DTU Library

Estimating road crashes in Denmark
An application of the capture-recapture method

Janstrup, Kira Hyldekær

Publication date:
2013

Document Version
Peer reviewed version

Kira Hyldekær Janstrup
Technical University of Denmark
Department of Transport
Traffic modelling and planning
kj@transport.dtu.dk

Estimating road crashes in Denmark: An application of the capture-recapture method

INTRODUCTION

The last couple of years have witnessed a growing interest in finding methods to estimate the exact number of road crashes. This interest has grown from the fact that police registered crashes are heavily under-reported and, moreover the under-reporting is biased (Derriks and Mak, 2007; Elvik and Mysen, 1999). In an earlier meta-analysis of under-reporting studies Elvik and Mysen (1999) found that the official road crash statistics in Denmark only catch 21% of the hospital injury crashes, thus missing 79%. In comparison, the under-reporting rates range between 21% and 88% for included countries in the meta-analysis. If only countries in Europe are included the under-reporting rates are smaller and range between 21% and 57%. The under-reporting rate varies considerably according to the degree of crash severity; in the present study, Elvik and Mysen found that that the official road crash statistics in Denmark is almost complete when it comes to fatalities; here it catches 97% of the hospital recorded road fatalities. Furthermore, they found that the reporting level for car occupants in Denmark by the police is 48% of that of hospitals where the same number for cyclists is only 10%. In Europe the reporting rate is generally low for cyclist crashes, with a reporting rate range between 8%-66%. Only Great Britain (66%) covers over 30% of the cyclist crashes. In a study from Denmark, Hels and Orozova-Bekkevold found that in a five year period, only 25% of emergency room cyclist crashes were reported by the police (Hels and Orozova-Bekkevold, 2007).

In general, two different methods have been applied to estimate the total number of road crashes: the capture-recapture method and the method developed by Reurings and Stipdonk (2011). The capture-recapture method is known from ecology, where it is used to estimate the total size of animal populations in the field by repeated marking and sampling individuals (Southwood and Henderson, 2000). The capture-recapture method was applied on road crash data from road crashes in the end of the 1990's by comparing hospital and police crash records and using the crash records that were recorded in both data sources in order to estimateing the total number of crashes. The method of Reurings and Stipdonk (2011) is inspired by the capture-recapture method and has been used on data from the Netherlands, although it necessitates access to all emergency data and not only the ones recorded as a road crash.

The increasing interest in using the capture-recapture method in road safety is reflected in an ample body of literature, accumulated since the 1990's (e.g. Thomas et al., 2012; Miller et al., 2012, Hassel et al., 2011; Lateef, 2010; Amoros et al., 2007, Meuleners et al., 2006; Tercero and Andersson, 2004; Morrison and Stone, 2000; Razzak and Luby, 1998). Most of these studies focused on a small subgroup of road users or specific crashes, such as alcohol-related crashes (Miller et al., 2012), road crashes with work related vehicles (Thomas et al., 2012), cyclist or pedestrian involved crashes (Tin et al., 2012; Dhillon et al., 2001; Roberts and

Scragg, 1994), heavy vehicles involved crashes (Meuleners et al., 2006), road crashes involving children or young people (Dhillon et al., 2001; Morrison and Stone, 2000; Roberts and Scragg, 1994), fatal crashes (Samuel et al., 2012; Lateef, 2010) or serious injury crashes (Amoros et al., 2007). Only a few studies include all injuries group and all types of road users (Martinez et al., 2012; Tercero and Andersson, 2004; Aptel et al., 1999).

While previous studies (e.g. Thomas et al., 2012; Miller et al., 2012; Samuel et al., 2012; Martinez et al., 2012; Tin et al., 2012; Salmi et al., 2012; Lateef, 2010; Meuleners et al., 2006, Tercero and Andersson, 2004; Dhillon et al., 2001; Morrison and Stone, 2000; Aptel et al., 1999; Razzak and Luby, 1998) referred to 1-5 year time period, the current study captures an eight year period, thus enlarging the data set and allowing a better representation of relatively rare crash types.

While the capture-recapture method is based on the assumption that some crashes are recorded both in police and hospital data, none of the above mentioned studies attempted to clarify the underlying factors for the crash appearance in the two data sources versus its appearance in a single data source only. In contrast to this, the current study focuses on understanding the under-reporting rate of road crashes in Denmark and revealing the underlying factors for reporting in hospital and police data. The data for the analysis is police and hospital crash data from Funen, the fourth largest island in Denmark, for the period 2003-2008. Almost 10% of the Danish population lives on Funen or at one of the nearby small islands, which belong to the emergency rooms on Funen. Therefore, the under-reporting on road crashes in Funen provides a good estimate of accident under-reporting in Denmark as a whole.

The current study has two main aims. The first aim is to estimate the under-reporting rate of road users involved in road crashes in Funen. The second aim is to estimate the likelihood of reporting in the two sources as a function of individual and crash characteristics. Understanding the heterogeneity in the reporting rate of a crash in the two data sources is essential for devising policy measures to increase the reporting rate by targeting specific population/road user groups or specific situational factors. Among the investigated factors are socio-demographic characteristics, trauma type and severity, and crash characteristics. The applied methodology for estimating the under-reporting rate is the capture-recapture method, while the applied methodology for estimating the likelihood of reporting a crash both to the police versus reporting to a single data source is the binary-probit model.

The total number of road users involved in a road crash on a part of Denmark, Funen, is estimated for the each of the years 2003 to 2008. The two sample capture-recapture method will be used on road crash data from the Danish Road Directorate and data from all emergency rooms on Funen. A (pseudo) civil registration number for each person involved in a road crash is listed in the two data sets and the linking procedure is done by those. Besides the traditionally variables (e.g. road user type, injury degree, length of hospital stay, time of the day the crash has happen), also a number socio-demographic variables is included in the analysis.

The importance of this study is because it has focus on the problem with homogeneity when the capture-recapture method is used. First an estimation of the under-reporting rate is calculated by using the capture-recapture method where the Chapman formulary is used to calculate the total number of people involved in a road crash at Funen. To understand the likelihood of reporting in the two sources a function of the individual and crash characteristics is build. The heterogeneity in the reporting rate model is build for data from the emergency room and for data from the police registration. A number of socio-demographic data is included in the analysis together with the traditionally variables.

The remainder of the paper is organized as follows. Section 2 presents the data and describes the variables used in the analysis. Section 3 presents the two methods used for the analysis. Section 4 presents the results, first the under-reporting rate and then the heterogeneity in the reporting rate. Last, section 5 offers a discussion and concluding remarks.

DATA

There were 34,270 road users who reported an involvement in a road crash to the police or the emergency room at Funen in the years 2003 to 2008. 14,870 road users involved in road crashes were registered by the police, and 24,568 road users involved in road crashes were registered by the emergency rooms. Of these crashes, 5,168 were registered both places.

The police registered database was obtained from the Road Directorate in Denmark, which collects all information on police registered road crashes in Denmark. The data registered by the police includes crash characteristics, mode types involved, crash location (e.g. intersection, motorway) and collision point(s). Information on the crash circumstances are also listed (e.g. condition of the surface, weather condition, speed limit at the concerned road). At last some information on the involved parties in the crash is listed (e.g. injury degree of the involved persons, age, gender, civil registration number). A municipality code is listed as well.

The data registered by the emergency rooms in Funen are collected at three hospitals covering all of Funen (Odense, Svendborg and Middelfart). An AIS (Abbreviated Injury Scale) code is recorded with diagnosis codes related to trauma type, crash characteristics (i.e., number of vehicles involved, the involvement of vulnerable road users and crash location) and personal information of the patients (i.e. age, gender, and civil registration number) is noted as well.

The road user injuries are recorded differently in the two crash registers: The police records injuries on a four step scale: no injury, slight injury, severe injury, death, whereas the emergency room records road user injury on an eight step AIS scale (reference). Thus, to be able to include severity degree in the analysis the end-result of the hospitalization at the emergency room was transformed into an injury scale parallel to that used by the police: If an injured road user’s stay ended with a fatality, the degree of severity was denoted as fatal. If a stay ended with a hospitalization then the degree of severity was denoted as a severe injury, and if a stay ended with the visit at the emergency room or the general practitioner the degree of severity was denoted as a slight injury.

Socio-demographic characteristics including education and information on the involved road users' family were obtained from the database of the Danish Statistical Bureau (Statistics Denmark).

The linking of the three data sets were conducted through the use of the individual civil registration number of the person involved in the road crash. Notably, previous studies (e.g., Thomas et al., 2012, Miller et al., 2012, Lateef, 2010, Amoros et al., 2006, Meulener et al., 2006) matched police and hospital records on the basis of matching characteristics (mostly date, gender and age) in the absence of an individual civil registration number. This may lead to false positive identification of matching records when the matched records are highly similar but do not derive from the same crash. The use of individual civil registration number allows to accurately matching of the two data sources without risk of false positive identification of similar crashes as the same crash.

While the whole data set was used to estimate the under-reporting rate, only 21,832 observations of road users involved in crashes were used for understanding the heterogeneity in reporting to the two data sources due to a high number of records with missing variables. Of the 21,832 records, 13,770 were police records and 4,807 appear both at the hospital and the police databases.

METHODS

The capture-recapture method with the Chapman formula was used to estimate the total number of road users involved in a road crash at Funen for each of the years 2003 through 2008. Then, a binary probit model was estimated to investigate the heterogeneity in the reporting rate. Two separate models were estimated for the two data sets: road users involved in road crashes registered at the emergency room only and road users involved in road crashes registered by the police only.

Capture-recapture

A two sampled capture-recapture method is used to estimate the total number of road users involved in a road crash at Funen. The Chapman capture-recapture formulary is defined as follows:

$$N = \frac{(m+1)(n+1)}{B+1} - 1 \tag{1}$$

N is the total number of road users who report a road crash, m is the number of road users who have reported exclusively to the police, n the number of road users who have reported exclusively to the emergency room and B is the number of road users who have reported both to the police and the emergency room. The variance and 95% confidence interval (CI) for the estimate of N is obtained by

$$Var(N) = \frac{(m+1)(n+1)(m-B)(n-B)}{(B+1)^2(B+2)} \quad (2)$$

$$95\%CI = N \pm 1.96\sqrt{Var(N)} \quad (3)$$

When using the capture-recapture method four assumptions have to be met. First, the population has to be closed, i.e. fixed in number, throughout the estimation period; second, there needs to be a perfect and unambiguous identification of subjects common to both registrations; third, there has to be independence between the two registrations, meaning that the probability of appearing in one register does not affect the probability of appearing in the other; and last, there must be homogeneity of capture by a given registration, i.e. that all subjects intersest should have the same probability of being registered by one of the two sources. The assumption about closed population means that there should be no entry or loss between the two sources, i.e. fixed in number; however, this is not the case when we talk about road crashes, because some road users only get registered by their own doctor. This will lead to an under-estimation of the total number of injured road users. The perfect identification of cases common to both registrations is surely met in this study since the linking is done by an individual pseudo civil registration number. The third condition, registration independence: It is known that there is a positive relation between appearing in the two sources used in this study, since the police sometimes call the emergency room and announce them of the road crash. This again will lead to under-estimation of the total number of injured road users. The assumption of homogeneity of the two registrations is difficult to handle, but to investigate this, the heterogeneity analysis is made.

Binary probit

A binary probit model is estimated to explore the probability that a crash involved road user is reported in the police register given that the same road user is already reported in the emergency room register and vice versa. According to the binary probit model, the probability to choose to report the crash to both sources is as follows:

$$P_{nmatch} = 1 - \Phi(\theta - \beta' z_n) \quad (4)$$

where P_{nmatch} is the probability of a person n to report the crash to the emergency room and the police, z_n is the aforementioned vector of individual and crash characteristic, and β and θ are parameters to be estimated. The corresponding unconditional log-likelihood LL over N registered injured persons is as follows:

$$LL = \sum_{n=1}^{N} \log\left[1 - \Phi\left(\theta - \beta' z_n\right)\right]^{d_n} \tag{5}$$

Field Code Changed

where d_n equals one if a person n registered the crash to the emergency room and the police, and zero otherwise.

RESULTS

Results of the capture-recapture method

Table 1 presents the results for the capture-recapture method for the total number of road users involved in a road crash at Funen in each of the years from 2003 through 2008.

Table 1. The total number of road users involved in a road crash at Funen by year

Year	Number of matched	Number of unmatched in police data	Number of unmatched in emergency room Data	Estimated number of people involved in a road crash (95% CI)
2003	930	1,812	3,096	11,864 (11,321-12,407)
2004	809	1,633	3,202	12,099 (11,491-12,708)
2005	753	1,503	3,085	11,491 (10,891-12,090)
2006	879	1,566	2,940	10,608 (10,117-11,100)
2007	917	1,802	3,409	12,820 (12,221-13,491)
2008	880	1,386	3,668	11,705 (11,162-12,247)
Total	5,168	9,702	19,400	70,683 (69,300-72,066)

In this number also the material damage only road crashes from the police are included, since some of the road users involved in those actually were registered at the emergency room as well. The number of road users involved in a material damage road crash was in total (8,697), and (4) road users were unknown to the police and therefore not linked to a road user in the emergency room registration.

In table 2 the results for the severity degree (fatal, severe and slight) are given and the number of registrations by the police and emergency room are also listed.

Table 2. The total number of road users involved in a road crash at Funen, divided by severity degree and year.

	Year	Number of Matched	Number of Unmatched in police data	Number of unmatched in emergency room data	Estimated number of road users injured in a road crash (95% CI)
Fatal	2003	19	9	2	31 (29-33)
	2004	20	8	1	29 (28-31)
	2005	17	7	4	30 (26-33)
	2006	28	3	2	33 (32-34)
	2007	27	8	5	41 (39-44)
	2008	24	8	3	36 (34-38)
Severe	2003	454	108	723	1,457 (1,411-1,503)
	2004	381	66	789	1,372 (1,329-1,416)
	2005	341	67	761	1,318 (1,271-1,365)
	2006	412	62	661	1,234 (1,201-1,268)
	2007	433	87	705	1,366 (1,325-1,408)
	2008	384	44	838	1,362 (1,326-1,398)
Slight	2003	457	112	2,370	3,519 (3,388-3,649)
	2004	408	94	2,411	3,467 (3,333-3,601)
	2005	395	70	2,320	3,195 (3,082-3,308)
	2006	439	83	2,270	3,229 (3,119-3,338)
	2007	457	96	2,698	3,817 (3,682-3,951)
	2008	472	71	2,826	3,793 (3,679-3,907)

The total number of road fatalities at Funen varies from 29 to 41 in the period 2003 to 2008, while the number of severely injured road users varies between 661 in 2006 to 838 in 2008. The number of slightly injured road users varies from 2,270 in 2006 to 2,826 in 2008.

Estimating the likelihood of reporting in the two data sources

Table 3 presents the model results for the likelihood that a road user involved in a road crash reported to the police also appears in the hospital records. Table 4 presents the model results for the likelihood that a road user involved in a road crash reported to the emergency room also appears in the police records.

Table 1. Estimations results of the binary probit model for the number of road users who appears in a police record also appears in an emergency room records

Variable	Categories	Coefficient	t-statistic
Age group	0-9 years old*)	-	-
	10-14 years old	-0.584	-2.75
	15-17 years old	-0.636	-3.24
	18-24 years old	-0.492	-2.58
	25-34 years old	-0.584	-3.07
	35-44 years old	-0.622	-3.26
	45-54 years old	-0.715	-3.73
	55-64 years old	-0.786	-4.08
	65-74 years old	-0.626	-3.19
	75 years old and above	-0.617	-3.10
Gender	Female*)	-	-
	Male	-0.255	-8.38
Living status	Other*)	-	-
	Partner	0.045	0.68
	Single	0.102	1.48
Education background	Other*)	-	-
	High	0.033	0.89
Transport mode	Car*)	-	-
	Van	0.012	0.21
	Truck or tractor	-0.234	-2.40
	Bus	-0.139	-0.74
	Motorcyclist	0.281	1.83
	Moped	0.399	5.03
	Cyclist	1.643	26.91
	Pedestrian	1.303	15.77
Seatbelt worn	No*)	-	-
	Yes	1.135	30.22
Helmet worn	No*)	-	-
	Yes	3.989	18.53
Number of motor vehicles involved in the crash	None*)	-	-
	One	0.242	3.58
	Two or more	0.688	9.43
Time of the day	7 am - 5 pm	-0.072	-2.46
	6 pm – 6 am*)	-	-
Year	2003*)	-	-
	2004	-0.102	-0.22
	2005	0.005	0.10

	2006	0.114	2.44
	2007	0.023	0.49
	2008	0.266	3.40
Under influence of drugs	No*)	-	-
	Yes	0.223	1.31
Under influence of alcohol	No*)	-	-
	Yes	0.168	3.60
Speed limit	0-60 km/h*)	-	-
	70-90 km/h	-0.102	-2.21
	100-130 km/h	0.315	3.47
Number of lanes on crash road	Other*)	-	-
	One	0.160	1.86
	Two	0.123	3.21
	Three or more	0.359	4.58
Intersection	No*)	-	-
	Yes	-0.210	-6.03
Severity degree	Material damage only*)	-	-
	Slight injury	1.379	30.23
	Serious injury	1.468	29.81
	Fatal injury	1.749	14.36
Number of observations		13,770	
Restricted log-likelihood		-5422	
Log-likelihood at estimates		6966	
McKelvey and Zavoina Pseudo R-square		0.6652	

Note: *) Reference category

Table 2. Estimations results of the binary probit model for the number of road users who appears in an emergency room record also appears in a police record

Variable	Categories	Coefficient	t-statistic
Age group	0-9 years old*)	-	-
	10-14 years old	0.109	1.06
	15-17 years old	0.418	4.49
	18-24 years old	0.410	4.58
	25-34 years old	0.492	5.45
	35-44 years old	0.584	6.47
	45-54 years old	0.532	5.81
	55-64 years old	0.594	6.32
	65-74 years old	0.575	5.68
	75 years old and above	0.427	3.99
Gender	Female*)	-	-

	Male	0.187	6.91
Living status	Other*)	-	-
	Partner	0.027	0.41
	Single	0.123	1.82
Education background	Other*)	-	-
	High	-0.051	-1.55
Transport type	Car*)	-	-
	Van	-0.143	-1.89
	Truck or tractor	0.050	0.29
	Bus	-1.014	-5.46
	Motorcyclist	1.049	13.42
	Moped	1.367	22.15
	Cyclist	0.832	17.12
	Pedestrian	1.700	23.41
Seatbelt	No*)	-	-
	Yes	2.105	49.64
Helmet	No*)	-	-
	Yes	0.043	0.98
Number of motor vehicles involved in the crash	None*)	-	-
	One	1.456	43.73
	Two or more	1.548	34.58
Time of the day	7 am - 5 pm	0.055	2.08
	6 pm – 6 am*)	-	-
Year	2003*)	-	-
	2004	-0.098	-2.26
	2005	-0.084	-1.93
	2006	-0.038	-0.88
	2007	-0.072	-1.63
	2008	0.107	1.40
Type of severity	Slight injury*)	-	-
	Serious injury	0.540	17.76
	Fatal injury	1.735	10.46
Type of injury	Other damage*)	-	-
	Head and spine	0.882	8.46
	Neck damage only	-0.445	-7.47
	Lower and upper extremity	0.185	2.67
	Lower extremity and spine	1.128	7.09
	Upper extremity damage only	-0.397	-8.22
	Spine damage only	0.681	10.04
Number of observations		21,832	

Restricted log-likelihood	-6135
Log-likelihood at estimates	10,747
McKelvey and Zavoina Pseudo R-square	0.5877

Note: *) Reference category

The model fits in both analyses are very good: 0.6652 and 0.5877, respectively, and it was found that many variables were significant at a 5% level.

The variable male is found significant at the 5% level with a negative estimate (-0.255) in the first model and with a positive estimate (0.187) in the second. It thus seems that from all the road users who get reported to the police, females have a higher chance of getting reported to the emergency room as well, where from all the road users who get reported to the emergency room, males have a higher probability of getting reported to the police. Education and status of living was not found significant in any of the analyses. Among transport modes, cyclists and pedestrians have the highest estimated likelihood of reporting to the emergency room given they were already reported to the police. Their coefficients were higher than those of mopeds and motorcyclist riders. In the second model pedestrians and moped riders had higher estimated coefficients than cyclists and motorcyclists. Therefore, from all crash involved road users who were reported to the emergency room, pedestrians and moped riders have the highest probability of reporting to the police as well. The coefficient for trucks or tractors was found negative and significant in the first model, meaning that heavy vehicles are less likely to get reported to the hospital once the crash is reported to the police.

The coefficient for seatbelt use was positive and significant in both models, while helmet use was positive but significant only in the first model. That is, crash involved road users who use safety gear and get reported to the police are more likely to get reported also to the hospital. Crash involved road users who wear seatbelts and get reported to the hospital are more likely to get reported to the police as well.

The coefficient for number of motor vehicles involved in the crash was positive, significant and increased with the number of motor vehicles involved. Namely, road users in crashes with a higher number of vehicles involved are more likely to be reported in both data sources.

The variable day was negative and significant in the first model and positive and significant in the second model. Namely, road users in crashes that are reported to the police during day are less likely to be reported to the hospital, whereas road users in crashes reported to the hospital during day are more likely to be reported to the police as well. Alcohol was found significant with a positive estimate; therefore, road users under the influence of alcohol will have a higher chance of reporting to the emergency room as well.

The coefficient for road users in crashes at intersections was negative and significant in the first model, meaning that road users in crashes that occur on intersections and reported to the police are less likely to be reported also to the hospital relative to crashes that occur on road sections.

The coefficient for road users in crashes that occur at roads with speed limits at or above 100 kilometres per hours turned out to be positive and significant, so relative to road users in crashes that occur on roads with lower speed limits, those in crashes that occur on motorways and are reported to the police have a higher probability of getting reported to the emergency room as well.

The coefficient for multi-lane roads was positive and significant, namely road users in crashes that occur on multi-lane roads and get reported to the police are more likely to get reported also to the hospital in comparison with crashes that occur on one-lane or two-lane roads.

The injury severity degree for the crash involved road user was found significant with positive estimates in both models; thus, the more serious an injury, the higher the likelihood of getting reported to both registers.

Road user trauma type turned out to be related to the probability of getting reported in the two data sources. Road users with head, spine and/or lower extremity injuries that are reported to the hospital have a higher likelihood of being reported also to the police. Crash involved road users with neck damage only have a higher likelihood of being reported to the hospital only.

CONCLUSION

In this paper, we estimated the total number of road users involved in road crashes; the estimate was based on the capture-recapture method. We also estimated a binary probit model to identify which people who reports to both sources and who reports only to one of the sources, police or emergency room.

The total number of road users involved in a road crash at Funen in the study period turned out to be much higher than the police recorded number. The number of fatalities was different in the two registration sources; this could be due to the fact that presumed suicides and sudden diseases before the crash (e.g. stroke) are excluded from the police recordings. In a review by Pompili et al. they found that the literature indicates that above 2% of the traffic crashes are suicide behaviour (Pompili et al., 2012). In a Swedish study from 2008 they found that 4% of fatalities in passenger cars were suicides (Björnstig et al., 2008). The missing registration of fatalies at the emergency room could be because road users who have died in a road crash are taken directly to the mortuary and therefore do not get registered at the emergency room. At last the different numbers in fatalities could be due to the fact that in some cases, the police simply do not know about the crash. As expected many road users with slight injuries or even severe injuries from road crashes only report to the emergency room. In the cases that slightly injured road users only got registered to the emergency room, it could be due to the fact that if a road user has injured the arm or hand in a road crash and nothing else has happened, they turn to the emergency room only and do not find it necessary to involve the police.

In the heterogeneity analysis the age group was found significant in both models and children in the age group 0 to 9 years old had the overall highest reporting rate to the emergency room when reported to the police. This could be due to the fact that children are always passengers that need help to get out of the car and are always taken to a health check at the emergency room after involvement in a road crash. We found a difference for males and females in the reporting rate. From all the road users who reported to the police, female road users had a higher tendency of reporting to the emergency room as well. This could due to the fact that females in general are more aware of their own health. At the same time we found that of all the road users who reported to the emergency room, males had a higher probability of reporting to the police as well, maybe because these road crashes are often more serious.
From the model of reported police cases we see that truck or tractor drivers had a higher chance of reporting only to the police maybe because they are not seriously hurt in the road crash and that most of these road crashes are material damage only. Crash involved vulnerable road users are often more severely hurt and maybe this is why they have a higher probability of getting reported to both sources. Crash involved seatbelt users were found in both models to have a higher probability of getting reported to both sources. This could be due to the fact that seat belt users are more risk aware in general. Moreover, if the road user wears a seatbelt, sometimes it is necessary to cut the car to evacuate him or her and it is possible that the default in this case would be to send the person to the emergency room. The number of motor vehicles involved in a road crash turned out to be positively correlated with the probability of getting reported to both sources. This could be because of the number of people who are involved in the crash. Many intersections road crashes are not very serious because of the low speed and are thus material damage only crashes. Therefore it seems reasonable that from all the crash involved road users who report to the police, those in a crash outside of an intersection had a higher probability of getting reported also to the emergency room. Road users involved in crashed on roads with higher speed limits had a higher probability of getting reported in both sources. This can possibly be explained by the severity of the crash. As expected the severity degree of road users involved in a road crash was found highly significant in both analysis and the probability of reporting to the police and the emergency room increased with the severity degree. Often the police arrive first to the crash site. In this case the police may call an ambulance and may decide which of the involved road users there should be send to the emergency room. That explains for example the fact that road users who have head, spine and/or lower extremity injuries are more likely to have been reported to the police because the police may have seen the injuries and sent the injured road users to the hospital while neck and higher extremity injuries are less visible and may occur several days after the road crash.
Overall it can be concluded that much information about the road crash involved road users is lost when only police recorded road crashes are included in crash modelling and what is even worse the number of severe and slight injuries are highly under-reported by the police. To get

a more correct picture of the amount of road users involved in a road crash in Denmark it is necessary to include other registration sources as well, as for example emergency room data.

REFERENCES

Amoros, E., Martin, J., Laumon, B. (2007). Estimating non-fatal road casualties in a large French County, using the Capture-Recapture method. *Accident Analysis and Prevention*. **39**, 483-490.

Amoros, E., Martin, J., Lafont, S., Laumon, B. (2006). Under-reporting of road crash casualities in France. *Accident Analysis and Prevention.* **38**, 627-635

Aptel, I., Salmi, L. R., Masson, F., Bourdé, A., Hanrion, G., Erny, P. (1999). Road accident statistics: discrepancies between police and hospital data in a French island. *Accident Analysis and Prevention*. **31**, 101-108.

Björnstig, U., Björnstig, J., Eriksson, A. (2008). Passenger car collision fatalities – with special emphasis on collision with heavy vehicles. *Accident Analysis and Prevention.* **40**, 158-166.

Derriks, H. M., Mak, P. M. (2007). Underreporting of road traffic casualties. *IRTAD Special Report*. http://www.internationaltransportforum.org/irtadpublic/pdf/repNDL2007.pdf

Dhillon, P. K., Lightstone, A. S., Peek-Asa, C., Kraus, J. F. (2001) Assessment of hospital and police ascertainment of automobile versus childhood pedestrian and bicyclist collisions. *Accident Analysis and Prevention*. **33**, 529-537.

Elvik, R., Mysen, A. B. (1999). Incomplete Accident Reporting. Meta-Analysis of Studies Made in 13 Countries. *Transportation Research Record*. Paper No. 99-0047.

Hassel, M., Asbjørnslett, B. E., Hole, L. P. (2011). Underreporting of maritime accidents to vessel accident databases. *Accident Analysis and Prevention*. **43**, 2053-2063.

Hels, T., Orozova-Bekkevold, I. (2007). The effect of roundabout design features on cyclist accident rate. *Accident Analysis and Prevention*. **39**, 300-307.

Lateef, M. U. (2010). Estimation of Fatalities Due to Road Traffic Crashes in Karachi, Pakistan, Using Capture-Recapture Method. *Asia Pac J Public Health*. 22/3/332.

Martinez, R., Go, J., Timbang, T. (2012). Capture-Recapture method: Traffic accident estimation along the circumferential road 5, National Capital region, Philippines. *Injury Prevention*. Doi:10.1136/injuryprev-2012-040590w.36.

Meuleners, L. B., Lee, A. H., Cercarelli, L. R., Legge, M. (2006). Estimating crashes involving heavy vehicles in Western Australia, 1999-2000: A Capture-Recapture method. *Accident Analysis and Prevention*. **38**, 170-174.

Miller, T. R., Gibson, R., Zaloshnja, E., Blincoe, L. J., Kindelberger, J., Strashny, A., Thomas, A., Ho, S., Bauer, M., Sperry, S., Peng, J., Singleton, M., Smith, T. J., Zhang, Y. (2012). Underreporting of Driver Alcohol Involvement in United States Police and Hospital Records: Capture-Recapture Estimates. 56th AAAM Annual Conference. 2012 October 14-17.

Morrison, A., Stone, D.H. (2000). Capture-Recapture: a useful methodological tool for counting traffic related injuries? *Injury Prevention.* **6**, 299-304.

Pompili, M., Serafini, G., Innamorati, M., Montebovi, F., Palermo, M., Campi, S.,
Stefani, H., Giordano, G., Telesforo, L., Amore, M., Girardi, P. (2012). Car accidents as a method of suicide: A comprehensive overview. *Forensic Science International.* **223**, 1-9.

Razzak, J. A., Luby, S.P. (1998). Estimating deaths and injuries due to road traffic accidents in Karachi, Pakistan, through the Capture-Recapture method. *International Journal of Epidemiology*. **27**, 866-870.

Reurings, M. C. B., Stipdonk, H. L. (2011). Estimating the Number of Serious Road Injuries in the Netherlands. *Elsevier*. doi10.1016/j.annepidem.2011.05.007.

Roberts, I., Scragg, R. (1994). Application of Capture-Recapture methodology to estimate the completeness of child injury surveillance. *Child health*. **30**, 513-514.

Samuel, J. C., Sankhulani, E., Qureshi, J. S., Baloyi, P., Thupi, C., Lee, C. N., Miller, W. C., Cairns, B. A., Charles, A. G. (2012). Under-reporting of Road Traffic Mortality in Developing Countries: Application of a Capture-Recapture Statistical Model to Refine Mortality Estimates. *Plos One*. Vol. 7, No. 2, e311091.

Salmi, L. R., Puello, A., Bhatti, J. (2012). Feasibility of a road traffic injury surveillance integrating police and health insurance datasets in the Dominican Republic. *Injury Prevention.* Doi:10.1136/injuryprev-2012-040580e.1.

Southwood, T.R.E., Henderson, P. (2000). *Ecological Methods*, 3rd edn. Blackwell Science, Oxford.

Tercero, F., Andersson, R. (2004). Measuring transport injuries in a developing country: an application of the Capture-Recapture method. *Accident Analysis and Prevention*. **36**, 13-20.

Thomas, A. M., Thygerson, S. M., Merrill, R. M., Cook, L. J. (2012). Identifying Work-related Motor Vehicle Crashes in Multiple Databases. *Traffic Injury Prevention*. Vol. 13, No. 4, pp. 348-354.

Tin, S. T., Woodward, A., Ameratunga, S. (2012). Completeness of injury outcome data in cohort of cyclists. *Injury Prevention.* **18(Suppl 1)**, A1-A246.