MISREPORTING INJURY SEVERITY IN EUROPEAN ROAD ACCIDENTS

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ABSTRACT

Apart from injury underreporting (i.e. casualties unavailable in police records, but possibly available in hospital records), it is also acknowledged that there exists an injury severity reporting inaccuracy problem ("misreporting"), covering in many countries for over 50% of all injuries, especially slight ones. The objective of this research is the analysis of injury severity misreporting in European countries, on the basis of in-depth fatal accident investigation data collected within the SafetyNet integrated research project. In this dataset, two distinct classifications are available concerning injury severity: "Police injury severity" and "SafetyNet medical outcome", i.e. as validated or corrected on the basis of additional data sources. After a thorough exploratory analysis of the data, logistic regression models were developed, in which the dependent variable indicated whether injury severity matched between the two classifications or not. The probability of misreporting injury severity was correlated with a number of road user, vehicle, road and accident characteristics. Overall, the data included several cases presenting injury severity misreporting. A general trend could be identified, according to which, the more complex the accident (e.g. higher traffic) and the accident site (e.g. junction, daytime), and the more vulnerable the road user (e.g. children, elderly, pedestrians), the higher the probability of injury severity score to be different between the police and SafetyNet. The results also suggest that score differences may be due either to recording bias (e.g. the Police tending to misreport injury severity incorrectly under certain conditions), or to a general difficulty in identifying the correct severity score in some cases. The results of such analyses may be a very first step towards the development of correction coefficients for injury severity misreporting.

Keywords: injury severity; misreporting; in-depth accident investigation data; logistic regression

INTRODUCTION

Literature review

The importance of working with reliable injury severity distributions for the assessment of any factor that is related to road traffic accidents is highlighted in several pieces of work so far, e.g. Elvik (2007). Compared to other aspects of data processing in the road safety field, available literature on injury severity misreporting is rather poor. The comparison between police reports and hospital records generally reveals significant under-reporting of road casualties (Hvoslef, 1994).

A number of studies report results from routine data linking at national level (i.e. in the USA for over a decade as part of the Crash Outcome Data Evaluation System – CODES, 1996), while others link data as part of a specific research project (Rosman, 2001, Amoros et. al., 2006; Petridou et al. 2009). Broughton et al. (2010) estimated injury mis-classification coefficients from linking police and hospital data in 7 European countries. Moreover, the level of under-reporting seems to be associated with several factors, such as length of stay in the hospital, physician in charge of the first aid, urban place of the crash, number and type of vehicles involved, day and time of the crash and blood alcohol concentration (Aptel et al., 1999; Lopez et. al., 2000).

Tsui et al. (2008) worked on the misclassification of injury severity among road casualties in police reports. The study in question investigates the discordance between police reports of road casualties' injury severity and the length of stay at hospital & Injury Severity Scale (ISS). Linking police and hospital records in Hong Kong by means of a multivariate binary logistic regression showed frequent over-estimation of injury severity by the police.

Background – Objectives

As regards road fatalities, the common EU definition of fatalities within 30 days from the accident has contributed significantly to the reduction of fatality under-reporting. However, no such definitions are available with respect to injuries (serious or slight), as also mentioned in recent pieces of work (e.g. Tsui et al., 2008).

The issue of injury under-reporting (i.e. of casualties who are unavailable in police records, but who can possibly be found in hospital records) is often examined at national level, by means of comparisons between macroscopic police and hospital data. However, as regards *inappropriate reporting* (i.e. misclassification of injury severity), little information is available in the literature. In general, it is acknowledged that there exists an injury severity reporting inaccuracy problem (from now on "misreporting"), covering in many countries for over 50% of all injuries (especially slight ones) (ETSC, 2007). Of course, some degree of mis-reporting is inevitable, as an injury may in fact evolve over time to become more or less severe than first reported. In fact the early reporting may be quite accurate based on available information, but upon further examination and/or time an injury is found to be less or more severe

Within the SafetyNet project of the 6th Framework Programme of the European Commission, an in-depth road accident database was created on the basis of Fatal Accident Investigation (FAI) data collected by means of retrospective methods, including cases of fatal accidents from seven European countries. In this dataset, two distinct classifications are available concerning injury severity at the level of individual road user:

- “Police injury severity”, i.e. injuries or complications directly due to the accident within 30 days of the crash, as recorded by the Police.
- “SafetyNet medical outcome”, i.e. overall outcome of the crash, validated or corrected on the basis of various additional data sources (hospital, insurance companies records etc.), as police only followed the situation of each individual’s health for a limited period of time.

In both classifications, there are four possible outcomes, namely "killed", "seriously injured", "slightly injured" and "not injured". In fact, the FAI database includes cross-checked, validated and enhanced data, on the basis of the initial Police records of this data. Consequently, all cases in the initial Police records are available in the FAI data.

The objective of this analysis is the identification of the degree of disagreement / mismatch between "Police" and "SafetyNet" scores and possible determinants. In particular, the analysis aims to investigate whether any prevailing factors emerge that are related to such differences, making the initial "Police injury severity" change when corresponded to "SafetyNet medical outcome" finally. It is therefore possible to examine the effect of several interesting parameters on the probability to record eventually accurate descriptions of the injury severity in a road accident. These factors involve all major components of road systems, namely network users, vehicles and roads. Moreover, some of those are seldom adequately stored in national databases.

It is noted that a careful examination of partial cases was required in the present analysis, as there were several rather incompatible pairs of misreporting, i.e. combinations of initial outcomes changing category in the end (e.g. cases switching from “slightly injured” to “not injured”, as opposed to “seriously injured” changing to “killed”, which is much more expected). Such an approach provided insight on the most promising field (data subsets) for further analysis.

METHODOLOGY – DATA

Data description

The FAI cases form a broad ranging, intermediate level, fatal accident dataset, which was developed on the basis of existing accident investigation infrastructure through retrospective investigation methods (Morris and Reed, 2006). The dataset was systematically selected according to a defined sampling plan so that the data were broadly representative of the

countries in which they were collected, namely France, Finland, Germany, Italy, the Netherlands, Sweden and the UK (Brace, 2005). Data were predominantly derived from the police documentation of fatal accident investigations in each country, and complemented with information derived from hospital records, insurance companies' records and prosecution records, currently resulting in 350 FAI cases (accidents) involving around 950 road users (casualties) in total (expected to mount up to 1,300 FAI cases involving around 3,500 road users in the final stage of data collection).

A representative national sample of between 2% and 10% of the fatal crashes in each country covered during the period 2003-2004 was investigated, depending on the magnitude of the fatal accidents population. In particular, each country had to provide a set of representative data according to an agreed matrix of criteria (Brace, 2005).

The level of detail recorded for the examined countries is considerably greater than the one obtained in the European CARE macroscopic database; 117 variables with more than 500 data values were typically gathered. Specific areas of data describe the overall accident circumstances, driver and vehicle characteristics, specific road infrastructure features, and descriptions of other crash participants. These variables and values conform to common definitions provided in the dataset Glossary (SafetyNet, 2006). The FAI database has a typical road accident database structure, with four separate areas concerning accident, roadway, vehicle and road user details respectively.

In this paper, the models developed and the results obtained concern the 1st pilot wave of FAI data. Table 1 presents the classification of these casualties per injury severity, according to the two classifications, the Police score and the SafetyNet score. The results suggest that important misreporting was present (and corrected) in the cases processed in the FAI data, especially as regards those casualties that were initially recorded by the Police as "seriously injured". A more detailed exploratory analysis of the data was required to identify the subsets of cases upon which the analysis should focus.

Table 1 – Distribution of casualties recorded in different severity scores (FAI 1 data)

Source	Killed	Seriously Injured	Slightly Injured	Not Injured	Grand Total
Police	328	247	163	205	**943**
SafetyNet	404	98	165	243	**910**
Difference	+76	-149	+2	+38	**-33**

Model type

The dependent variable considered in the analysis of the examined FAI data was at first a binary one, indicating whether the two classifications (Police and SafetyNet) are the same or different. As explained previously, this exploratory analysis is intended to suggest a subset of available data on which analyses would be most meaningful. After attempts involving broader subsets, it was concluded that this would be the case for the “seriously injured” cases of Police scores.

Dealing with a not so common dependent variable calls for careful examination of available candidate predictors: Independent variables should be selected on the basis of their potential explanatory value with respect to the specific research question of injury severity misreporting. Once the main promising explanatory variables are identified, more elaborate (multinomial) models may be fitted to a 3-category response variable for the casualties initially recorded as "serious" by the Police, i.e.:

- changing to less severe injury,
- remaining the same,
- changing to more severe injury.

However, quite a few variables in the FAI database may exhibit high overlap in terms of variance, implying multicollinearity if included simultaneously in a model. In order to address such uncertainties, some descriptive analysis of various variables precedes the building of models, so that the latter is performed in an appropriate manner.
In the following subsections, logistic regression models are developed to compare alternative combinations of injury severity scores between the police and SafetyNet team records, for those casualties that were initially recorded as "serious" by the police. Binomial regression models are presented, for the probability of the occurrence of misreporting between the police and SafetyNet severity scores.

All explanatory variables have been defined as categorical ones (see Table 2).

Table 2 – Variables and values used in the analysis

Variable	Values
Misreporting	0: Different Recording, 1: Same recording
Body Region Most Injured	0: Head/Thorax/Multiple, 1: All other (known) cases
Crash Participants	0: 1, 1: >=2
Road User Class	0: Driver / Passenger, 1: Pedestrian
Age	0: 15 - 54, 1: 0 - 14 / >=55
Gender	0: Male, 1: Female
Impairment	0: No, 1: Yes
Resident of region	0: No, 1: Yes
Familiar with region	0: No, 1: Yes
Avoidance manoeuvre	0: No, 1: Yes
Motorway (road type)	0: No, 1: Yes
Speed Limit	0: <50, 1: >50
Weather Conditions	0: Dry, 1: Wet
Light Conditions	0: Daylight/Dazzling sunlight, 1: Other (known) cases
Carriageway Type	0: Dual divided, 1: Other cases (uniform)
Number Of Lanes	0: 1/direction, 1: >=2/direction
Junction	0: No, 1: Yes
Area type	0: Rural, 1: Urban / Mixed
Traffic conditions	0: Light, 1: Normal / Heavy
Vertical Alignment	0: Flat, 1: Uphill / Downhill
Horiz. Alignment	0: Straight, 1: Bend / Junction / Other
Most harmful event	0: 1st event, 1: 2nd-plus event
Vehicle Type	0: 4wheelers, 1: 2wheelers & pedestrian / shoe vehicle

Crash Participants	0: 1, 1: >=2
Road Conditions	0: Dry, 1: Other
Event Type 1	0: Non-collision, 1: Collision
Accident Day	0: Weekdays, 1: Weekend

RESULTS

Exploratory analysis

According to the examination of possible injury severity combinations between the two aforementioned classifications, there are quite a few cases in which the severity score changes from the Police to the SafetyNet records (see Table 3). These represent a proportion in the range of 20-35% of police severity scores as far as “fatal/not injured/slightly injured” scores are concerned. “Seriously injured” constitutes a notably different case, with almost 60% of initial scores changing to some other severity category. Parts of the cases initially rated as "serious" by the police are afterwards categorized either as "slightly" injured (20%), as “fatal” (30%) or as "unknown” (10%) by SafetyNet.

Table 3 – Corresponding injury severity for the two severity scores in the FAI 1 data

	SafetyNet Medical Outcome					
Police Injury Severity	Fatal	Serious	Slight	Not Injured	Unknown	Grand Total
Fatal	328					**328**
Serious	75	95	50	2	25	**247**
Slight		3	111	40	9	**163**
Not Injured			4	201		**205**
Unknown	1				10	**11**
Grand Total	**404**	**98**	**165**	**243**	**44**	**954**

Note: Figures in the diagonal (grey) present the cases where the original reporting was correct; off-diagonal cells (white) present misreporting.

The last subset mentioned is analysed in this paper, as the one exhibiting the most frequent misreporting problem. Further exploration showed that the validity of an analysis examining cases from all participating countries in a single subset of the available data is strongly influenced by Italian cases. In fact, it appears that this country, which has contributed more than 40% of total cases in the pilot FAI data, reveals some striking differences when compared to the other countries (see Table 4), in terms of misreporting extent for cases with an initial score of “seriously injured”. The Italian data collection team confirmed that the examined FAI data included several cases dated before year 2003, a time by which the common 30-days definition of fatality had not been adopted in Italy, so that a large degree of misreporting may be attributed to serious injuries ending up as fatalities.

The respective values of all other countries (Sweden, Germany, France, Finland and the United Kingdom) present most similar distributions, it is therefore acceptable to treat those cases in a uniform way.

Table 4 – Corresponding injury severity for the two recording systems (FAI 1 data): Italy (413 cases)

Police Injury Severity	SafetyNet Medical Outcome					
	Fatal	Serious	Slight	Not Injured	Unknown	Grand Total
Fatal	87					87
Serious	70	15	45	2	19	151
Slight			24	38	5	67
Not Injured				99		99
Unknown					9	9
Grand Total	157	15	69	139	33	413

Two rather different data subsets are thus formed, allowing for direct comparison. Three main conclusions may be drawn from the exploratory analysis of the data:

- In all countries except Italy, the large majority of cases is on the diagonal, i.e. there are proportionately few differences between the injury severity recorded by the police and by the SafetyNet team.
- In the group of all countries except Italy, cases of misreporting are relatively more frequent for the entries that have been initially rated as “serious” by the police; approximately 11% of these cases ended up in a different severity category for the SafetyNet score.
- Italy constitutes an exception to the general picture, as a larger proportion of Police scores were initially incorrect and needed to be corrected in the FAI database. Especially with respect to seriously injured road users according to the Police, only about 10% of these were appointed this score correctly, possibly due to lack of training for assessing injury conditions. As mentioned, changes in score can take place in both directions (i.e. to a status of either heavier or less severe type of casualty).

It was therefore decided to develop different models for Italy and all the other countries; given the different patterns identified, it is likely that different determinants may be identified as well.

A binomial model for Italy

Italy contributed 132 known cases (casualties) in the FAI 1 database.

The model developed yields the probability of observing the same severity score from the Police and the SafetyNet team for casualties recorded as "serious" by the Police, in relation to the explanatory variables. As a part of the process, all variables were initially tested alone, in order to see whether they are significant when no other effect is present.

The best performing model is presented in Table 5.

Table 5 – Parameter estimates of the best fitting binary logit model (probability of misreporting - Italy)

Variables	**Parameter estimates**			
	B	S.E.	Sign.	Exp(B)
Traffic(normal/heavy)	-1.791	0.628	0.004	0.167
Traffic(light)	.	.	.	.
Vehicle Type(pedestrians-riders)	-1.550	0.830	0.062	0.212
Vehicle Type(occupants)	.	.	.	.
Junction(yes)	-1.103	0.670	0.100	0.332
Junction(no)	.	.	.	.
Gender(female)	-1.643	0.850	0.053	0.193
Gender(male)	.	.	.	.
Constant	0.150	0.563	0.790	1.161

There is certain improvement from the "empty" model in terms of fit, as indicated by the likelihood ratio. Its value is reduced from 93.470 to 74.288. Another useful indicator of the quality of the model can be obtained by means of the percentage of correctly classified cases; more than 91% of the outcomes are correctly predicted by the model (98.2% of different and 40% of matching scores)[1]. These results are quite satisfactory.
Some interesting conclusions may be drawn:

- The heavier the traffic, the more likely it becomes to observe misreporting of injury severity between Police and SafetyNet.
- The same appears to hold for the presence of a junction.
- Non-matching scores are also more frequent for female road users. No straightforward interpretation may be applied, at least not before further investigation of the type of misreporting is carried out by means of a multinomial model
- Two-wheelers riders and pedestrians are much more likely to have their injury severity changed than vehicle occupants. This appears reasonable as far as the change from serious injuries to fatalities is concerned. A multinomial model would be useful in verifying that.

These results may be considered to suggest that, in Italy, the more complex the conditions of the accident, the higher the probability of different severity scores between the police and SafetyNet as regards those individuals initially classified as "serious" by the police. It may be the case that higher traffic volumes (and consequently more accident participants), the presence of junctions etc. make data collection and classification a more complex task for the police, increasing the probability of errors in recording. This may be better understood when considering that all FAI cases concern fatal accidents, which are already more complex cases for the Police carrying out the accident investigation.

[1] The low prediction of cases with not-changing score may be attributed to the fact that matching entries are very few (10% of the total). Subsequently, a model cannot capture very well individuals with injury severity status remaining “seriously injured”.

A binomial model for all other countries

All other countries except Italy contributed 90 known cases (6 more were excluded from the analysis as unknown). The results of the analysis are presented in Table 6.

Table 6 – Parameter estimates of the best fitting binary logit model (probability of misreporting - other countries)

Variables	**Parameter estimates**			
	B	S.E.	Sign.	Exp(B)
Age(0-14 / 55+)	-1.689	0.776	0.030	0.185
Age(15-54)	.	.	.	.
Light Conditions(dusk/night)	2.087	1.129	0.065	8.064
Light Conditions(daylight)	.	.	.	.
Area(urban/mixed)	-2.062	0.980	0.035	0.127
Area(rural)	.	.	.	.
Constant	2.666	0.632	0.000	14.378

Since the standard likelihood ratio (as a statistic test) equals 62.790 for the empty model and the likelihood statistic for this model equals 49.45, a chi-square test verifies that the three selected predictors produce a really improved model (reduction by 13.341 with three degrees of freedom).

About 91% of the cases are correctly predicted by the model (100% of matching and 20% of non-matching scores). Since the model is developed around the prediction of the majority of cases - i.e. the matching ones -, there is room for improvement concerning the prediction of the non-matching cases.

Similarly to the preceding analysis for Italy, in the case of all other countries the main findings are the following:

- The absence of daylight appears to enhance matching scores between the two recording systems. It is likely that Police recording is more careful during the night, in an attempt to compensate for the more complicated conditions during the night. This is not too profound and should be further investigated.
- It appears that there is increased probability to obtain different score eventually for individuals who are either very young or rather old (reference age group: 15-54). This is a significant and rather strong effect. Some justification could be provided by the fact that children and aged people are often more vulnerable to deteriorate when injured; this addresses the shift from the state of injured to that of killed.
- The same observation as the one stated for the individuals of age closer to the two extremes holds for individuals participating in collisions occurring in urban or mixed areas.

Although the significant predictors are rather few, it may also be suggested that, the more complex the conditions of the accident (e.g. urban environment), or the more vulnerable the road user groups (children/elderly), the higher the probability of different severity scores between Police and SafetyNet.

In addition to the models presented above, multinomial models have been produced for Italy and the remaining countries respectively, focusing again on misreporting of serious injuries only, with a multinomial dependent variable (0: change to fatality, 1: same outcome, 2: change to slight or no injury). In this case, the effect for each of the independent variables was tested for two contrasts between each of the "change" categories and the "same" category (0 vs. 1 and 2 vs. 1). This process serves as a means to investigate whether the parameters identified in the binomial models work on one or both directions (final injury severity status heavier or lighter than "seriously injured"). This is a meaningful order to follow, as some factors may only work towards one direction (misreporting implying over- or under-estimation of the injury severity), while others may work towards both over- and underestimation.

In the case of Italy, the main finding of an unordered multinomial model was that the role of heavy traffic was verified in both directions (i.e. when investigating change of status from "seriously injured" to "killed" or "slightly injured"). The other variables found significant in the binomial model where not equally well verified in this more detailed analysis.

A similar model for the other examined countries together yielded that two variables (age and area type) are marginally significant when considering the case of status change from "seriously injured" to "killed", in the same way as in the respective binomial model (but not at all the other way round).

CONCLUSION

This paper is dealing with the misreporting issue, as defined in the introductory section. In-depth data collected in terms of the EU co-funded project SafetyNet are utilised to perform a comparative analysis between police and SafetyNet records of road network users involved in accidents and initially stored as seriously injured. As the relative international literature is rather limited, the importance of this analysis is quite large, given the importance of an as accurate as possible classification of road accident casualties. This involves classifications of injury severity per accident-causing factor (typically, drink & driving or excessive speeding), or across age and other road user characteristics, etc.

The analyses performed on the pilot FAI data mainly revealed two issues with respect to the investigation of accurate injury severity reporting:

- The selection of an appropriate subset of variables
- The interpretation of conclusions/implications provided by such an analysis

The results of such analyses may be a very first step towards the development of correction coefficients for inappropriate severity recording (misreporting).

From the results obtained by the time of this pilot data collection, a general trend could be identified, according to which, the more complex the accident and the accident site, and the more vulnerable the road user, the higher the probability of injury severity score to be

different between the police and SafetyNet. An additional issue that needs to be addressed is whether score differences are mainly due to recording bias (e.g. the Police may tend to record severity incorrectly under some conditions), or to the lack of a sound definition of injury severity (making it difficult to identify the correct severity score).

Summarizing the results of the binomial models, it is interesting to note that the "person's age" variable was most significant for all countries but non-significant in the model for Italy. It may be that, in the other countries, serious injuries' reporting problems may come from the type of injury and not from reporting errors as such. It is reasonable to assume that the scores obtained by the Police in the other countries are mainly influenced by special injury features alone, as non-matching scores only represent a very small proportion of total cases. On the other hand, additional parameters related to the type of accident are dominant in the Italy model, suggesting presence of recording bias (to be further investigated during later stages of analysis).

Multinomial models were built as well, aimed at further analysing the major conclusions drawn through the respective binomial models. All predictors that appeared to be significant in the respective binomial models have been tested in the multinomial ones. In most cases, it was found that the impact of the selected variables on the dependent variable was practically of the same kind (i.e. towards matching or non-matching of Police and SafetyNet records), but not always of the same magnitude and direction.

However, additional predictors that were not found significant in the binomial models could be significant in the multinomial models. For example, if "females" have an increased probability of “overestimation” of their injury severity by the Police in relation to "males", and at the same time a decreased probability of an “underestimation” of their injury severity by the Police in relation to "males", then because the two types of misreporting are pooled together in the binomial model, the effect of “gender” would not appear significant in the case of the binomial model. This may be further pursued by means of analysing the final FAI database, once the initial findings presented here are further examined and either verified, or somehow reconsidered.

Overall, the examined pilot wave of FAI data included several cases presenting injury severity misreporting, especially as regards Italy. The analysis of these cases allowed for some interesting indications to be obtained, as regards the presence of a few non-random factors in misreporting of casualties recorded as "serious" by the Police. These cases have been very demanding in cross-checking, correcting and processing in the FAI database. The retrospective methods used allowed for the necessary adjustments to be made, so that the use of the "SafetyNet medical outcome" score can be considered fully reliable. It is noted, however, that these cases are unlikely to be included in the final FAI dataset. The aim of the FAI data processing is to eventually include in the database cases that did not initially present misreporting.

It may be stated that the analysis of the examined data reveals differences in severity scores, largely observed due to recording bias (e.g. the Police tends to record severity incorrectly

under some conditions). The lack of a sound international definition of injury severity also hinders the identification of the correct severity score. At least partly, the examined observation may simply be attributed to the fact that in some cases severe injuries have an increased probability of becoming fatal ones – a hint that also deserves further investigation. However, the systematic factors identified suggest that other types of misreporting are observed as well.

In any case, these results should be considered with some caution, given the small sample size of the FAI1data. It would be most interesting to have a larger data subset of individuals initially stored as seriously injured. The final FAI database may provide such a detailed and high quality dataset, and more insight on the degree of Police reporting errors in relation to other factors making individuals eventually change injury severity scores.

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