level of protection offered. Further analysis of the GB data is needed to understand the effects of car size.

This analysis enables reductions in crash involvement risk and risk of fatal or serious injury to be juxtaposed, the multinomial logistic regression model suggested that the risk of a seriously injured casualty reduced by 2.6% for each increase in model year. In contrast the crash involvement risk reduced by only 1.2% in one model year and this confirms that the emphasis in vehicle safety has been on improving crashworthiness rather than crash involvement risks. There are further opportunities to improve crash protection but this analysis supports an increased emphasis on improvements to crash avoidance.

There are limitations to the analysis in this study that derive from the statistical methods utilised and from the exposure data. The roadworthiness testing data for calendar year 2011 has been the basis of estimates of the annual distance travelled by cars according to their make, model and year of manufacture. Older or high mileage cars tend to be removed from the fleet as they become unroadworthy meaning that the older cars for which mileage remains available will tend to be those with lower overall mileage. Manual methods were used to inspect the data and exclude these older cars from the analysis but it is possible there are still inaccuracies remaining that could result in the mileage of the older cars analysed being under-represented and hence crash involvement rates being over-represented.

The exposure data used in the present paper have only recently become available and its application for road and vehicle safety analysis represents a step forward in understanding population effects. Nevertheless, the analysis implies that the nature of the exposure to traffic is similar across categories of car. For example, it assumes that large cars undertake similar journeys in similar traffic to small cars of the same year of manufacture.

The models developed to estimate reductions in injury or crash involvement risk aim to control for the range of driving styles by including driver-specific factors within the model as is standard practise. However, it is possible that driver age and sex are not sufficiently strong as substitute indicators. Data from naturalistic studies are needed to improve the understanding of the relationship between driving style and crash risk in order to improve models of road safety.

V. CONCLUSIONS

The present paper has analysed GB national level accident and newly available exposure data to estimate the relationship of crash involvement and injury risk with the year of manufacture of cars. Conclusions of the research are:

1. The availability of comprehensive population-based exposure data provides a valuable resource for assessing crash involvement rates.
2. Cars manufactured after 2008 typically had a crash involvement rate that was 36% below that of cars manufactured in 2000 for the accident year 2011.
3. The year of manufacture of a car is a significant predictor of both crash involvement and serious injury risk. Other factors including driver sex, age and car size are significant for crash involvement and car mass is a highly significant predictor of serious injury risk.
4. Year of manufacture was not found to be a predictor of fatality risk.

VI. ACKNOWLEDGEMENT

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VII. REFERENCES

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