

**Predicting road casualties in Flanders in relation to an ageing population: combining decomposition and disaggregation**

**Authors:**

Kurt Van Hout, Tom Brijs, Stijn Daniels, Elke Hermans, and  
Geert Wets (corresponding author)  
Transportation Research Institute (IMOB), Hasselt University  
Wetenschapspark 5/6, 3590 Diepenbeek, Belgium  
Fax: +32(0)11 26 91 99  
Tel.: +32(0)11 26 -- -- {91 42; 91 55; 91 56; 91 41; 91 58}  
E-mail: {kurt.vanhout; tom.brijs; stijn.daniels; elke.hermans; geert.wets}@uhasselt.be

**First submitted:** 2012-08-01

**Word counts:**

Abstract	207
Body of paper	5111
Figures (NF*250)	3*250
Tables (NT*250)	2*250
Photographs (NP*250)	0*250
<u>References</u>	<u>924</u>
Total	7492

## **ABSTRACT**

This paper describes an approach to predict casualty rates in the Flanders region of Belgium. The objective of the paper is to demonstrate the strength of the proposed approach that combines the decomposition method with a disaggregate analysis as a prediction approach to study road safety problems. The prediction for the Flanders region will hereby serve as an illustration for this approach.

The evolution of the number of casualties is explained by its components exposure and risk, where exposure is further decomposed into population numbers and the travel patterns of its individuals. Upon the decomposition a disaggregate approach is followed to take into account the various differences in exposure and risk that exist between distinct subgroups.

A reduction of the number of casualties with 57% is found in 2020 compared to 2001. Our approach however also allows to determine the relative contribution of each component to the casualty rate. Because of the different trends in population, exposure and risk, casualty numbers evolve differently for different groups. Therefore their share in the total traffic casualties will change and new target groups for road safety policy emerge. In Flanders older women will be such new target group since it will become one of the most sizeable casualty groups.

## 1 INTRODUCTION

It was shown by [1] that countries that have defined an explicit road safety target have experienced a substantial reduction in road fatalities, through the implementation of concrete actions to improve road safety. However, in order to set realistic road safety targets and to define appropriate measures an adequate insight in long term road safety developments is needed [2,3]. In that respect projections of the expected number of traffic victims are being modeled in several countries [4].

A common practice is to decompose road safety in 2 dimensions: exposure and injury risk [5]. Exposure describes the magnitude of the activity resulting in casualties. It is usually measured in terms of the number of vehicle kilometers or a proxy like population numbers. Risk represents the probability of becoming a road casualty, given a certain level of exposure. Both exposure and risk, however, differ importantly between different subgroups in the population or for different parts of the transportation network [5,6,7]. With respect to age, a U-shaped curve is typically found for the per km-crash involvement where younger and older drivers experience an increased risk compared to the group of middle-aged drivers [8,9,10,11,12,13]. Older persons also show a distinct travel pattern [12,14,15] as they make less and shorter trips. Moreover, especially older women are less likely to possess a drivers' license.

Both exposure and risk evolve over time. As a consequence the number of casualties will change. By decomposing the number of casualties into different dimensions, the impact of each force provides useful information for road safety policy makers. Socio-demographic processes are the driving forces behind changes in population composition and consequently also influence exposure. In addition, these developments are not equal for all subgroups in the population [16,17,18]. For instance, in most western countries populations are ageing. The share of older persons in the total population numbers increases while the number of 25-40-year old decreases. Furthermore, in the future more of the elderly will possess a drivers' license inducing a modal shift.

Safety measures are also often targeted to specific road user groups or parts of the transportation network. It is therefore no surprise that different groups of road users experience different changes in risk [5,19]. In view of these findings it is desirable to analyze and predict the safety and mobility of these specific groups separately. Therefore a more disaggregate approach is required [5].

This paper describes an approach to predict casualty rates in the Flanders region of Belgium. Casualty rates are calculated as the product of exposure and risk, where exposure is obtained from population numbers, disaggregated by age, gender and modal choice, combined with individual travel performance, modeled from travel survey data. This way the effect of an ageing society on road safety can be studied. The focus of the paper will therefore be on demonstrating the strength of the proposed approach that combines the decomposition method with a disaggregate analysis as a prediction approach to study road safety problems. The prediction for the Flanders region will hereby serve as an illustration for this approach.

## 2 BACKGROUND

According to official accident statistics 436 persons were killed on Flemish roads in 2010. Of these deaths, 136 were car drivers, 48 car passengers, 61 cyclists and 57 pedestrians. 96 of them were 65 years or older. 3,879 more persons were seriously injured, 1,012 of them car

drivers, 675 car passengers, 781 cyclists and 388 pedestrians. 541 of the seriously injured were older than 65.

## 2.1 Socio-Demographic Trends

Several socio-demographic trends influence exposure. Since travel characteristics vary with personal attributes such as age, gender, work status and ownership of a drivers' license [13,20,21], changes in the prevalence of these attributes will affect the global amount of distance traveled, even when population numbers remain constant.

Demographic prognoses made by the Research Centre of the Flemish Government indicate that the number of inhabitants in Flanders will increase from just under 6 million in 2000 to over 6,6 million in 2030 [22]. As in most western countries, the Flanders region is also confronted with the challenges of an ageing society since the share of elderly will continue to increase [23].

Since more young people take up higher education, they enter the workforce at a higher age. At the other end of the age spectrum, people are encouraged to work longer. Furthermore, women entered the workforce later in history. As a consequence the activity rate of older women is still much lower than that of men of comparable age [24]. In the future more women will participate in the workforce and the activity rate will increase more compared to men where the activity rate is already high.

A similar phenomenon appears with the possession of a drivers' license. As the percentage of men owning a license is already high for all ages, little changes are to be expected in the future. Less women own a drivers' license [25]. The difference is particularly profound at higher age. However, since older cohorts with a lower possession rate are gradually replaced by younger cohorts with a higher possession rate the share of women owning a drivers' license will gradually increase in the future.

## 2.2 Decomposition And Disaggregation

In road safety research a decomposition of the road casualty problem into the components exposure and risk is not new. Oppe developed a framework to analyze the relationship between exposure and risk that is based on learning theory [26]. For exposure, he uses a logistic function of time with its characteristic S-shaped form. Risk is assumed to decrease exponentially over time. The number of casualties is then modeled as the product of exposure and risk [27].

Aggregate models relate the number of accidents or fatalities to some general exposure measure [3]. Several authors used vehicle kilometers as exposure measure [28], while other authors used an approximation such as fuel consumption or population numbers [29]. Overall numbers (of road safety or mobility) however do not give a true understanding of the nature of the influence of mobility on road safety [18], because average numbers hide significant differences. Although aggregate models can be used to describe general trends, they are unable to represent changes caused by modal shift or by different evolutions within specific sub-groups of the population. In this case, disaggregate modeling is more appropriate [5], stratifying by characteristics such as infrastructural differences, time of day, age and gender.

Stipdonk et al [19] stipulate that there are two arguments in favor of projecting stratifications as compared to just fitting a simple negative exponential trend to the sum directly [19]. Firstly, stratification enables using data on distance travelled, stratified by traffic mode or

other characteristics like age, gender or part of the road network. Secondly, differences in casualty rate trends can be taken into account when calculating the expected number of casualties. Stratification also enables to add explanatory factors that relate to a specific subgroup.

A further improvement of road safety forecasts involves including explanatory factors (such as safety measures, demographic changes or weather influence) [19]. These explanatory variables will replace part of the obscure and unexplained trend.

Stratifying exposure data is however not done easily. In fact, the lack of sufficient data often induces the use of general exposure measures [18]. Indeed, stratification requires more detailed data than is often available. The use of travel survey data can then help to gain insight in the relation between mobility and road safety [27].

### 3 STUDY DESIGN

The total number of persons killed or seriously injured in a road crash (KSI) is calculated by following formula in which  $P_{a,g,c}$  represents the number of persons of age  $a$ , gender  $g$  and personal characteristics  $c$  including work status, possession of a drivers' license and hometown.  $D_{a,g,m,c}$  stands for the distance traveled by a person of age  $a$ , gender  $g$  and personal characteristics  $c$  by travel mode  $m$ .  $R_{a,g,m}$  finally is the injury risk faced by a person of age  $a$ , gender  $g$  while traveling with mode  $m$ . The different factors will be further elaborated in the following section.

$$KSI = \sum_{a,g,m,c} P_{a,g,c} * D_{a,g,m,c} * R_{a,g,m}$$

In this paper the number of persons killed or seriously injured in road crashes in Flanders is estimated up to 2020. Exposure is calculated on an individual level. In order to reduce calculation time a 1% sample is taken from the population data gathered in the socio-economic survey of 2001, containing information on the almost 6 million inhabitants of the Flemish region. In SAS Enterprise Guide a simple random sample without replacement is drawn from these data, stratified by age group (5 years) and gender. The result is a sample of 59,703 persons. Population level values are then obtained by adding weight factors to each individual in the sample.

Exposure itself is the product of population numbers and personal travel performance which is defined as the distance traveled by a person with certain characteristics (age, gender, work status, hometown, etc.) by traffic mode. Changes in exposure will reflect changes in population numbers, population characteristics and personal travel performance. The changes will be implemented in consecutive steps. This will allow us to study the effect of each of the included parameters separately.

#### 3.1 Updating The Population

Changes that are included in this study are (1) demographic changes (population numbers in relation to age, gender and hometown), (2) work status (the share of employed, unemployed, students and other inactive persons) and (3) changes in drivers' license ownership. External forecasts are used to simulate the first two socio-demographic processes (section 3.1.1), while drivers' license ownership is modeled from Flemish travel survey data (section 3.1.2).

##### 3.1.1 Socio-Demographic Change

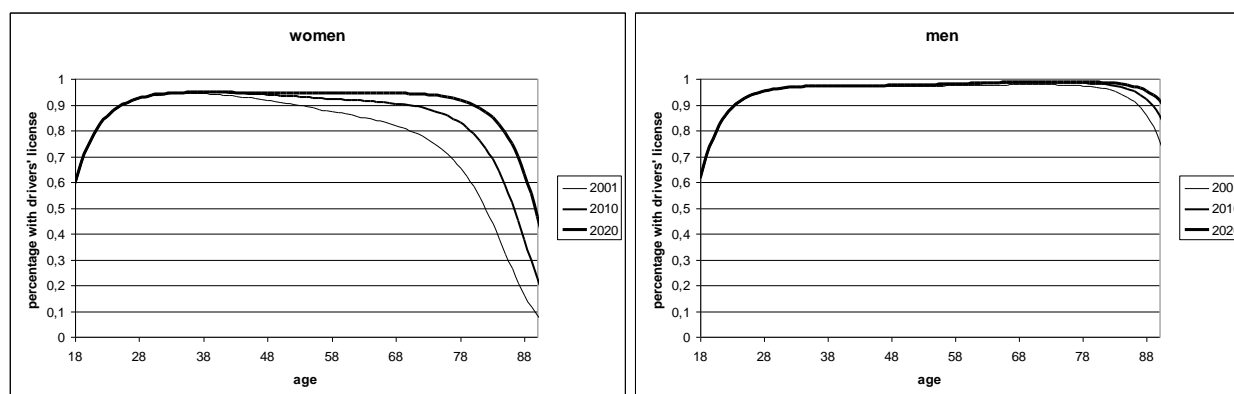
Demographic changes are incorporated by adjusting the weight factors of the sample according to the existing population forecasts by the Research Centre of the Flemish Government. These population forecasts are available disaggregated by age, gender and hometown. In a next step evolutions in the activity rate per age group (adapted by the policy research centre WAV from the survey on the labor force) are included in the population forecasts [30]. The activity rate is the proportion of employed and unemployed persons compared to the total population (also including the professionally inactive part among which students, pensioners, house wives and disabled people) of the same age group. This information is again implemented by adjusting the weight factors in such a way that total population numbers by age, gender and hometown remain unchanged. The activity rate is available disaggregated by gender and 5-year age groups.

The number of people aged 55 and older increases, while the population between 25 and 40 years old shrinks. Because older persons are less likely to be active on the labor market and to own a license, demographic changes alone will lead to a global decreasing activity rate and drivers' license ownership. When also work status is updated the average activity rate of women will increase, while that of men still slightly decreases.

### *3.1.2 Drivers' License Ownership*

The socio-economic survey does not contain any information on drivers' license ownership. The increasing possession of a license is therefore added to the population sample as the probability that a person owns a license. This probability is modeled from the data in the Flemish travel surveys that were carried out in 1994, 2000, 2007, 2009 and 2010 and it depends on personal characteristics (age, gender, work status) and location of hometown (or its urban character) [30]. Apart from age, time has two other aspects that will influence the probability of having a license. The first aspect is the generation effect. People that are born in the same period share a similar history which will influence some of their characteristics. It is defined by the year of birth of that person. The second one is the period effect. This factor is linked primarily to the demand side of the transportation system. For instance, the presence of public transportation, the cost of owning a car and spatial planning will influence the likelihood of a drivers' license. These cohort effects clearly reflect in the drivers' license ownership among women in Flanders between 2000 and 2010 [30]. Where for women younger than 55 years the license rates are fairly constant, the license ownership of older women is increasing significantly as younger cohorts with higher licensure rate replace gradually the older cohorts.

This evolution is expected to continue in the future. To include this evolution in the population forecast a model was built to predict the license rate for future years as a function of the explanatory variables the time effects age, year of birth and year of survey and the personal characteristics gender, work status and urbanization of the hometown. Since license ownership is a binary variable a binary logit model is used. In order to capture the inverse U-shape of license ownership by age, a 4<sup>th</sup> order multinomial is used. This also results in a smooth curve opposed to the results that are found when a categorical variable is used for age. A categorical variable leads to discontinuities around its border values. Due to cohort effects this then causes irregularities in predicting license ownership. It is further assumed that license rates do not decrease over time. The resulting license rates clearly show a distinct increase for older women, while for men the differences are limited (figure 1).



**FIGURE 1 Evolution of drivers' license ownership for working people not living in a big city as a function of age**

Source: adapted from [30]

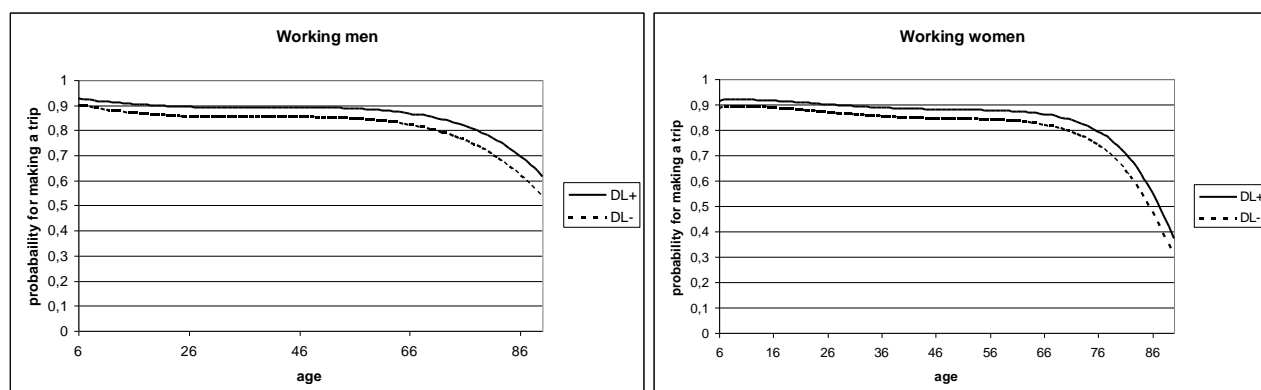
Integrating these model results in the population forecasts leads to a very slight increase of license ownership for men aged 18 or more from 90% in 2001 to 92% in 2020. For women the increase is much more substantial. 71% of all women of 18 years and older owned a license in 2001. In 2020 the percentage climbs to 81% because of the younger cohorts gradually replacing the older cohorts.

### 3.2 Exposure Trends

The development of the exposure on population level is explained by the evolution of the population numbers and the changes in the travel patterns of the individuals. For that purpose the individual travel performance is modeled from the data gathered in the aforementioned travel surveys and linked to the persons in the 1% sample. In a first step the probability that a certain person makes at least one trip during the day is modeled. In the second step a model is built to determine the distance traveled by different traffic modes. In the third step the travel performances of the individuals from the sample are multiplied with the weights accorded to them. These weights evolve over time and represent the socio-demographic changes that occur.

#### 3.2.1 Probability Of Trip Making

The probability that a certain person makes at least one trip during a day is modeled by a binary logit model. Age, year of birth, work status and possession of a drivers' license show a significant influence on the probability of carrying out a trip. The results indicate that the likelihood of making a trip is fairly constant over a broad age range. Only people over 70 years old are less likely to travel (figure 2). Working men and women are also more likely to undertake at least one trip compared to inactive and unemployed people. License ownership is also related to more frequent trip making.



**FIGURE 2** Probability of making at least one trip per day as a function of age for working men and women, with (DL+) or without (DL-) a drivers' license  
 Source: adapted from [30]

### 3.2.2 Travel Distance

For those persons who made at least one trip, the distance traveled per day as a car driver, car passenger, cyclist or pedestrian is modeled as a function of the aforementioned variables. The travel surveys contain too little information on journeys with other travel modes to derive accurate models on the required level of disaggregation. Neither do they contain information about children younger than 6 years old. Therefore these young children are also excluded from further analysis. Age, gender, work status, possession of a drivers' license and the degree of urbanization all play a distinct role in predicting the distance traveled by an individual per day. Changes in the prevalence of these variables will therefore also change exposure. Furthermore the variables will influence the travel distances differently for the distinct travel modes, therefore also influencing the modal split.

### 3.2.3 Population Level Exposure

By multiplying the travel distance with the weights accorded to the individuals from the sample and sum these results over subpopulations stratified by gender, age group and traffic mode the exposure for each of these groups is calculated. The global distance traveled as a car driver increases with 8.4% in 2020 compared to the base year 2001 (table 1). Distances traveled as car passenger, cyclist and pedestrian increase with 6.8%, 7.3% and 9.3% respectively. However, large differences exist between the various subgroups. In the age group of 35-44 year old, we find that fewer kilometers will be traveled in 2020 than in 2001, mainly due to the falling population numbers. In the age group of the 65-74 year old however the distance traveled increases. A modal shift also occurs since the distances traveled by the distinct traffic modes evolves differently too. This modal shift will be the most profound for older women.



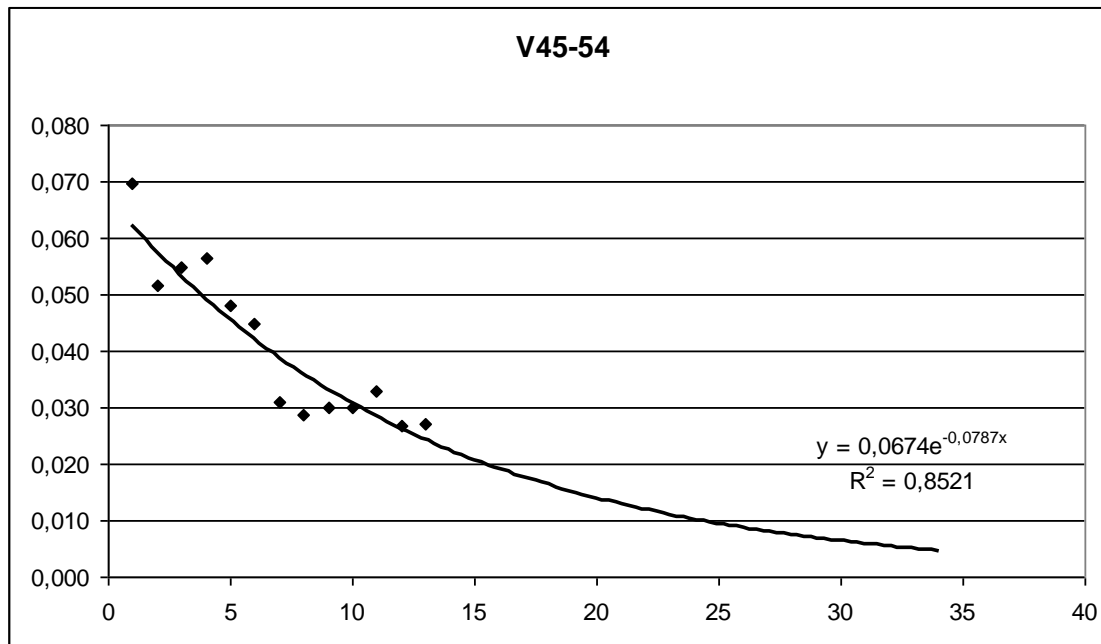
**TABLE 1 Relative increase of distance traveled by traffic mode, age and gender**  
Source: adapted from [30]

	Total	Age: 35-44		Age: 65-74	
		Men	Women	Men	Women
<b>Car driver</b>	+8.4%	-12.8%	-5.3%	+32.0%	+73.5%
<b>Car passenger</b>	+6.8%	-12.2%	-9.9%	+24.2%	+18.3%
<b>Cyclist</b>	+7.3%	-12.8%	-11.3%	+23.7%	+7.1%
<b>Pedestrian</b>	+9.3%	-10.8%	-12.4%	+25.3%	+15.2%

### 3.3 Risk

In the previous section the exposure measure was determined and can be stratified according to gender, age and travel mode. For the period 1997-2009 the numbers of killed and seriously injured road users are available from Statistics Belgium and can be stratified by the same variables.

For the period 1997-2009, injury risk is calculated as the yearly number of casualties (killed or seriously injured) divided by the calculated yearly exposure, both stratified by age group, gender and travel mode. In accordance with Oppe [28], the resulting time series are then extrapolated to 2010-2020 following an exponential regression curve (figure 3), giving the estimates for future injury risk. By multiplying for each year the extrapolated risk with the calculated exposure for that subgroup we get the prediction for the number of killed and seriously injured road users in that group between 2010 and 2020. The total number of traffic victims is then simply the sum of the victims in each subgroup.



**FIGURE 3 Extrapolation of risk for car drivers (women aged 45-54; 1997-2020)**  
Source: adapted from [30]

#### 4 CASUALTY FORECAST

Due to data limitations the results from this paper are restricted to the four traffic modes described earlier. Data on children younger than 6 years are also not included in the analysis. All results must therefore be considered within these limitations.

The expected number of road users killed or seriously injured in traffic accidents will be 57% lower in 2020 compared to 2001 (table 2). This decrease is mainly caused by a generally falling casualty rate. Indeed, when risk is assumed constant at the 2001 level a mild increase with 8% in the number of victims is expected (table 2). This is slightly less than the predicted population growth of 10% but in line with the expected increase in distance traveled.

These general figures hide however substantial differences. Both exposure and casualty risk evolve differently according to age, gender and traffic mode. Exposure is to a large extent influenced by population changes. Contrary to the increase of the total population the age group of 25-44 year old inhabitants will diminish in the nearby future, while a significant increase is expected for people aged 55 or older. Changes in work status also contribute to changes in exposure since the individual travel performance depends on this status. Working people are in general more likely to undertake a journey and travel more by car and less as a pedestrian. Since working status will change most for older women (more than a doubling of the share of working women aged 60-64 is expected), its effect on exposure will be most profound in this age group. A last variable that was considered is the increasing drivers' license ownership, increasing the likelihood of a journey and the distance traveled as a car driver but decreasing the distance traveled as a passenger or a cyclist. Again its effect is most distinct for older persons, especially for women.

At the same time a decrease in risk is found for most subgroups. This trend seems to be most clear for car occupants. In fact, pedestrians have benefited least from the general increase in road safety and in some cases trends are even slightly increasing (e.g. among women in the age groups 25-34 and 65-74 the risk tends to increase). The same is true for cyclists (risk increases for men aged 25-34 and for women aged 75 and older). Although differences exist, no clear influence of gender or age on risk evolution is found.

As a consequence of these inequalities the number of casualties in the distinct subgroups will change differently. In order to estimate the impact of the factors separately, the number of casualties is predicted in four successive steps where each factor is added on at a time. The results are summarized in table 2. In the first step only demographic changes are included in the population forecast. The resulting change in casualty numbers compared to the 2001 level is given in the column DEMO. In the second step the expected changes in work status are added to the population forecast and its combined effect on casualty numbers is calculated. The results for some groups are presented in column SOCIO of table 2. The third step involves adding the changing licensure rate to the population forecast. The results are given under column DL. In the three previous steps the number of casualties is calculated with the constant risk of 2001. Therefore, the changing risk is used to calculate the casualty numbers in the fourth and final step. The exposure used in this step is the same as the one used in step 3. The results are shown in table 2 under the column RISK.

The results in table 2 make clear that all factors (demographics, work status, drivers' license, risk) included in the study will influence the prediction results. In view of the significant

differences that exist between different groups in the total population considering exposure and risk trends, the followed disaggregate approach seems appropriate.

The decreasing number of casualties is only possible when the injury risk will continue to fall. The expected changes in exposure will in fact cause a slight increase in the number of casualties. But even the inclusion of other than demographic variables will influence the results. This is especially clear with women. When only demographics are included an increase of 6% casualties among women is expected. When also the increasing activity rate and possession of a drivers' license is included the increase doubles to 12%. For men the effect of these additional variables is less obvious, mainly because of the relative small differences that exist between different age groups and the relative small changes that are expected for the extra variables.

Not only the extended decomposition into different components proves useful, also the disaggregate approach used in this study delivers results that cannot be obtained by a more aggregate method. Different casualty reductions are found for men compared to women, for different age groups and for different travel modes. Furthermore different groups are influenced differently by the included factors. The effect of activity rate and drivers' license on the number of casualties is not only larger for women than for men, it is also bigger for older persons. The augmented share of persons that work and own a drivers' license will also cause the number of car driver casualties to be higher than expected based on the basic demographic forecasts. Therefore the decision to (not) include these factors will influence the results in a distinct way for the different groups.

**TABLE 2 Prediction of the number of road users killed or seriously injured in crashes (KSI) in 2020 compared to 2001 when only demographic change is accounted for (DEMO), when also work status is accounted for (SOCIO), when also possession of drivers- license is accounted for (DL) and when also changes in risk are accounted for (RISK)**

Source: adapted from [30]

		<b>KSI 2001</b>	<b>DEMO</b>	<b>SOCIO</b>	<b>DL</b>	<b>RISK</b>
<b>Total</b>	<b>Men</b>	2,879	+5%	+5%	+5%	-57%
	<b>Women</b>	1,766	+6%	+8%	+12%	-57%
<b>35-44</b>	<b>Men</b>	437	-13%	-13%	-13%	-62%
	<b>Women</b>	253	-11%	-8%	-7%	-72%
<b>65-74</b>	<b>Men</b>	209	+27%	+27%	+28%	-39%
	<b>Women</b>	193	+15%	+15%	+25%	-26%
<b>75+</b>	<b>Men</b>	169	+44%	+44%	+47%	-38%
	<b>Women</b>	148	+21%	+21%	+41%	-7%
<b>Car driver</b>		2375	+2%	+4%	+7%	-76%
<b>Car passenger</b>		891	+4%	+4%	+5%	-64%
<b>Cyclist</b>		945	+13%	+13%	+10%	-23%
<b>Pedestrian</b>		433	+12%	+12%	+13%	-13%

Since the number of casualties evolves differently according to age, gender and travel mode, the share of the distinct subgroups will also change in the future. Where nowadays young males (16-24) make out the largest group of victims, their share gradually diminishes while the share of 25-34 year old males remains constant hereby becoming the largest group of victims in

2020. Women aged 65 or older make out a little over 7% of the traffic victims in 2001. Their share will however double in 2020 making them a new important target group for policy measures.

In 2001 car occupants make out 70% of the casualties. In 2020 their share falls below 50%. The share of cyclists however almost doubles from 20% in 2001 to 37% in 2020. The share of pedestrians also doubles from 9% to 19% in the same time span. This again urges for a renewed attention for these vulnerable road users.

## 5 DISCUSSION

### 5.1 Methodology

The evolution of the number of casualties is explained by its components exposure and casualty rate. In addition to former studies where exposure itself is modeled as a time series [5,28], exposure is in this study further decomposed into population numbers (including its characteristics) and the travel patterns of its individuals. This enables including new explanatory parameters in casualty forecasting such as demographic change and changes in travel preferences of certain groups. In this way the effect of changes in the explanatory mechanisms on mobility can be modeled instead of using trend analysis on the mobility itself. A further integration of this approach in traffic models will create extra possibilities towards spatial and temporal disaggregation of exposure and risk which has been disregarded in this study. This might be interesting when studying the impact of an ageing society on road safety because of the differences in travel patterns of older persons [12,14,15]. In that respect Kam [31] points to the differences in accident risk at different road types. Changes in road use will therefore also influence general risk.

The injury risks for the different subgroups on the other hand are extrapolated by a simple exponential regression as proposed by Oppe [28], although more sophisticated methods exist for trend analysis. In this regard, a trend analysis is not always a suitable tool to predict the future [32]. More advanced methods that fit the data better are however not necessarily more useful for predicting future trends than the simple trends lines that are used in our study.

Upon the decomposition a disaggregate approach is followed as recently promoted by Stipdonk et al [19]. Exposure is hereby disaggregated on the individual level while casualty rate is disaggregated on the level of subpopulations (by gender, age and traffic mode). Stipdonk et al [19] consider two indications to decide on stratifications: (1) crash groups with different developments of the crash rates over time and (2) crash groups with different crash rates, combined with different development of the mobility between different crash groups over time. The results show, consistent with [2], that both casualty rate, risk evolution and mobility development show important differences between the subgroups. The disaggregate approach therefore proves to be useful.

Two conditions have to be met however: (1) stratified mobility data have to be available and also (2) a sufficient number of crash data. The first condition is fulfilled by combining population data with travel survey data. Because the travel surveys give too little information on less used travel modes such as motorized two-wheelers and public transportation, our study was limited to four modes: car driver, car passenger, cyclist and pedestrian. Stipdonk et al [19] suggest in this respect to project the total number of casualties for the other traffic modes. On the

second condition they state that even when stratification results in small numbers with high variance, it will still enable an improvement of the prognosis.

## 5.2 Results

The total number of traffic casualties is expected to decrease with 57% in 2020 compared to 2001. The number of traffic casualties aged 65 or older however will only decrease with 29% in that period. When risk is held constant, an increase of the total number of casualties with 8% respectively 34% is found. Other authors [33,34] predicted the number of older casualties assuming a constant risk (per licensed driver or per kilometer traveled). Lyman et al [33] found for all ages an increase of the number of drivers involved in police reported crashes with 34% and with 39% for fatal crashes between 1999 and 2030. For drivers aged 65 or older the increase is estimated at 178% respectively 155%. Their prognosis compares with the increase we found for the exposure as a car driver for these age groups, ranging from an increase between 52% for men aged 65-74 and 275 for women aged 75 or older. Burkhardt & McGavock [34] found the number of older casualties to triple over a period of 30-40 years, again assuming constant risk. The increase was assumed to follow the increased exposure because of the increasing number of license holders, increased number of trips and increased trip length and was estimated to grow with 465% for drivers aged 65 or older, which is significantly higher than the increase in exposure we found.

Although these general figures are useful for road safety policy, our approach offers other possibilities to improve road safety policy. The decomposition of the number of casualties into population, travel behavior and risk enables to measure the relative contribution of each component to the casualty rate. We find e.g. that changes in exposure are largely dictated by changes in demographics. Nevertheless other evolutions will influence exposure and therefore the number of casualties. Changes in work status and drivers' license ownership contribute e.g. significantly to changes in exposure for older persons. This particularly is the case for older women. It clearly shows that measures in other policy domains will also influence road safety and that projections of the number of casualties should not be based only on population numbers. From the results we also learn that the number of casualties will only decrease when measures are taken that continue to reduce the accident risk. When risk stagnates and only socio-demographic changes are included, the number of casualties will in fact increase.

The results of this study confirm the existence of considerable differences in exposure and risk between the different population groups as found in other studies (e.g. [19]). Because differences in risk exist between different groups, changes in the composition and characteristics of the population will reflect in general risk, even when risk for all subgroups is held constant. The number of casualties may therefore be influenced by systemic changes [35] and is not only affected by the introduction of road safety plans.

Because of the different trends in population, exposure and risk, casualty numbers evolve differently for different groups. Therefore their share in the total traffic casualties will change and new target groups for road safety policy emerge. Our disaggregate approach is very useful to bring forward these shifts. Older women will in the future become one of the most sizeable groups in road safety policy. Specific measures to tackle this problem will be required since their problems differ from those experienced by younger road users that form the main target for policy at present.

## 6 LITERATURE

- [1] Wong, S.C. and N.N. Sze. Is the effect of quantified road safety targets sustainable? *Safety Science*, Vol. 48, 2010, pp. 1182-1188.
- [2] Wesemann, P., Y. van Norden and H. Stipdonk. An outlook on Dutch road safety in 2020; future developments of exposure, crashes and policy. *Safety Science*, Vol. 48, 2010, pp. 1098-1105.
- [3] COST 329. *Models for traffic and safety development and interventions*. Directorate General for Transport, European Commission, 2004.
- [4] Martensen & Dupont (Eds.). *Forecasting road traffic fatalities in European countries: model and first results*. Deliverable 4.2 of the EC FP7 project DaCoTA, 2010.
- [5] Van den Bossche, F., G. Wets and T. Brijs. Analysis of road risk per age and gender category: a time series approach. *Proceedings of the 86<sup>th</sup> Annual Meeting of the Transportation Research Board*, Washington, D.C., 2007.
- [6] Factor, R., D. Mahalel and G. Yair. Inter-group differences in road-traffic crash involvement. *Accident Analysis and Prevention*, Vol. 40, 2008, pp. 2000-2007.
- [7] Beck, L.F., A.M. Dellinger and M.E. O'Neil. Motor Vehicle Crash Injury Rates by Mode of Travel, United States: Using Exposure-Based Methods to Quantify Differences. *American Journal of Epidemiology*, Vol. 166 (2), 2007, pp. 212-218.
- [8] Massie, D.L., K.L. Campbell and A.F. Williams. Traffic accident involvement rates by driver age and gender. *Accident Analysis and Prevention*, Vol. 27, 1995, pp. 73-87.
- [9] Evans, L. Risks older drivers face themselves and threats they pose to other road users. *International Journal of Epidemiology*, Vol. 29, 2000, pp. 315-322.
- [10] Davidse, R.J.. *Ouderen achter het stuur. Identificatie van aandachtspunten voor onderzoek*. SWOV-rapport D-2000-5. SWOV, 2000.
- [11] Ryan, G.A., M. Legge and D. Rosman. Age related changes in drivers' crash risk and crash type. *Accident Analysis and Prevention*, Vol. 30, 1998, pp. 379-387.
- [12] Langford, J. and S. Koppel. Epidemiology of older driver crashes – Identifying older driver risk factors and exposure patterns. *Transportation Research Part F*, Vol. 9, 2006, pp. 309-321.
- [13] Whelan, M., J. Langford, J. Oxley, S. Koppel and J. Charlton. *The elderly and mobility: A review of the literature*. Monash University Accident Research Centre, 2006.

- [14] Fildes, B., B. Corben, S. Kent, J. Oxley, T. Minh Le and P. Ryan. *Older road user crashes*. Monash University Accident Research Centre, 1994.
- [15] Van Hout, K. and T. Brijs. *Ouderen en verkeersveiligheid. Een probleemanalyse*. Steunpuntrapport RA-MOW-2009-014. Steunpunt Verkeersveiligheid, 2009.
- [16] Hjorthol, R.J., L. Levin and A. Sirén. Mobility in different generations of older persons. The development of daily travel in different cohorts in Denmark, Norway and Sweden. *Journal of Transport Geography*, Vol. 18, 2010, pp. 624-633.
- [17] Ferguson, S.A., E.R. Teoh and A.T. McCartt. Progress in teenage crash risk during the last decade. *Journal of Safety Research*, Vol. 38, 2007, pp. 137-145.
- [18] Stipdonk, H. and E. Berends. Distinguishing traffic modes in analysing road safety development. *Accident Analysis and Prevention*, Vol. 40, 2008, pp. 1383-1393.
- [19] Stipdonk, H., P. Wesemann and B. Ale. The expected number of road traffic casualties using stratified data. *Safety Science*, Vol. 48, 2010, pp. 1123-1133.
- [20] Bush, S. *Forecasting 65+ Travel: An Integration of Cohort Analysis and Travel Demand Modeling*. Massachusetts Institute of Technology, 2003.
- [21] Janssens, D., M. Cools, W. Miermans, K. Declercq and G. Wets. *Onderzoek Verplaatsingsgedrag Vlaanderen 4.2 (2009-2010). Verkeerskundige interpretatie van de belangrijkste tabellen (Analyserapport)*. IMOB, 2011.
- [22] Willems, P., E. Pelfrene, C. Van Peer and E. Lodewijckx. *Metadata bij de 'SVR-Bevolkingsprojecties 2009-2030'*. Studiedienst van de Vlaamse Regering, 2011.
- [23] Pelfrene, E.. *Ontgroening en vergrijzing in Vlaanderen 1990-2050. Verkenningen op basis van de NIS-bevolkingsvooruitzichten*. Ministerie van de Vlaamse Gemeenschap, Afdeling Planning en Statistiek, 2005.
- [24] Marissal, P., P. Medina Lockhart, C. Vandermotten and G. Van Hamme, G. m.m.v. C. Kesteloot. *De socio-economische structuren van België. Exploitatie van de gegevens over de werkgelegenheid van de socio-economische enquête van 2001*. FOD Economie, K.M.O., Middenstand en Energie, 2006.
- [25] Van Hout, K. and T. Brijs. *De invloed van de vergrijzing op de verkeersveiligheid. Toekomstige populatiekenmerken*. Steunpunt Verkeersveiligheid, 2011.
- [26] Van den Bossche, F.A.M., K. Vanhoof, G. Wets and T. Brijs. Macroscopic road safety modeling: a state space approach applied to three Belgian regions. In: Sloboda, B.W. (ed). *Transportation Statistics*, 2009.

- [27] Van den Bossche, F., G. Wets and T. Brijs. *The use of travel survey data in road safety analysis*. Steunpuntrapport RA-2005-72. Steunpunt Verkeersveiligheid, 2005.
- [28] Oppe, S. Macroscopic models for traffic and traffic safety. *Accident Analysis and Prevention*, Vol. 21, 1989, pp. 225-232.
- [29] Van den Bossche, F. and G. Wets (2003). *Macro Models in Traffic Safety and the DRAG Family: Literature Review*. Steunpuntrapport RA-2003-08. Steunpunt Verkeersveiligheid, 2003.
- [30] Van Hout, K. and T. Brijs. *De invloed van de vergrijzing op de verkeersveiligheid. Een prognose van het aantal doden en zwaargewonden in 2030*. Steunpuntrapport RA-MOW-2011-026. Steunpunt Verkeersveiligheid, 2012.
- [31] Kam, B.H. A disaggregate approach to crash rate analysis. *Accident Analysis and Prevention*, Vol. 35, 2003, pp. 693-709.
- [32] Elvik, R. The stability of long-term trends in the number of traffic fatalities in a sample of highly motorised countries. *Accident Analysis and Prevention*, Vol. 42, 2010, pp. 245-260.
- [33] Lyman, S., S.A. Ferguson, E.R. Braver and A.F. Williams. Older driver involvements in police reported crashes and fatal crashes: trends and projections. *Injury Prevention*, Vol. 8, 2002, pp. 116-120.
- [34] Burkhardt, J.E. and A.T. McGavock. Tomorrow's Older Drivers. Who? How Many? What Impacts? In *Transportation Research Record: Journal of the Transportation Research Board*, No 1693, Transportation Research Board of the National Academies, Washington, D.C., 1999, pp. 62-70.
- [35] Bhalla, K., M. Ezzati, A. Mahal, J. Salomon and M. Reich. A Risk-Based Method for Modeling Traffic Fatalities. *Risk Analysis*, Vol. 27 (1), 2007, pp. 125-136.