Assessing the impact of road safety policy measures in Flanders: modelling approach and application

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Titel **Impact van verkeersveiligheidsmaatregelen in Vlaanderen: methodologie en toepassing**

Samenvatting

Gedurende de voorbije decennia zijn er wereldwijd heel wat initiatieven ondernomen om de verkeersonveiligheid terug te dringen. Maar ondanks deze inspanningen blijft het aantal ongevallen en verkeersslachtoffers onverantwoord hoog. Om de verkeersveiligheid te verhogen worden daarom doelstellingen vooropgesteld en maatregelen genomen. De vooropgestelde reductie van het aantal verkeersongevallen en –slachtoffers binnen een bepaalde tijdspanne werkt vaak als een extra motivatie voor de betrokken partijen om nog bijkomende inspanningen te leveren en een concreet verkeersveiligheidsprogramma op te stellen en acties te ondernemen.

Om de vooropgestelde doelstellingen in Vlaanderen te bereiken, heeft de Vlaamse overheid een Verkeersveiligheidsplan Vlaanderen (Departement Mobiliteit en Openbare Werken, 2008) opgesteld waarin 33 verkeersveiligheidsmaatregelen werden voorgesteld. Deze beleidsaanpak moet er voor zorgen dat het aantal doden en zwaargewonde verkeersslachtoffers teruggedrongen wordt tot een maximum van 250 doden en 2 000 zwaargewonden tegen 2015 (Departement Mobiliteit en Openbare Werken, 2008). In 2020 zouden deze aantallen nog verder gedaald moeten zijn tot 200 doden en 1 500 zwaargewonden (Vlaanderen in Actie, 2011).

In dit onderzoek wordt een model voor Vlaanderen ontwikkeld dat ons in staat stelt om het effect op de verkeersveiligheid in Vlaanderen te kwantificeren wanneer we een set van regionale en lokale maatregelen doorrekenen. De methodologie draagt er toe bij dat enerzijds inzicht verkregen wordt in de mate waarin de voorgestelde maatregelen bijdragen tot het bereiken van de vooropgestelde verkeersveiligheidsdoelstellingen en dat anderzijds maatregelen tegenover elkaar kunnen afgewogen worden.

Meer concreet worden in dit Vlaamse rekenmodel op een stapsgewijze manier de effecten van een maatregelenpakket doorgerekend. De toepassing richt zich op een set van zes verkeersveiligheidsmaatregelen uit het Verkeersveiligheidsplan Vlaanderen (Departement Mobiliteit en Openbare Werken, 2008) die op regionale of lokale schaal op wegvakken geïmplementeerd worden. Bovendien wordt er een uitsplitsing gemaakt naar drie wegtypes: autosnelwegen, gewestwegen en gemeentewegen. De methodologie bestaande uit 5 stappen is gebaseerd op Reurings et al. (2009). (1) In de eerste stap van het model wordt de verkeerssituatie en de verkeersveiligheidssituatie in het referentiejaar (2007) beschreven. (2) Daarna wordt de baselineprognose uitgewerkt waarin het aantal letselongevallen, doden, zwaar- en lichtgewonden berekend wordt voor de periode 2008 tot 2015 wanneer er enkel rekening wordt gehouden met de veranderingen van de verkeersprestatie en de autonome verandering van het risico. (3) In de maatregelprognose worden, naast deze twee aspecten, ook de effecten van het maatregelpakket in rekening gebracht. (4) Dit leidt tot een voorspelling van het aantal bespaarde letselongevallen, doden en zwaar- en lichtgewonde slachtoffers op wegvakken in Vlaanderen in 2015 berekend in geval een maatregelpakket (bestaande uit zes maatregelen) wordt geïmplementeerd tussen 2008 en 2015. (5) Op basis van de besparingen en de investeringskosten wordt een kosten-batenanalyse geïllustreerd.

Graag willen we benadrukken dat de beschrijving van de methodologie en de inventarisatie van de datanoden de belangrijkste focus van deze studie is. Daarnaast wordt in dit rapport het model zo goed mogelijk geïmplementeerd aan de hand van een illustratie die gebaseerd is op de meest recente datasets die ter beschikking waren toen de studie van start ging (eind 2010). Omdat de resultaten van deze illustratieve doorrekening sterk beïnvloed worden door de vele aannames die (moeten) gebeuren doorheen het rekenproces, willen we extra benadrukken dat de bekomen resultaten enkel een richting aangeven en zeker geen enkele getalmatige waarde hebben. De illustratie is dus een ‘proof of concept’.

In het algemeen kunnen we besluiten dat dit rekenmodel veel mogelijkheden biedt voor beleidsmakers om hun beleid te optimaliseren en af te stemmen op de vooropgestelde verkeersveiligheidsdoelstellingen. Ondanks de relatief ver gevorderde uitwerking van het model zijn er enkele aspecten waarmee men rekening dient te houden bij toekomstig onderzoek en gebruik. Hierbij denken we aan het hoge detailniveau van de gebruikte datasets, de gedetailleerde beschrijving van de geplande maatregelen, de beperkte beschikbaarheid van (gedetailleerde) Vlaamse informatie over de effectiviteit van maatregelen en het ongevallenprofiel. Eén van de grote uitdagingen voor deze methodologie zou de implementatie zijn in een GIS-applicatie.

English summary

In the last few decades, many initiatives were taken world-wide to reduce traffic unsafety. However, in spite of these efforts the number of accidents and traffic casualties remains inordinately high. Therefore targets are set and measures are taken to increase traffic safety. The aimed reduction of the number of traffic accidents and casualties within a certain time frame often constitutes an extra motivation for concerned parties to make additional efforts and draw up a concrete road safety plan and take action.

To meet the targeted objectives in Flanders, the Flemish government has formulated the Road Safety Plan Flanders (Department Mobility and Public Works, 2008) in which 33 road safety measures were presented. This policy has to ensure that the number of fatalities and seriously injured are pushed back to a maximum of 250 fatalities and 2,000 seriously injured in 2015 (Department Mobility and Public Works, 2008). In 2020, these numbers have to be reduced even further to 200 fatalities and 1,500 seriously injured (Flanders in Action, 2011).

In this research, a model for Flanders is developed which enables us to quantify the impact on traffic safety in Flanders when considering a set of regional and locational measures. On the one hand, the used methodology allows us to gain insight in the degree to which the planned measures will contribute to meet the targeted road safety objectives and on the other, it allows us to compare measures with each other.

More specifically, in this Flemish computational model, the impact of a set of measures is calculated step by step. The application focuses on a set of six road safety measures from the Road Safety Plan Flanders (Department Mobility and Works, 2008) which are being implemented on road segments on a regional or locational scale. Moreover, a distinction is made between three road types: highways, secondary roads and local roads. The methodology, which consists of 5 steps, was based on Reurings et al. (2009). (1) In the first step of the model a description is given of the traffic situation and the traffic safety situation in the reference year (2007). (2) Subsequently, the baseline prognosis is made. In this prognosis the number of injury accidents, fatalities, and seriously and slightly injured casualties is calculated for the period from 2008 until 2015, only taking into account changes in the number of vehicle kilometres and the autonomous risk change. (3) In addition to these two aspects, the measure prognosis also takes into account the impact of the set of measures. (4) This leads to a prediction of the reduction of injury accidents, fatalities and seriously and slightly injured casualties on road segments in Flanders in 2015, calculated based on the implementation of a set of measures (consisting of six measures) between 2008 and 2015. (5) Based on savings and investment costs, a cost-benefit analysis is illustrated.

We would like to emphasize that the main focus of this study lies in the description of the methodology and an inventory of data needs. In this report the model is moreover implemented as well as possible by means of an illustration based on the most recent data sets which were available at the start of the study (end of 2010). Since the results of this illustrative calculation are strongly influenced by the many assumptions that had to be taken throughout the computational process, we want to explicitly emphasize that the obtained results only indicate a direction and should by no means be taken literally. The illustration is therefore a ‘proof of concept'.

In general we can conclude that this computational model offers a lot of opportunities for policymakers to optimize and attune their policy to the targeted road safety objectives. Despite the relatively advanced development of the model, there are some aspects which have to be taken into account in future research and use. Examples are the high level of detail of the used data sets, the detailed description of the planned measures and the limited availability of (detailed) Flemish information on the effectiveness of measures and accident profiles. One of the big challenges for this methodology would be its implementation in a GIS-application.

Contents

1. INTRODUCTION

Road safety crashes are an important issue in today's society. During the previous decennia and years, a lot of attention has been devoted to road safety. Despite the improvements in terms of a reduction in the number of injury accidents and the number of casualties in the past, the road safety toll is still unacceptably high. In order to achieve a better level of road safety, targets are often set and measures taken. Expressing the desired road safety result that a country or region wishes to achieve over a given timeframe serves as a significant catalyst for motivating stakeholders. The value of setting targets to reduce road fatalities and casualties has been widely recognized (Elvik, 2001; Wong et al., 2006; Wong & Sze, 2010). In order to achieve the postulated targets, additional effort is often required. Consequently, road safety programs and actions are developed and implemented.

In this study, we focus on Flanders in which a road safety plan was introduced in 2007 describing 33 valuable road safety measures for reducing the number of fatally and seriously injured persons in Flanders to maximum 250 fatalities and maximum 2 000 seriously injured persons by 2015 (Departement Mobiliteit en Openbare Werken, 2008). Moreover, the ambition has been stated to become on an equal footing with the best performers in Europe as currently, there is still a twice as high risk to become involved in a fatal accident in Flanders compared to the SUN-countries (Sweden, United Kingdom and the Netherlands) (Vlaanderen in Actie, 2011).

At this moment, Flanders does not dispose of a computational model to calculate the effects of road safety measures at a regional level. Such an estimation model which assists regions to calculate the road safety effects of both regional and locational measures and to aid in selecting the most efficient measures is a valuable tool. The regional road safety explorer (RRSE) (*verkeersveiligheidsverkenner voor de region VVR*) model developed by the SWOV (Janssen, 2005; Reurings, Wijnen, & Vis, 2009; SWOV, 2009a; Vis & Reurings, 2010) is used as starting point for Flanders. This computational model has been partly developed in previous reports for the Policy Research Centre Mobility & Public Works, track Traffic Safety (*Steunpunt Mobiliteit en Openbare Werken, spoor Verkeersveiligheid*): Nambuusi et al. (2009, 2010). However, the present report provides additional information about the methodology and illustrates it using a broader and more recent data set. This report does not only focus on highway road segments but applies the set of road safety measures to the three main road categories: highways, secondary roads (*gewestwegen en provinciewegen*) and local roads (*gemeentewegen*). More in detail, the implementation of the model is an illustration in which we compute the number of injury accidents, fatalities, seriously injured persons and slightly injured persons that can be expected in Flanders by 2015 in case a set of six measures from the road safety plan would be put in place. This illustration shows policymakers how to gain insight in the progress towards the targets that can be anticipated when applying their road safety action program.

At the same time, this implies a number of research challenges. Detailed data need to be obtained with respect to the road safety situation in the reference period and with respect to each measure (such as the size of the population possibly affected by the measure; the share of persons (e.g. wearing a helmet) before and after the measure; the effectiveness of the measure in terms of injury accidents, fatalities, serious injuries and slight injuries; the cost of the measure in case one wants to draw conclusions in terms of efficiency; etc.). Furthermore, given that we want to make a realistic prediction into the future, changes in exposure (such as an increase in kilometers travelled) need to be taken into account.

It is important to note that the description of the methodology and the inventory of the data needs are the main focus of this report. In addition, we implement the model using an illustration which is based on the most recent data sets available at the start of this study (end of 2010). The results of this example are highly affected by the assumptions made during the assessment process. Therefore, we want to emphasize that the obtained numbers have no actual meaning and further development of an as realistic as possible assessment for Flanders is needed. The illustration is thus a proof of concept.

1.1 Objective of the report

The objective of this report is the description of the developed model for Flanders to assess the effects of road safety measures at the regional level and help in future decision making.

The report focuses on the modeling approach and the application in the form of the assessment of the effectiveness of a set of road safety measures. In the following chapters, the methodology of the computational model is described and the assessment of a set of six road safety measures is illustrated to indicate the value of the model. In addition, the advantages and challenges encountered during the development of the model are discussed and aspects for further improvement highlighted.

1.2 Organization of the report

This report starts with an overview of the methodology and the illustration is described. Afterwards, the five stages of the model are considered in detail. Firstly, the methodology of each step is described and secondly the application is discussed. Finally, we give possibilities for future research and a conclusion.

2. Overview of methodology and illustration

This chapter gives a short overview of the stages of the computational model and introduces the set of six road safety measures which are used in this report to illustrate the value of the model.

2.1 Methodology

The computational model is based on a stepwise calculation of the road safety effects – and its corresponding cost-benefit ratios – of a set of measures. The calculation steps and formulae are based on Reurings et al. (2009). However, the methodology in this report is slightly adjusted to fit the specific Flemish spatial and traffic context. Figure 1 presents the various stages of the model after a short description of each stage is given.

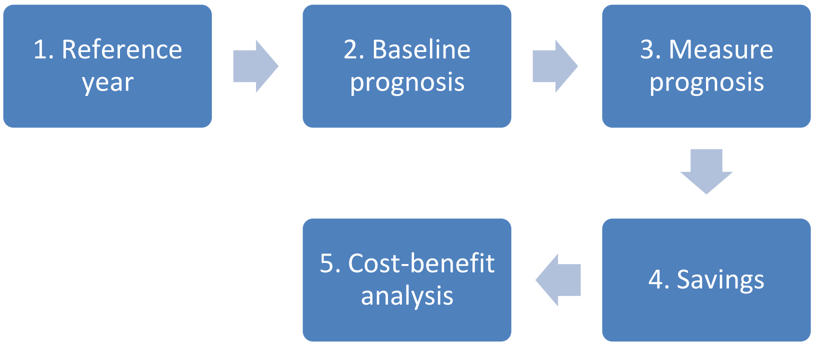

Figure 1 Stages of the model

The **reference year** describes the traffic performance and safety situation for a selected year. The road safety situation comprises the number of injury accidents, slight casualties, serious casualties and fatalities per road segment and intersection category. The **baseline prognosis** contains the road safety situation before the impact of measures is taken into account but with the inclusion of the change in traffic performance and the change in autonomous risk. Once the baseline prognosis is determined for each year, the safety effects of the selected road safety measures can be calculated by taking the safety effectiveness of the measures into account. These road safety measures might be implemented at a regional (all municipalities in Flanders) or local level (one or several municipalities). The prediction of the road safety situation in the application year of the measure is given in the **measure prognosis**. The number of **savings** is the difference in injury accidents, slight and serious casualties and fatalities between the baseline and the measure prognosis. Finally, the **cost-benefit analysis** is used to determine whether the benefits (i.e. increase of road safety) of a measure outweigh its costs (e.g. investments).

2.2 Illustration

The description of the methodology of the five stages is complemented with the assessment of a set of road safety measures on road segments in Flanders. This illustration is based on Flanders most recent data sets which were available at the start of this study (end of 2010) and on a set of six road safety measures of the Flemish Road Safety Plan (Departement Mobiliteit en Openbare Werken, 2008).

The computational model gives the opportunity to calculate the effects of road safety measures which are implemented at road segments or at intersections, both at regional or local level. In this report we focus on the implementation of a set of six road safety measures on three main road categories: highways, secondary roads (*gewestwegen en provinciewegen*) and local roads (*gemeentewegen*). The implementation of road safety measures at intersections is not considered in this report because of the lack of traffic performance data at intersection level in Flanders; however, the described methodology focuses both on road segments and intersections.

The choice for three road categories (highways, secondary roads and local roads) is based on the following considerations. First, the three categories have each their own level of authority: the highways and secondary roads are under the jurisdiction of the Flemish government and their provincial departments, whereas the local roads are governed by the municipalities. The road safety measures which will be implemented are thus directed to one of these governmental levels. Second, the distinction between these road categories is often registered in the data sets concerning the road safety situation and the traffic performance situation[1]. Finally, the function (i.e. traffic versus residential function) and the form (spatial planning, the activities located near the road and the road environment) differs significantly between highways on the one hand and secondary and local roads on the other hand[2]. These differences often result in different accident risks and also have an influence on the implementable road safety measures. It is worth noting that a more detailed distinction between different categories (such as a further distinction between roads inside and outside the urban area) is possible in this model. However – as we will discuss in Section 8. – a more detailed categorization is only valuable if the other data needs are also available at this detailed level.

The selected road safety measures can be implemented at a regional scale (i.e. Flanders) or at a more local scale (i.e. per Flemish municipality). Compared to the Dutch model – where the method is applied for the different regions (comparable to the Flemish provinces) – this study focuses on Flanders as one region and on the Flemish municipalities at the local scale. Therefore, a road safety measure is always applied to all road segments of a certain road category in a certain municipality. However, it is important to note that the implementation of measures at a more detailed level (for instance road segment x of a certain road category in a certain municipality) is possible when using GIS-based data sets. In this report, only the starting point is briefly described to examine whether GIS-based data sets for Flanders contain the necessary data to implement this computational model (paragraph 0and 4.2).

The traffic performance and road safety situation for each road type in each Flemish municipality is available for the reference year 2007[3]. From 2008 until 2014 a set of six road safety measures is implemented and the savings are calculated for the year 2015. The six road safety measures are briefly described in Table 1 and more detailed information for each measure can be found in the measurement information cards in appendix 11.1 . It should be emphasized that these measures are only used for illustrative purposes. The choice of the locations on which the measures are applied as

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[1] Although we make a distinction between the three main road categories based on the available data sets, it is important to note that the quality of the category assignment might be low. For example: each secondary road in Flanders has one road number and (sometimes several) street names whereas a local road has only a street name and no number. If the street name of a secondary road is filled in on the accident form (*verkeersongevallenformulier VOF*), the road is automatically labeled as a local road because the road number is not available. This might result in an overrepresentation of the accidents on local roads and an underrepresentation on the secondary roads.

[2] Whereas in the Netherlands the distinction between the different road categories is often more stringent, several Flemish secondary and local roads are not distinguishable.

[3] The reference year is 2007 because this is the most recent year for which the detailed road safety situation (i.e. injury accidents, slight and serious casualties and fatalities) per municipality and per road type was available at the start of the data inventory (end of 2010).

well as the year of implementation were determined hypothetically[4]. In addition, it is important to note that the results of this illustration are highly affected by the assumptions made during the assessment process. Therefore ,we want to emphasize that the obtained numbers have no actual meaning and further development of an as realistic as possible assessment for Flanders is needed.

Table 1 Description of six road safety measures

Measure	***Year(s) of implementation***	***Location***	***Influence on***
Campaign usage child restraints	2008	Regional	Slight casualties, serious casualties, fatalities
100 fixed speed cameras	2009	Local: secondary roads	Injury accidents, slight casualties, serious casualties, fatalities
Dynamic congestion warning system	2010	Local: highways	Injury accidents, slight casualties, serious casualties, fatalities
1750 km new bicycle lanes	2011-2013	Local: secondary and local roads	Injury accidents, slight casualties, serious casualties, fatalities
Section speed control	2012	Local: highways	Injury accidents, slight casualties, serious casualties, fatalities
Mandatory bicycle helmets for children	2014	Regional	Slight casualties, serious casualties, fatalities

The following chapters describe successively the five stage of the computational model. For each stage the methodology is described which is followed by the discussion of the assessment of the set of six road safety measures at road segments in Flanders.

[4] A more realistic model for Flanders should incorporate the road safety measures which are actually described in the policy proposals. A detailed description concerning the time of implementation and the exact location is essential to work out a realistic model.

3. The reference year

3.1 Methodology

The first stage describes the traffic and road safety situation in a particular year. This reference year is the basis for the calculation. The traffic situation consists of traffic performance, i.e. the annual number of kilometers travelled by motorized vehicles per road category and the annual number of motorized vehicles through an intersection category. The road safety situation comprises the number of injury accidents, slight casualties, serious casualties and fatalities per road segment and intersection category. Underreporting of road safety quantities is taken into account by multiplying the registered quantities by an underreporting factor per severity level. Underreporting is lower for some severity levels (e.g. Reurings, Bos, & van Kampen, 2007). Moreover, different categories of road segments and intersections might have different underreporting levels. In this report, it is assumed that all road segments and intersections have the same underreporting factor. The computation is illustrated for injury accidents (IAs). The other severity levels are incremented in a similar manner.

$IAs_c = IAs_{c,registered} * f_{c,accident}$ with

IAs_c = incremented number of injury accidents on all infrastructures belonging to road segment or intersection category c in the reference year

$IAs_{c,registered}$ = registered number of injury accidents on all infrastructures belonging to road segment or intersection category c in the reference year

$f_{c,accident}$ = underreporting factor for the number of injury accidents on category c

Apart from the number of injury accidents, slight casualties, serious casualties and fatalities, the road safety situation in the reference year is reflected by various indicators. The most important ones are: the accident risk (r_c), the number of casualties per injury accident ($N_{0,c}$), the number of slight casualties per total casualties ($N_{1,c}$), the number of serious casualties per total casualties ($N_{2,c}$) and the number of fatalities per 100 casualties ($N_{3,c}$) per road segment or intersection category. The accident indicators are computed as follows:

$r_c = \frac{IAs_c}{TP_c}$; $N_{0,c} = \frac{C_c}{IAs_c}$; $N_{1,c} = \frac{SLC_c}{C_c}$; $N_{2,c} = \frac{SC_c}{C_c}$ and $N_{3,c} = \frac{FATs_c}{C_c} * 100$ with

IAs_c = incremented number of injury accidents on all infrastructures belonging to road segment or intersection category c in the reference year

TP_c = traffic performance on all infrastructures belonging to road segment or intersection category c in the reference year

C_c = number of casualties on all infrastructures belonging to road segment or intersection category c in the reference year

SLC_c = number of slight casualties on all infrastructures belonging to road segment or intersection category c in the reference year

SC_c = number of serious casualties on all infrastructures belonging to road segment or intersection category c in the reference year

$FATs_c$ = number of fatalities on all infrastructures belonging to road segment or intersection category c in the reference year

3.2 Data needs for the Flemish model

As described in the paragraph above, we need data concerning the traffic safety situation and the traffic situation for each municipality regarding the reference year. The reference year is the most recent year for which all the required data sets are available. For this study, the inventory of the data needs started near the end of 2010. At that moment, 2007 was the most recent year for which data sets concerning the road safety situation were available. First, we made an inventory of the different available accident data sets. This research resulted in the following data sets:

- The accident database of the Federal Government Economy (*Federale Overheidsdienst (FOD) Economie*) (Directorate-general Statistics and Economic information / *Algemene directie Statistiek en Economische informatie (AD SEI)*) contains information concerning the injury accidents and the casualties per severity level per municipality for 2007. In addition, the database makes a distinction between the three road categories (highway, secondary road and local road) and between accidents located on a road segment or on an intersection. Furthermore, the profile of each casualty is also recorded.
- The localized accident database of Flanders (*Departement Mobiliteit en Openbare Werken (MOW)*) contains information concerning the injury accidents and the casualties per severity level for 2007. In addition, there is a variable containing localization information. This variable makes it possible to link the accident information to a GIS-layer. Based on this GIS-layer the road category, the municipality and the exact location (on a road segment or on an intersection) can be derived.

Second, an inventory of the available databases concerning the traffic situation was made:

- Five-yearly traffic performance data per municipality for 2005 (*Weglengte en wegverkeer per gemeente 2005*: FOD Mobility and Traffic *(FOD Mobiliteit en Vervoer)*).
- Traffic performance data at several permanent measurement points on Flemish highways and secondary roads (not on local roads) for 2007 (*Jaarlijkse verkeerstellingen – Agentschap Wegen en Verkeer (AWV)*).

Although the localized accident database and the traffic performance data of AWV might improve the level of detail of the model by linking them by means of a GIS-layer, we decided to do the assessment by means of the accident database of the FOD Economie (AD SEI) and the traffic performance data of the FOD Mobility and Traffic. This decision was mainly based on timing considerations and the high workload to integrate the GIS-layer in the model.

3.3 Application

The road safety situation in the reference year 2007 is based on the accident database of the Federal Government Economy (FOD Economie, AD SEI). This data set provides the registered number of injury accidents, slight casualties, serious casualties and fatalities for each of the three road types (i.e. highways, secondary road and local roads) within each of the 308 Flemish municipalities for 2007. In addition, the data set has the possibility to make a distinction between accidents or casualties at road segments or at intersections. In this report, a road segment is defined as all the roads of a certain road type within a certain municipality. Each municipality has thus maximum three road segments: a highway, a secondary road and a local road.

One pitfall of using registered road safety quantities is underreporting. Since 2002, the Flemish accident data is adjusted with a correction factor for each police zone to correct for the differences between the number of bookings (*proces-verbaal PV*) and the number of accident forms (*verkeersongevallenformulier VOF*) in the particular police zone (BIVV, 2010). However, we know that there is still some underreporting of accidents, such as single accidents and accidents with cyclists. Therefore we also apply – in accordance with the methodology described in paragraph 3.1 – the underreporting factors obtained from the literature (Elvik & Mysen, 1999). These underreporting factors are used to increase road safety quantities in order to better approximate reality. It is important to note that these two corrections for underreporting are based on two different causes for underreporting: more PV's than VOF's on the one hand and general underreporting on the other hand. The road safety quantities in Flanders in the reference year 2007 are described in Table 2. These values are the summation of all the road safety quantities in all the Flemish municipalities for that road type[5].

Table 2 Road safety situation at the road segments in 2007 summed over all Flemish municipalities
(source: accident database FOD Economie, AD SEI)

Road type	***Severity level***	***Registered quantity per severity level****	***Underreporting factor*** *(Elvik & Mysen, 1999)*	***Incremented quantity***
Highways	IAs	2 375.03	1.75	4 156.30
	SLC	2 816.68	1.90	5 351.69
	SC	633.78	1.30	823.91
	FATs	74.00	1.05	77.70
Secondary roads	IAs	1 025.39	1.75	1 794.43
	SLC	1 263.17	1.90	2 400.02
	SC	171.05	1.30	222.37
	FATs	23.00	1.05	24.15
Local roads	IAs	15 968.81	1.75	27 945.42
	SLC	18 132.75	1.90	34 452.22
	SC	2 288.86	1.30	2 975.52
	FATs	306.00	1.05	321.30

** Corrected with the Flemish correction factors from the accident data set (FOD Economie, AD SEI).*

IAs = injury accidents, SLC = slight casualties, SC = serious casualties, FATs = fatalities

Apart from the number of injury accidents, slight casualties, serious casualties and fatalities, the road safety situation in the reference year is reflected by various road safety indicators[6]. The traffic situation is needed to calculate the injury accident risk of a road type in a certain municipality. Due to the lack of traffic performance data per road

[5] It is important to note that these numbers are not comparable with the numbers on the website of the FOD Economie, AD SEI because the numbers on the website contain both the accidents on road segments and on intersections.

[6] The road safety indicators are: injury accident risk (IAs risk or r_c), the number of casualties per injury accident (C per IAs or $N_{0,c}$), the number of slight casualties per total casualties (SLC per C or $N_{1,c}$), the number of serious casualties per total casualties (SC per C or $N_{2,c}$) and the number of fatalities per 100 casualties (FATs per 100C or $N_{3,c}$) per road.

type and per municipality for the reference year 2007, we have to use the traffic performance data of 2005 (*Weglengte en wegverkeer per gemeente 2005*: FOD Mobiliteit en Vervoer). The traffic performance data (in million vehicle km per year) of 2005 for each individual road segment in each Flemish municipality is therefore adjusted with a factor which is based on the evolution of the traffic performance between 2005 and 2007 at the regional level per road type (*Afgelegde afstanden door motorvoertuigen*: FOD Economie, AD SEI). The calculation of the traffic situation in 2007, based on the traffic situation in 2005 can be found in appendix 0.

Based on the road safety quantities in Table 2 and the traffic situation, the five road safety indicators are calculated. The traffic situation and the road safety indicators for Flanders can be found in Table 3. These values are also calculated per road type per municipality.

Table 3 Traffic performance situation and road safety indicators per road type in 2007 summed over all Flemish municipalities

Road type	***TP****	***IAs risk***	***C per IAs***	***SLC per C***	***SC per C***	***FATs per 100C***
Highways	22 054.90	0.188	1.505	0.856	0.132	1.243
Secondary roads	22 000.88	0.082	1.475	0.907	0.084	0.913
Local roads	12 574.46	2.222	1.351	0.913	0.079	0.851

** Traffic performance (TP) in million vehicle kilometer per year.*

The results in Table 3 show that in 2007 the injury accident risk (IAs risk) was the highest on local roads with 2.22 injury accidents per million driven kilometers. The number of casualties per injury accident was the highest on highways (1.505 C per IAs), whereas the number of slight casualties per casualty was highest on local roads (0.913 SLC per C). The number of serious casualties and fatalities per casualty was the highest on highways (respectively 0.132 SC per C and 1.243 FATs per 100C).

4. BASELINE PROGNOSIS

4.1 Methodology

Having described the reference situation, the baseline prognoses can be calculated. The baseline prognosis contains the number of injury accidents, slight casualties, serious casualties and fatalities before the impact of measures is taken into account. To determine the baseline prognosis, two developments outside the influence of the user of the model are taken into account. They include the change in traffic performance and the change in autonomous risk. At this stage, the baseline prognosis concerning traffic performance and road safety quantities is calculated.

4.1.1 Baseline prognosis for traffic performance

Traffic performance increases each year to some extent (Federaal Planbureau, 2008). It implies uncertainty about the future. Thus, different scenarios representing specific growth rates in traffic performance might be considered. Every growth scenario consists of a set of traffic performance growth factors relating to a particular year and infrastructure category. The baseline traffic performance for infrastructure category c in year t due to growth scenario A ($TP_{A,c,t}$) is given by:

$TP_{A,c,t} = g_{A,c,1} * g_{A,c,2} * \dots * g_{A,c,t} * TP_c$ with

$g_{A,c,t}$ = growth factor for traffic performance in year t on road segment or intersection category c due to growth scenario A

TP_c = traffic performance on road segment or intersection category c in the reference year

4.1.2 Baseline prognosis for road safety quantities

This section presents formulae for the baseline prognoses of the road safety quantities. The computations for injury accidents are given first, followed by those for total casualties, fatalities, serious casualties and lastly slight casualties.

a. Baseline prognosis for the number of injury accidents

The baseline prognosis for the number of injury accidents is obtained by multiplying a category's traffic performance and its baseline risk. The baseline risk is determined by the risk in the reference year and the autonomous risk change. The baseline risk $br_{c,t}$ on category c in year t after the reference year is given by:

$br_{c,t} = f_{c,1} * f_{c,2} * \dots * f_{c,t} * r_c$ with

$f_{c,t}$ = modification factor for the autonomous risk on category c in year t

r_c = accident risk for category c in the reference year (paragraph 3.)

The baseline prognosis for the number of injury accidents, $b\_IAs_{A,c,t}$ in year t on category c due to growth scenario A, is given by:

$b\_IAs_{A,c,t} = br_{c,t} * TP_{A,c,t}$ with

$br_{c,t}$ = baseline risk in year t for category c

$TP_{A,c,t}$ = traffic performance in year t on category c due to growth scenario A (paragraph 4.1.1)

b. Baseline prognosis for the number of casualties

The baseline prognosis for the number of casualties, $b\_C_{A,c,t}$ in year t on category c due to growth scenario A is given by:

$b\_C_{A,c,t} = b\_IAs_{A,c,t} * N_{0,c}$ with

$b\_IAs_{A,c,t}$ = baseline prognosis for the number of injury accidents in year t on category c due to growth scenario A (paragraph 4.1.2 a)

$N_{0,c}$ = number of casualties per injury accident on category c in the reference year (section 3.)

c. Baseline prognosis for the number of fatalities

The baseline prognosis for the number of fatalities, $b\_FATs_{A,c,t}$ in year t on category c due to growth scenario A, is given by:

$b\_FATs_{A,c,t} = \frac{N_{3,c}}{100} * b\_C_{A,c,t}$ with

$b\_C_{A,ct,}$ = baseline prognosis for the number of casualties in year t on category c due to growth scenario A (paragraph 4.1.2 b)

$N_{3,c}$ = number of fatalities per 100 casualties on category c in the reference year (paragraph 3.)

d. Baseline prognosis for the number of serious casualties

The baseline prognosis for the number of serious casualties, $b\_SCs_{A,c,t}$ in year t on category c due to growth scenario A, is given by:

$b\_SCs_{A,c,t} = N_{2,c} * b\_C_{A,c,t}$ with

$b\_C_{A,ct,}$ = baseline prognosis for the number of casualties in year t on category c due to growth scenario A (paragraph 4.1.2 b)

$N_{2,c}$ = number of serious casualties per total casualties on category c in the reference year

e. Baseline prognosis for the number of slight casualties

The baseline prognosis for the number of slight casualties, $b\_SLC_{A,c,t}$ in year t on category c due to growth scenario A, is given by:

$b\_SLC_{A,c,t} = b\_C_{A,c,t} - b\_FATs_{A,c,t} - b\_SC_{A,c,t}$ with

$b\_C_{A,ct,}$ = baseline prognosis for the number of casualties in year t on category c due to growth scenario A (paragraph 4.1.2 b)

$b\_FATs_{A,c,t}$ = baseline prognosis for the number of fatalities in year t on category c due to growth scenario A (paragraph 4.1.2 c)

$b\_SC_{A,c,t}$ = baseline prognosis for the number of serious casualties in year t on category c due to growth scenario A (paragraph 4.1.2 d)

4.2 Application

In this section, the baseline prognoses for the three road types in Flanders are discussed. The baseline prognoses last from 2008 until 2015 and describe the traffic and road safety situation when no additional measures are taken into account. In this study, we use only one growth scenario mainly because of time restrictions; however, the implementation of other growth scenarios (for which additional data is required) is similar to the method presented above.

4.2.1 *Baseline prognosis for traffic performance*

Traffic performance changes from year to year. This information is incorporated into the model by the implementation of growth rates in traffic performance. An inventory of the available data sets for the determination of the growth rates was made:

- Traffic performance data per road type for 1985-2007 (*Aantal voertuigkilometer afgelegd door het wegverkeer, zonder bromfietsen, ongeacht het land van registratie, naar type weg*: FOD Economy, AD SEI).
- Traffic performance data at several permanent measurement points on Flemish highways and secondary roads for 1985 – 2008 (*Synthese verkeerstellingen 1985-2008*: FOD Mobility and Traffic).

Although the traffic performance data of FOD Mobility and Traffic might improve the level of detail of the model by coupling them with a GIS-layer[7], we decided to determine the growth rate by means of the traffic performance data per road type for 1985-2007 (FOD Economy, AD SEI). Because this data set contains no traffic performance information per municipality, we have to assume that all road segments belonging to a particular road type have the same growth rate as that category, thus the growth rate is independent on the municipality.

This prediction of the yearly growth in vehicle kilometers for each road type for the period 2008-2015 is based on a logarithmic trend function applied on the traffic performance between 1985 and 2007 for each road type (Figure 2).

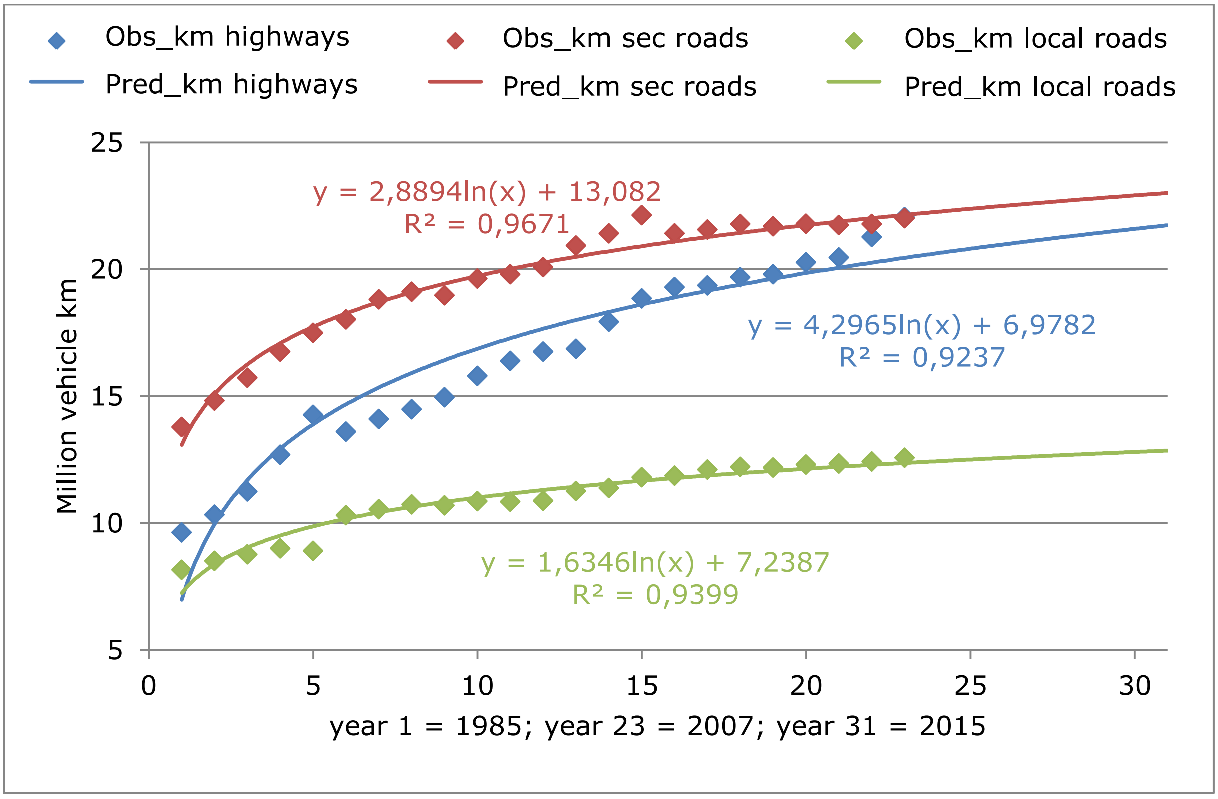

Figure 2 Observed and predicted traffic performance (1985-2015)

[7] The linkage of the traffic performance data set 1985-2008 (FOD Mobility and Traffic) with a GIS-layer can provide traffic performance data for each individual road segment in each municipality. This data can thus be used to determine a more detailed growth factor for the road segments which are included in the data set. Further research is needed to determine whether the GIS-layer with traffic performance data contains enough data to code all road segments in all municipalities.

Traffic performance values on category c for the year 2007-2015 ($TP\,predicted_{c,t}$ and $TP\,predicted_{c,t-1}$) are calculated by means of the logarithmic trend function (Figure 2) and are labeled as 'predicted driven kilometers'. The predicted growth factor ($g_{c,t}$) in year t on road segment c is determined by the following formula:

$$g_{c,t} = \frac{TP\,predicted_{c,t}}{TP\,predicted_{c,t-1}}$$

The results of these calculations are shown in Table 4, where the number of observed driven kilometers (Obs_km), the predicted driven kilometers (Pred_km) and the growth factor (g) are given for the three road types. The growth factor between 2008 and 2015 shows an average yearly increase of 0.6% in the number of vehicle kilometers.

Table 4 Growth factors for traffic performance (TP in billion vehicle km)

Year	Highways			Secondary roads			Local roads		
	Obs_km	*Pred_km*	*g*	*Obs_km*	*Pred_km*	*g*	*Obs_km*	*Pred_km*	*g*
1985	9.63	6.98		13.78	13.08		8.15	7.24	
1986	10.32	9.96	1.42677	14.82	15.08	1.15309	8.50	8.37	1.156522
1987	11.24	11.70	1.17497	15.72	16.26	1.07766	8.76	9.03	1.079168
1988	12.69	12.93	1.10566	16.75	17.09	1.05113	9.00	9.50	1.052050
1989	14.26	13.89	1.07412	17.49	17.73	1.03773	8.90	9.87	1.038376
1990	13.60	14.68	1.05638	18.02	18.26	1.02971	10.31	10.17	1.030196
1991	14.10	15.34	1.04513	18.81	18.70	1.02439	10.54	10.42	1.024782
1992	14.48	15.91	1.03740	19.11	19.09	1.02063	10.73	10.64	1.020948
1993	14.95	16.42	1.03180	18.97	19.43	1.01783	10.69	10.83	1.018099
1994	15.79	16.87	1.02757	19.63	19.74	1.01567	10.86	11.00	1.015902
1995	16.38	17.28	1.02427	19.80	20.01	1.01395	10.84	11.16	1.014160
1996	16.75	17.65	1.02163	20.08	20.26	1.01256	10.88	11.30	1.012746
1997	16.86	18.00	1.01948	20.93	20.49	1.01141	11.26	11.43	1.011578
1998	17.93	18.32	1.01769	21.41	20.71	1.01045	11.38	11.55	1.010597
1999	18.85	18.61	1.01618	22.13	20.91	1.00963	11.80	11.67	1.009762
2000	19.29	18.89	1.01490	21.41	21.09	1.00892	11.86	11.77	1.009043
2001	19.36	19.15	1.01379	21.56	21.27	1.00830	12.10	11.87	1.008419
2002	19.68	19.40	1.01282	21.78	21.43	1.00777	12.21	11.96	1.007871
2003	19.80	19.63	1.01198	21.69	21.59	1.00729	12.18	12.05	1.007387
2004	20.27	19.85	1.01123	21.79	21.74	1.00686	12.30	12.14	1.006957
2005	20.46	20.06	1.01056	21.74	21.88	1.00649	12.34	12.22	1.006572
2006	21.27	20.26	1.00996	21.78	22.01	1.00614	12.42	12.29	1.006225
2007	22.05	20.45	1.00943	22.01	22.14	1.00583	12.57	12.36	1.005912
2008		20.63	1.00894		22.26	1.00555		12.43	1.005627
2009		20.81	1.00850		22.38	1.00530		12.50	1.005367
2010		20.98	1.00810		22.50	1.00506		12.56	1.005129
2011		21.14	1.00773		22.60	1.00485		12.63	1.004910
2012		21.30	1.00739		22.71	1.00465		12.69	1.004708
2013		21.45	1.00708		22.81	1.00446		12.74	1.004522
2014		21.59	1.00679		22.91	1.00429		12.80	1.004349
2015		21.73	1.00652		23.00	1.00414		12.85	1.004188

The growth factors in Table 4 are used to determine the baseline traffic situation in year t for the three road types in each municipality by means of the following formula:

$TP_{c,t} = g_{c,1} * g_{c,2} * ... * g_{c,t} * TP\ observed_c$ with

$g_{c,t}$ = growth factor for traffic performance in year t on road segment category c (Table 4)

$TP\ observed_c$ = observed traffic performance on road segment category c in the reference year 2007 in the municipality under consideration

Flanders' baseline traffic situation at the three road types in 2008-2015 is shown in Table 5.

Table 5 Baseline traffic performance summed over all Flemish municipalities (in million vehicle km)

Year	***Highways***	***Secondary roads***	***Local roads***
2008	22 252.11	22 123.07	12 645.21
2009	22 441.27	22 240.27	12 713.08
2010	22 623.00	22 352.87	12 778.28
2011	22 797.88	22 461.23	12 841.02
2012	22 966.40	22 565.64	12 901.48
2013	23 129.00	22 666.39	12 959.81
2014	23 286.09	22 763.72	13 016.17
2015	23 438.03	22 857.86	13 070.68

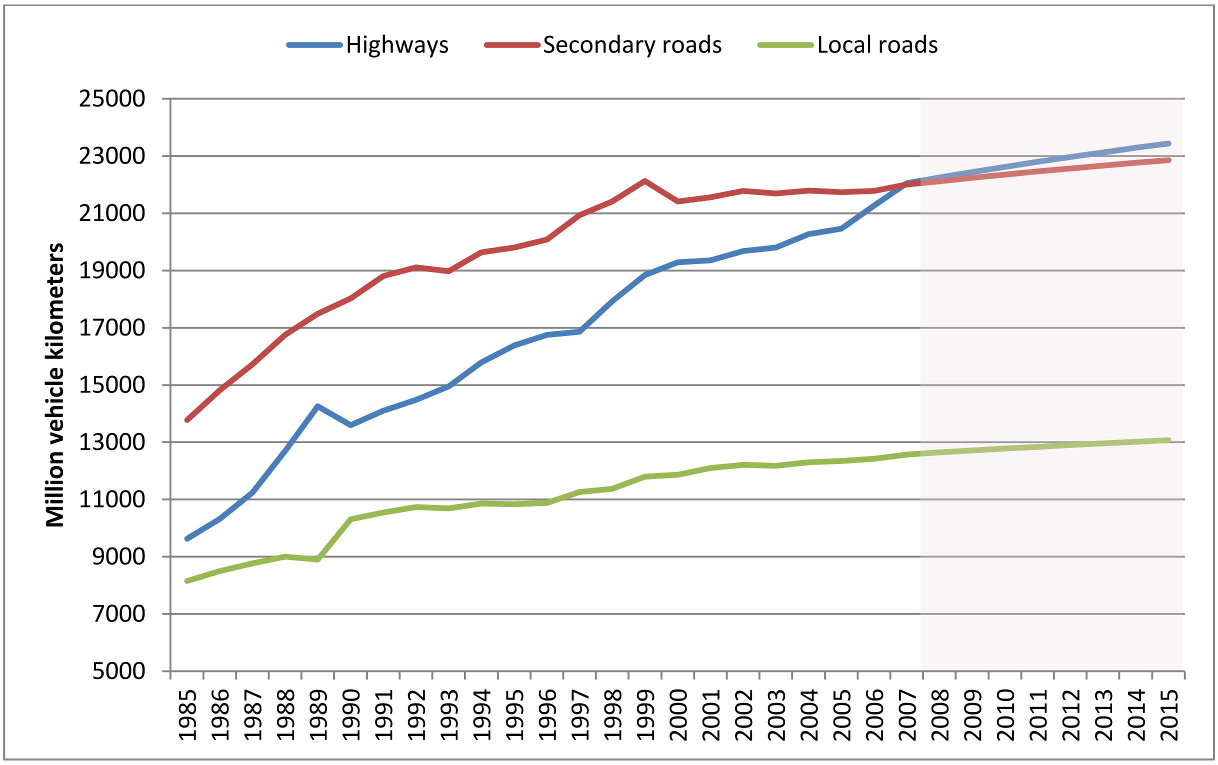

Figure 3 Traffic performance in Flanders (1985-2007: observed data; 2008-2015: predicted)

4.2.2 Baseline prognosis for road safety quantities

In this paragraph the baseline prognosis for the road safety situation is described. The number of injury accidents, slight casualties, serious casualties and fatalities are calculated for the period 2008-2015 when no road safety measures (business-as-usual) are taken into account. However, the changes in autonomous risk should be taken into account.

a. Baseline injury accident risk

The baseline risk is determined by the risk in the reference year and the autonomous risk change. This autonomous risk change is based on accident data from previous years. An inventory of the available accident data sets which contain the necessary information for several years was made:

- The Flemish injury accident data from 1985-2007 (*Evolutie van het aantal letselongevallen in Europa (1970, 1978-2007)*: Vlaamse studiedienst) provide the total number of injury accidents in Flanders per year. This database has thus not the possibility to allocate the autonomous risk change to a certain road category or a certain municipality.
- The accident database of the Federal Government Economy (*Federale Overheidsdienst (FOD) Economie*) (Directorate-general Statistics and Economic information / *Algemene directie Statistiek en Economische informatie (AD SEI)*) contains the injury accidents and the casualties per severity level per municipality for 1997-2007. In addition, the database makes a distinction between the three road categories and between accidents located on a road segment or on an intersection.
- The localized accident database of Flanders (*Departement Mobiliteit en Openbare Werken (MOW)*) contains the injury accidents and the casualties per severity level for 1996-2007. In addition, there is a variable containing localization information. This variable makes it possible to link the accident information to a GIS-layer. Based on this GIS-layer the road category, the municipality and the exact location (on a road segment or on an intersection) can be derived.

Although the last two accident data sets contain more detailed information concerning the road safety situation, the Flemish injury accident data from 1985-2007 (*Evolutie van het aantal letselongevallen in Europa (1970, 1978-2007)*: Vlaamse studiedienst) are used to predict the modification factor for the autonomous risk for the period 2008-2015. This decision was mainly based on the fact that we chose to take a relatively long period of past data into account (in order to better determine a trend).

Because the accident data used makes no distinction between the three road types or between road segments and intersections, we assume that the autonomous risk is independent on the road type and the accident location (i.e. road segment or intersection). In addition, the differences in risk between the three road types are already taken into account in the reference period.

The prediction of the modification factor for autonomous risk is based on a logarithmic trend function applied on the injury accident risk between 1985 and 2007. The accident risk in year t (from 1985 to 2007) is determined by dividing the number of injury accidents in year t by the traffic performance in year t. The injury accident risks and the logarithmic trend function are shown in Figure 4.

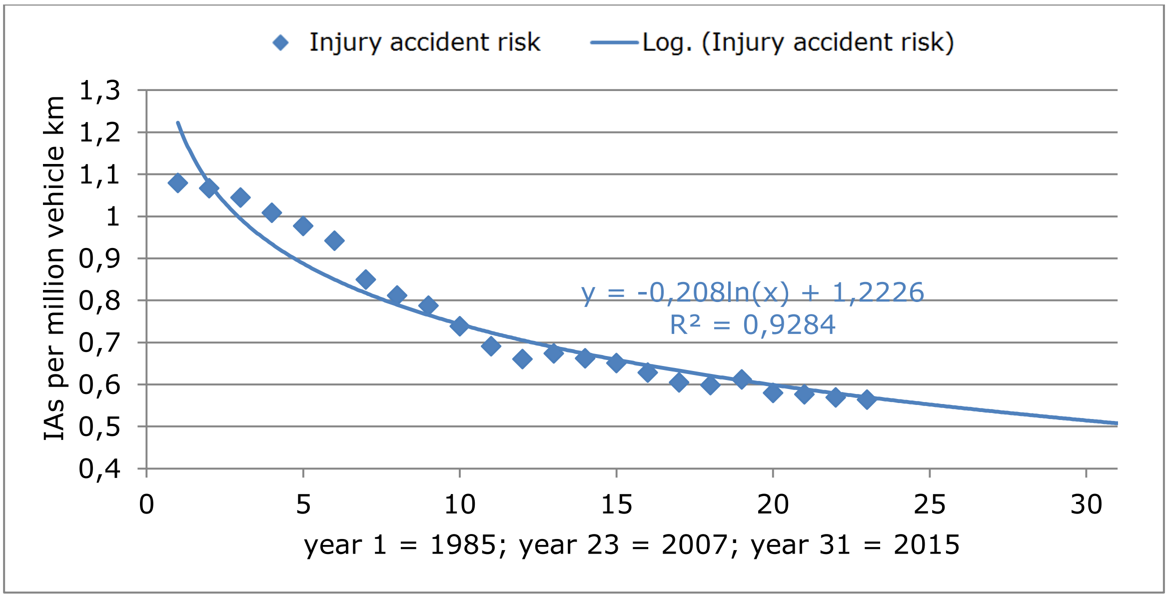

Figure 4 Observed and predicted injury accident risk (1985-2015)

The decreasing trend over time of the injury accident risk can be explained in terms of a collective learning process (European Cooperation in Science and Technology, 2004), caused by the ever-increasing knowledge of the traffic safety problem and the constant improvement of the safety performance of the road transport system. For example, cars and roads become better equipped, traffic safety education improves and legislation and enforcement efforts have also increased over time. All these measures result in a decreased risk over time.

The logarithmic function is used to calculate the predicted injury accident risk for the period 1985-2015. The decreasing rate for these predicted value is determined by means of the following formula:

$$decreasing\ rate = \frac{value\ log\ model_t - value\ log\ model_{t-1}}{value\ log\ model_{t-1}}$$

The modification factor for autonomous risk is than estimated by diminishing the decreasing rate from 1:

$f_t = 1 - decreasing\ rate_t$ with

f_t = modification factor for the autonomous risk in year t

The determination of the decreasing rate and the modification factor is illustrated in detail in Table 6 and Table 7.

Table 6 Estimation of modification factor for autonomous risk

Year	***x***	***IAs (registered on 3 road types + intersections)***	***Traffic performance (3 road types + intersections)***	***Observed IAs risk***	***Value log model*** $(-0.208\ ln(x) + 1.2226)$	***Decreasing rate***	***Modification factor*** (f_t)
1985	*1*	34057	31557	1.079	1.223		
1986	*2*	35894	33648	1.067	1.078	-0.1180	0.8820
1987	*3*	37313	35722	1.045	0.994	-0.0783	0.9217
1988	*4*	38752	38433	1.008	0.934	-0.0603	0.9397
1989	*5*	39710	40646	0.977	0.888	-0.0497	0.9503
1990	*6*	39485	41923	0.942	0.850	-0.0428	0.9572
1991	*7*	36909	43447	0.850	0.817	-0.0378	0.9622
1992	*8*	35968	44319	0.812	0.790	-0.0340	0.9660
1993	*9*	35129	44613	0.787	0.765	-0.0311	0.9689
1994	*10*	34179	46283	0.738	0.743	-0.0287	0.9713
1995	*11*	32487	47022	0.691	0.723	-0.0267	0.9733
1996	*12*	31505	47707	0.660	0.705	-0.0250	0.9750
1997	*13*	33050	49049	0.674	0.689	-0.0236	0.9764
1998	*14*	33583	50715	0.662	0.673	-0.0224	0.9776
1999	*15*	34353	52778	0.651	0.659	-0.0213	0.9787
2000	*16*	33023	52564	0.628	0.645	-0.0204	0.9796
2001	*17*	32073	53020	0.605	0.633	-0.0196	0.9804

Table 7 Estimation of modification factor for autonomous risk (continue)

Year	*x*	*IAs (registered on 3 road types + intersections)*	*Traffic performance (3 road types + intersections)*	*Observed IAs risk*	*Value log model* $(-0.208\, ln(x) + 1.2226)$	*Decreasing rate*	*Modification factor* (f_t)
2002	*18*	32120	53673	0.598	0.621	-0.0188	0.9812
2003	*19*	32844	53671	0.612	0.610	-0.0181	0.9819
2004	*20*	31522	54360	0.580	0.599	-0.0175	0.9825
2005	*21*	31445	54540	0.577	0.589	-0.0170	0.9830
2006	*22*	31571	55470	0.569	0.579	-0.0165	0.9835
2007	*23*	31935	56630	0.564	0.570	-0.0160	0.9840
2008	*24*				0.561	-0.0156	0.9844
2009	*25*				0.552	-0.0152	0.9848
2010	*26*				0.544	-0.0148	0.9852
2011	*27*				0.536	-0.0144	0.9856
2012	*28*				0.529	-0.0141	0.9859
2013	*29*				0.522	-0.0138	0.9862
2014	*30*				0.514	-0.0135	0.9865
2015	*31*				0.508	-0.0133	0.9867

Based on the injury accident risk from the reference period and the modification factor for autonomous risk the baseline injury accident risk for road segments is determined (methodology see paragraph 4.1.2). The values of the modification factor and the baseline risks are given in Table 8.

Table 8 Baseline risk for 2008-2015

Year	***Modification factor autonomous risk (f_t)***	***Baseline risk ($br_{c,t}$)***		
		Highways	***Secondary roads***	***Local roads***
2008	0.9844	0.186	0.080	2.188
2009	0.9848	0.183	0.079	2.155
2010	0.9852	0.180	0.078	2.123
2011	0.9856	0.177	0.077	2.092
2012	0.9859	0.175	0.076	2.063
2013	0.9862	0.172	0.075	2.034
2014	0.9865	0.170	0.074	2.007
2015	0.9867	0.168	0.073	1.980

The baseline risk for injury accidents decreases from year to year due to the declining rate of the modification factor for the autonomous risk. Between 2008 and 2015, there is an overall average yearly decrease of the injury accident risk of 1.4%. As an example: the injury accident risk on local roads decreases from 2.22 injury accidents per million vehicle kilometers in 2007 (Table 3) to 2.19 in 2008 and decreases further to 1.98 injury accidents per million vehicle kilometers in 2015.

b. Baseline prognosis for number of injury accidents, slight casualties, serious casualties and fatalities

The traffic performance and the baseline risk for injury accidents obtained in Table 5 and Table 8 respectively are used to compute the baseline prognosis for the various road safety quantities. The procedure has been described in paragraph 4.1.2 . The baseline prognosis for road safety per severity level in 2008-2015 is provided in Table 9[8]. In addition, the number of injury accidents and casualties for the three road types in 2004[9]-2015 is illustrated in Figure 5 and Figure 6.

From Table 9, a decrease in road safety quantities is observed from year to year. These results depend on the growth in traffic performance and the autonomous risk

[8] A comparison of the road safety situation between the baseline prognosis and recently available detailed accident figures (2008 and 2009) (FOD Economie, AD SEI) show rather limited differences in the numbers on road segments. As an example: the number of fatalities on highway segments in 2008 was according to the model 76.13, whereas in reality 71.40 (numbers corrected with the Flemish correction factor and with Elvik's underreporting factor) persons died in a traffic accident on a highway. In 2009, there were 75.62 fatalities to be expected according to the model and 74.55 in reality. These very small differences may be attributed to the regression-to-the-mean phenomenon.

[9] The graph starts from 2004 because due to a change in the division of secondary roads and local roads, the situation before 2004 is not comparable with the situation from 2004 onwards.

change. If the growth in traffic performance outweighs the decline in the autonomous risk per year, an increase in road safety quantities is realized, and vice versa. In this case, the decline in autonomous risk (-1.4% on average) is higher than the growth in traffic performance (0.6% on average) per year for the period 2008-2015 causing a decreasing trend in the road safety quantities.

Table 9 Baseline road safety situation for 2008-2015 summed over all Flemish municipalities

Year	*Road type*	*IAs*	*SLC*	*SC*	*FATs*	*C*
2008	Highways	4 070.27	5 254.87	805.62	76.13	6 136.62
	Secondary roads	1 776.34	2 375.82	220.12	23.91	2 619.85
	Local roads	27 665.63	34 107.29	2 945.73	318.08	37 371.10
2009	Highways	4 042.67	5 241.55	800.16	75.62	6 095.01
	Secondary roads	1 758.69	2 357.85	217.94	23.67	2 593.82
	Local roads	27 392.67	33 849.41	2 916.66	314.94	37 002.38
2010	Highways	4 015.17	5 183.73	794.72	75.10	6 053.55
	Secondary roads	1 741.47	2 329.18	215.80	23.44	2 568.42
	Local roads	27 126.17	33 442.23	2 888.29	311.88	36 642.40
2011	Highways	3 987.79	5 148.39	789.30	74.59	6 012.27
	Secondary roads	1 724.65	2 306.68	213.72	23.21	2 543.61
	Local roads	26 865.82	33 121.25	2 860.57	308.89	36 290.70
2012	Highways	3 960.56	5 113.23	783.91	74.08	5 971.22
	Secondary roads	1 708.21	2 284.70	211.68	22.99	2 519.36
	Local roads	26 611.29	32 807.46	2 833.47	305.96	35 946.89
2013	Highways	3 933.50	5 078.29	778.55	73.57	5 930.42
	Secondary roads	1 692.13	2 263.19	209.69	22.77	2 495.65
	Local roads	26 362.32	32 500.51	2 806.96	303.10	35 610.57
2014	Highways	3 906.62	5 043.59	773.23	73.07	5 889.89
	Secondary roads	1 676.39	2 242.15	207.74	22.56	2 472.45
	Local roads	26 118.62	32 200.08	2 781.01	300.30	35 281.39
2015	Highways	3 879.93	5 009.13	767.95	72.57	5 849.66
	Secondary roads	1 660.99	2 221.55	205.83	22.35	2 449.73
	Local roads	25 879.97	31 905.86	2 755.60	297.55	34 959.01

IAs = injury accidents, SLC = slight casualties, SC = serious casualties, FATs = fatalities, C = SLC + SC + FATs

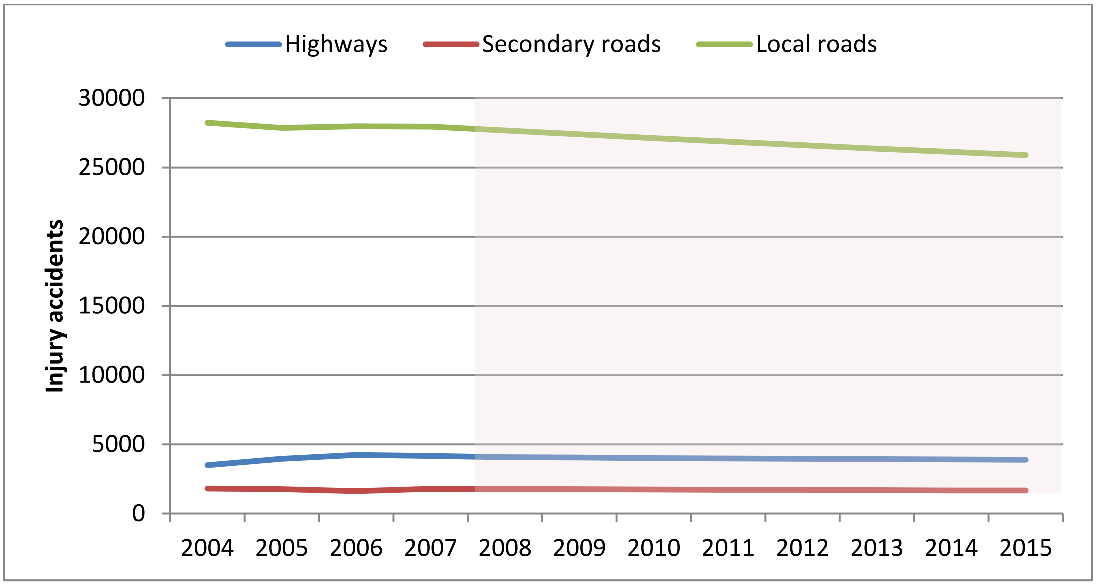

Figure 5 Injury accidents per road type summed over all Flemish municipalities (2004-2007: registered but inclusion of underreporting factor (1.75); 2008-2015: baseline prognosis)

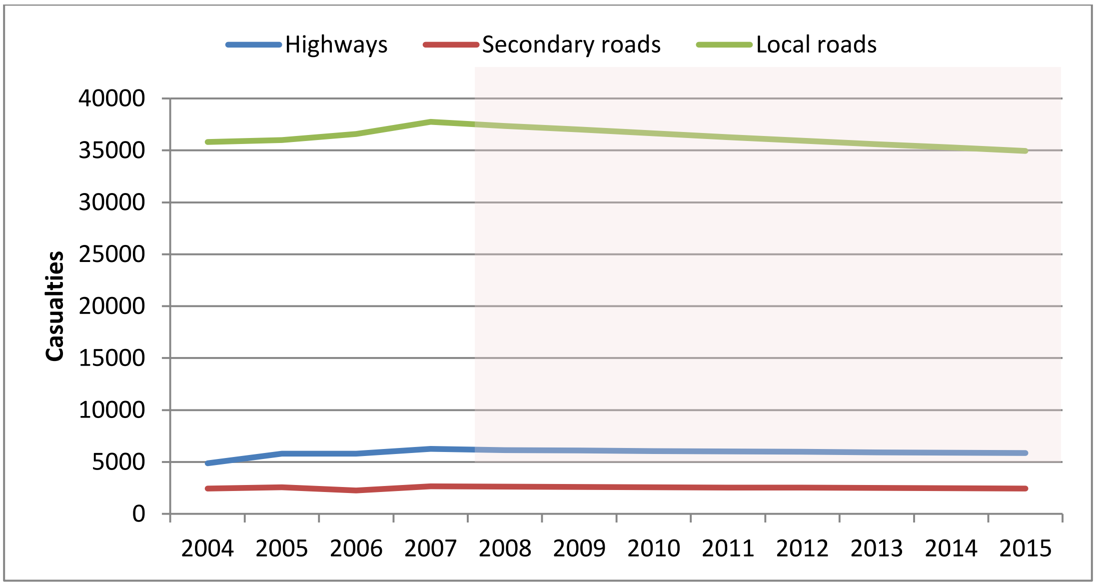

Figure 6 Casualties per road type summed over all Flemish municipalities (2004-2007: registered but inclusion of underreporting factor (slight casualties: 1.9; serious casualties: 1.3; fatalities: 1.05); 2008-2015: baseline prognosis)

5. MEASURE PROGNOSIS

5.1 Methodology

In this phase of the model, the impact of the road safety measures is calculated on the number of injury accidents, slight casualties, serious casualties and fatalities. For each measure, the number of injury accidents and casualties which can be affected by the measure and the effectiveness or the modification factor per severity level is required. The modification factor is the expected proportion of the traffic safety quantities remaining after the measure is applied.

5.1.1 Number of injury accidents and casualties which can be affected by the road safety measure

To determine the impact of a road safety measure on the road safety situation, the number of injury accidents and the number of slight casualties, serious casualties and fatalities which can be affected by the measure should be known. This is important because the modification factor will only be implemented for the accidents or casualties which can be affected by the road safety measure. For example: an increased usage of child restraints will only influence the severity of the accidents in which unrestrained children are involved.

This calculation starts with the determination of the number of injury accidents and casualties which correspond with the profile of the accidents or casualties which can be affected by the road safety measure. A detailed accident data set can be used to filter the road safety situation to the desired profile (e.g. children who are passenger of a motorized vehicle). On the other hand, an indication of the proportion of injury accidents or casualties which can be affected by the measure could be found in the literature. For example: speeding is a causal factor for 30% of the fatalities (Shinar, 2007) so speeding cameras can influence these 30% of fatalities.

In addition, the location at which the measure is implemented is also important in this stage. Two types of measures need to be distinguished with respect to the location: regional and locational measures. Flanders is defined as the region, so regional measures are applied in the region of Flanders and influence the road safety situation in all the Flemish municipalities. Locational measures are applied on a road segment in a certain municipality. However, as was described in paragraph 0, we define a road segment as all roads of a certain road type within a certain municipality. This means for example that a locational measure applied on a secondary road in municipality M influences the road safety situation on all secondary roads in that municipality M. For locational measures, it is thus important that the number of injury accidents and casualties which can be affected are known for the road segments in the municipalities which are affected.

It should be noted that in an ideal situation, traffic performance data and road safety data would be available for each kilometer of road segment within a municipality. This detailed data would provide the possibility to calculate the impact of locational measures per kilometer and not per municipality.

5.1.2 Computing effectiveness of measures

Once the number of injury accidents and casualties which can be affected by the measure are known, the effectiveness of the measure can be assessed. First, the regional measures are described after which the locational ones are explained.

a. <u>Regional measures</u>

Regional measures have an impact on road safety in the entire region of Flanders with respect to one or several categories. From the baseline prognosis, $b\_IAs_{c,t}$, $b\_SLC_{c,t}$, $b\_SC_{c,t}$ and $b\_FATs_{c,t}$ denote the number of injury accidents, slight casualties, serious casualties and fatalities respectively. It is important to notice that the baseline prognosis for year t incorporates the road safety situation in year t when no measures were taken into account in year t. However, the measures of year t-1 are considered in the calculation of the updated baseline prognosis for year t.

Assume P regional measures are applied in year t on category c with modification factors given by $V_{IAs,P}$, $V_{SLC,P}$, $V_{SC,P}$ and $V_{FATs,P}$ (deduced from international or regional literature or studies). The remaining road safety quantities in year t on category c after applying P measures are obtained by multiplying the modification factors and the road safety quantities in the baseline. This is illustrated by the following equations:

$$IAs_{c,t} = b\_IAs_{c,t} * V_{IAs,1} * V_{IAs,2} * \dots * V_{IAs,P}$$

$$SLC_{c,t} = b\_SLC_{c,t} * V_{SLC,1} * V_{SLC,2} * \dots * V_{SLC,P}$$

$$SC_{c,t} = b\_SC_{c,t} * V_{SC,1} * V_{SC,2} * \dots * V_{SC,P}$$

$$FATs_{c,t} = b\_FATs_{c,t} * V_{FATs,1} * V_{FATs,2} * \dots * V_{FATs,P}$$

b. <u>Locational measures</u>

One of the objectives of the model is to assess the effectiveness of locational measures on safety. However, not all measures can be applied on all road or intersection categories, for example a roundabout on a highway. Further, certain measures can only be implemented at locations as it may be very expensive to apply them in the entire region. Such measures are termed locational measures and only have an effectiveness at the location they are applied on. The effectiveness of locational measures on road safety is obtained as follows. Suppose K locational measures are applied at a particular location, loc, with modification factors given by $V_{IAs,K}$, $V_{SLC,K}$, $V_{SC,K}$ and $V_{FATs,K}$ for injury accidents, slight casualties, serious casualties and fatalities respectively. The remaining number of injury accidents ($IAs_{loc,t}$), slight casualties ($SLC_{loc,t}$), serious casualties ($SC_{loc,t}$) and fatalities ($FATs_{loc,t}$) at a location, loc, in year t after applying K locational measures is given by the following equations:

$$IAs_{loc,t} = b\_IAs_{loc,t} * V_{IAs,1} * V_{IAs,2} * \dots * V_{IAs,K}$$

$$SLC_{loc,t} = b\_SLC_{loc,t} * V_{SLC,1} * V_{SLC,2} * \dots * V_{SLC,K}$$

$$SC_{loc,t} = b\_SC_{loc,t} * V_{SC,1} * V_{SC,2} * \dots * V_{SC,K}$$

$$FATs_{loc,t} = b\_FATs_{loc,t} * V_{FATs,1} * V_{FATs,2} * \dots * V_{FATs,K}$$

5.1.3 Dependence among measures

The methodology utilized to compute the effectiveness of measures (paragraph 5.1.2) is based on the assumption that the effect of each measure on road safety is independent of other measures. Nevertheless, this assumption is likely to be incorrect in some cases. One would expect dependence (interactions) between some combinations of measures, For example, the combination of enforcement and communication (Elvik et al., 2009). Such interactions are not taken into account by this methodology, however have been some forms of interactions investigated in the past, such as linearity, synergy and substitution effects on road safety (Nambuusi et al., 2010). The hypothesis in this report is that the six selected measures affect road safety independently.

5.2 Application

In this phase of the model, the impact of road safety measures is calculated on the number of injury accidents, slight casualties, serious casualties and fatalities. In this report we focus on the implementation of a set of six measures on the three road categories: highways, secondary roads and local roads. The six road safety measures are described in Table 21 and more detailed information for each measure can be found in the measurement information cards in appendix 11.1 .

The following paragraphs describe successively the assessment of the six road safety measures on the road safety situation. It is important to note that the results of this illustration are highly affected by the assumptions made during the assessment process. Therefore, we want to emphasize again that the obtained numbers have no actual meaning and further development of an as realistic as possible assessment for Flanders is needed.

Table 10 Description of six road safety measures

Measure	***Year of implementation***	***Location***	***Influence on***
Campaign usage child restraints	2008	Regional	Slight casualties, serious casualties, fatalities
100 fixed speed cameras	2009	Local: secondary roads	Injury accidents, slight casualties, serious casualties, fatalities
Dynamic congestion warning system	2010	Local: highways	Injury accidents, slight casualties, serious casualties, fatalities
600 km new bicycle lanes	2011	Local: secondary roads (200km) and local roads (400km)	Injury accidents, slight casualties, serious casualties, fatalities
600 km new bicycle lanes	2012	Local: secondary roads (200km) and local roads (400km)	Injury accidents, slight casualties, serious casualties, fatalities
Section speed control	2012	Local: highways	Injury accidents, slight casualties, serious casualties, fatalities
550 km new bicycle lanes	2013	Local: local roads (550km)	Injury accidents, slight casualties, serious casualties, fatalities
Mandatory bicycle helmets for children	2014	Regional	Slight casualties, serious casualties, fatalities

5.2.1 2008: Campaign usage child restraints

The first road safety measure is taken in 2008. Suppose a regional campaign is organized in Flanders to raise the usage of child restraints. It is important to notice that an increased usage of child restraints only has an influence on the severity of the accident (i.e. number of slight casualties, serious casualties and fatalities), and not on the number of injury accidents.

First, we need to know the number of injury accidents in which unrestrained children are involved as well as the number of unrestrained children who were slightly, seriously or fatally injured in an accident per road type per municipality in 2007. The number of casualties per severity level are determined by means of a filtering process of the accident database of the Federal Government Economy (*FOD Economie, AD SEI*). Victims with an age below 12 years and who were passenger of a car (or small truck) were selected per road type and per municipality. Remember that these values should be incremented by means of the underreporting factor f_c (paragraph 3.1).

In this report, it is assumed that the proportion of children who are injured in an accident remains the same over years when no measures are taken into account. The number of casualties for the baseline prognosis of 2008 is thus determined by the following formula:

$$b\_SLC_{child,2008,c} = b\_SLC_{total,2008,c} * \frac{SLC_{child,2007,c}}{SLC_{total,2007,c}}$$ with

$b\_SLC_{child,2008,c}$ = the baseline number of slight casualties in 2008 on category c where the victim was younger than 12 years old and was a passenger of a car (or small truck)

$b\_SLC_{total,2008,c}$ = the total baseline number of slight casualties in 2008 on category c

$SLC_{child,2007,c}$ = the number of slight casualties in 2007 on category c where the victim was younger than 12 years old and was a passenger of a car (or small truck)

$SLC_{total,2007,c}$ = the total number of slight casualties in 2007 on category c

The same formula is used for serious casualties and fatalities. The total numbers for these parameters for the local roads can be found in Table 11.

It is important to notice that not all the children who were injured can be influenced by the measure because also a proportion of them were already restrained in their child restraint. Vesentini and Willems (2006) observed that almost 37% of the children between 0 and 12 year are not restrained in the car. In this report, the same percentage is assumed. This means that maximum 37% of the injuries can be avoided by the measure. However, it is assumed that the campaign increases the child restraint usage only partly to a percentage of 84% (16% of the children remains unrestrained in the car)[10]. Based on the number of restrained children in the baseline prognosis and the measure prognosis, the number of children who are additionally restrained is determined. Finally, this is the number of children who are affected by the measure. However, Schoon and van Kampen (1992) estimated that child restraints reduce the chance of a serious injury with 30% and the chance of a fatal injury with 50%. In this report, it is assumed that the chance of a slight injury is reduced by 20%. Based on these effectiveness values and the number of children who additionally use child restraints due to the measure, the number of saved casualties is determined. These calculations are shown below and illustrated for local roads in Table 11.

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[10] These numbers are calculated for Flanders by using the evolution in the percentage of children who are restrained in 2006 and 2008 in the Netherlands (SWOV, 2010), see also Appendix 11.1.1.

$$b\_SLC_{child,2008,c,not\ restrained} = b\_SLC_{child,2008,c} * 0.37$$

$$m\_SLC_{child,2008,c,not\ restrained} = b\_SLC_{child,2008,c} * 0.16$$

$$m\_SLC_{child,2008,c,additionally\ restrained} = m\_SLC_{child,2008,c,not\ restrained} - m\_SLC_{child,2008,c,not\ restrained}$$

or

$$m\_SLC_{child,2008,c,additionally\ restrained} = b\_SLC_{child,2008,c} * 0.21 \qquad (0.21 = 0.37 - 0.16)$$

$$m\_SLC_{child,2008,c,saved} = m\_SLC_{child,2008,c,additionally\ restrained} * 0.20$$

These formulas are similar for serious casualties and fatalities.

To summarize, the campaign to raise the usage of child restraints reduces the number of slight injuries, serious injuries and fatalities respectively with 36.15, 1.31 and 0.33. The number of injury accidents is not affected by this measure.

Table 11 Calculation of road safety situation on local roads for measure 2008

		IAs	***SLC***	***SC***	***FATs***	***C***
2007	total	27 945.42	34 452.22	2 975.52	321.30	37 749.04
	children in car	n.d.	869.54	21.00	3.15	893.68
2008 baseline	total	27 665.63	34 107.29	2 945.73	318.08	37 371.10
	children in car	n.d.	860.83	20.78	3.12	884.73
	children not restrained (37%)	n.d.	318.51	7.69	1.15	327.35
2008 measure	children not restrained (16%)	n.d.	137.73	3.33	0.50	141.56
	children additionally restrained	n.d.	180.77	4.36	0.65	185.79
	savings	n.d.	36.15	1.31	0.33	37.79
	total	27 665.63	34 071.13	2 944.42	317.76	37 333.31

Values are summed over all Flemish municipalities
IAs = injury accidents, SLC = slight casualties, SC = serious casualties, FATs = fatalities, C = SLC + SC + FATs
n.d.: data not determined from accident database because measure does not influence the number of injury accidents

5.2.2 2009: 100 fixed speed cameras

In 2009, suppose the secondary roads in Flanders are equipped with 100 extra fixed speed cameras. This is a locational measure applied in 100 different municipalities; only a small region around the speed camera location is affected by the measure. Due to data restrictions[11], it is assumed that the speed cameras have an influence on the road safety situation on all secondary roads in the municipality in which the camera is installed.

Extensive research showed that there is a direct relationship between driving speed on the one hand and the risk and severity of an accident on the other hand (Elvik, Hoye, Vaa, & Sorensen, 2009; Safetynet, 2009; SWOV, 2009b). Therefore, both the number of injury accidents as the number of casualties is affected by this speeding measure.

The assessment of this measure starts with the calculation of the updated baseline prognosis for 2009. Remember that in 2008 a campaign was organized which reduced the number of casualties. Therefore, the baseline prognosis for 2009 which was calculated in paragraph 4.1.2 cannot be used to estimate the effect of the speed cameras. This new baseline prognosis is estimated with the same formulas as in paragraph 4.1 , with the only exception that the road safety situation of 2008 is used as reference instead of 2007. As an example:

$br_{c,2009} = f_{2009} * r_{c,2008}$ where

$r_{c,2008} = \frac{IAs_{c,2008}}{TP_{c,2008}}$

$b\_IAs_{c,2009} = br_{c,2009} * TP_{c,2009}$

Remember that the baseline number of injury accidents in 2008 was not affected by the child seat restraints, so the injury accident risk for 2008 and 2009 according to this calculation is the same as the risk according to the formula in the baseline scenario for 2008 and 2009 (paragraph 4.1.2 a). As a result, the baseline number of injury accidents in 2009 which is determined in this step is the same as the baseline number of injury accidents according to paragraph 4.1.2 a.

However, the number of slight casualties, serious casualties and fatalities was influenced by the measure in 2008. Therefore, the updated baseline prognosis for the number of casualties in 2009 in this step differs from the baseline scenario for 2009 which was determined in paragraph 4.1.2 because in the last mentioned paragraph it was assumed that no additional measures were taken into account. The updated baseline prognosis for 2009 where the campaign of 2008 is taken into account is calculated following the approach of paragraph 4.1.2 ; with the only exception that the risk indicators are not based on the reference year but on the road safety situation of 2008:

$m\_N(0)_{c,2008} = \frac{m\_C_{c,2008}}{m\_IAs_{c,2008}}$

$m\_N(1)_{c,2008} = \frac{m\_SLC_{c,2008}}{m\_C_{c,2008}}$

$m\_N(2)_{c,2008} = \frac{m\_SC_{c,2008}}{m\_C_{c,2008}}$

$m\_N(3)_{c,2008} = \frac{m\_FATs_{c,2008}}{m\_C_{c,2008}} * 100$

Due to the measure in 2008, these risk indicators are changed and therefore the updated baseline number of casualties in 2009 differs from the number of casualties in the baseline scenario (paragraph 4.1.2).

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[11] In an ideal situation, traffic performance data and road safety data would be available for each kilometer of road segment within a municipality. This detailed data provides the possibility to calculate the impact of locational measures per kilometer and not per municipality.

Based on this new baseline prognosis for 2009 the assessment of the installation of 100 fixed speed cameras on secondary roads can start. First, we determine the number of injury accidents and casualties in which speeding was involved. According to the literature (Staten-Generaal van de Verkeersveiligheid, 2007) approximately 20 to 35% of the road accidents have an excessive or inappropriate speed as a main causal factor. In addition, Shinar (2007) found that speeding plays an important role in at least 30% of all fatalities. In this report, it is assumed that speeding is a main causal factor in 20% of all injury accidents, in 20% of the slight casualties, in 25% of the serious casualties and 30% of the fatalities. The results of these calculations are shown in Table 12.

Meta-analysis of the effectiveness of fixed speed cameras (Erke, Goldenbeld, & Vaa, 2009) showed that fixed speed cameras reduce the number of injury accidents with approximately 35% and the number of fatalities with 39%. In this report, it is assumed that the number of slight casualties and serious casualties reduces respectively by 30 and 35%. Due to the fact that this measure is a locational one, 100 secondary road segments in 100 municipalities are selected on which the 100 fixed cameras are installed. Based on the road length per municipality (*Lengte van het verharde wegennet in km 2005*: FOD Economie, AD SEI) and the estimated number of injury accidents in 2008, the 100 road secondary segments with the highest injury accident risk per kilometer road were selected.

Based on the effectiveness factors, the savings – caused by the installation of 100 fixed speed cameras – are estimated for the particular secondary road segments. These values are shown in Table 12.

Table 12 Calculation of road safety situation on secondary roads for measure 2009

		IAs	***SLC***	***SC***	***FATs***	***C***
2009 baseline	total	1 758.69	2 350.17	217.84	23.67	2 591.69
	speeding	351.74	470.03	54.46	7.10	531.60
2009 measure	savings	94.55	124.33	15.82	2.41	142.56
	total	1 664.14	2 225.85	202.02	21.26	2 449.13

Values are summed over all Flemish municipalities
IAs = injury accidents, SLC = slight casualties, SC = serious casualties, FATs = fatalities, C = SLC + SC + FATs

5.2.3 2010: Dynamic warning congestion system

Suppose that in 2010 several highway segments in Flanders are equipped with a dynamic warning congestion system.

Before starting the assessment of this measure, the baseline road safety situation for 2010 is calculated. This baseline prognosis estimates the number of injury accidents and casualties when no measure is taken in 2010 but it takes into account the effects of the measures in 2008 and 2009, the change in traffic performance and the change in autonomous risk.

The selection of the 12 highway segments on which the system is installed, has been done in consultation with the Flemish Government (see appendix 11.1.3). Based on this selection, we estimate the number of rear-end injury accidents on these highway sections by means of the accident database of the Federal Government Economy (*FOD Economie*) (*AD SEI*) for the reference year 2007. These road safety numbers were corrected with the underreporting factor of 1.75 (Elvik & Mysen, 1999). The baseline number of injury accidents on the selected highway segments for 2010 is determined by means of the following formula:

$$b\_IAs_{congestion,2010} = b\_IAs_{total,2010} * \frac{IAs_{congestion,2007}}{IAs_{total,2007}}$$ with

$b\_IAs_{congestion,2010}$	= the baseline number of rear-end injury accidents in 2010 on the selected highway segments
$b\_IAs_{total,2010}$	= the total baseline number of injury accidents in 2010 on highways
$IAs_{congestion,2007}$	= the number of rear-end injury accidents in 2007 on the selected highway segments
$IAs_{total,2007}$	= the total number of injury accidents in 2007 on highways

The baseline number of slight casualties, serious casualties and fatalities due to rear-end accidents in 2010 is determined by means of the risk indicators which are based on the updated baseline road safety situation of 2010. Table 12 shows that approximately 28.5% of all injury accidents on highways were rear-end accidents on the selected highway segments. Depending on the severity level, approximately 24 to 30% of all casualties occurred in these kind of rear-end accidents.

The effectiveness of the dynamic congestion warning system can now be assessed on the updated baseline road safety situation of 2010. According to the Flemish road safety plan (Departement Mobiliteit en Openbare Werken, 2008), this measure has the potential to reduce the number of rear-end injury accidents with 25 to 30%. The highest effectiveness factor is used because the literature showed that this measure has the potential to reduce the number of secondary collisions at the end of the queue with 46% (Departement Mobiliteit en Openbare Werken, 2008; Pesti et al., 2008). In this report, we use thus an effectiveness factor of 30% for injury accidents. In addition, it is assumed that the number of slight casualties, serious casualties and fatalities reduces with 30%.

Table 13 Calculation of road safety situation on highways for measure 2010

		IAs	***SLC***	***SC***	***FATs***	***C***
2007	total	4 156.30	5 351.69	823.91	77.70	6 253.31
	rear-end	1 181.60	n.d.	n.d.	n.d.	n.d.
2010 baseline	total	4 015.17	5 178.79	794.24	74.99	6 048.02
	rear-end	1 148.79	1,570.57	215.05	18.06	1,803.69
2010 measure	savings	344.64	471.17	64.52	5.42	541.11
	total	3 670.53	4 707.62	729.72	69.58	5 506.91

Values are summed over all Flemish municipalities
IAs = injury accidents, SLC = slight casualties, SC = serious casualties, FATs = fatalities, C = SLC + SC + FATs
n.d.: data not determined from accident database

5.2.4 2011: 600 kilometer new bicycle lanes

In the period 2011-2013 suppose that secondary and local roads are equipped with 1750 kilometer new bicycle lanes. In 2011 a total of 600 kilometer is constructed of which 200 kilometer on secondary roads and 400 kilometer on local roads.

Just as with the calculation of the previous measures, the updated baseline prognosis for 2011 is determined. This baseline prognosis describes the road safety situation for 2011 when no measures are assessed in 2011 but when the measures between 2008 and 2010 are taken into account.

Because this measure influences the safety situation of the bicyclists, the number of injury accidents with a bicyclist and the number of bicyclists who were slightly or seriously injured or who died in an accident were selected from the accident data base for 2007 (*FOD Economie*) (*AD SEI*). These numbers are augmented with the underreporting factors (paragraph 3.) and the updated baseline prognosis for 2011 is estimated.

Based on this updated baseline prognosis, the accident risk per kilometer per road type per municipality is calculated. The municipalities with the highest accident risk per kilometer are selected: the top 20 for the secondary roads and the top 40 for the local roads. In each selected municipality, 10 kilometer of new bicycle lanes are constructed on the concerning road type. This results in 200 kilometer new bicycle lanes on secondary roads (20 x 10km) and 400 kilometer on local roads (40 x 10km).

In this report, it is assumed that in the selected municipality half of the bicycle accidents and casualties occur on road segments which will be equipped with new bicycle lanes (see Table 14 "bicycle on selected segments"). This is a rough estimation because the exact accident location is not included in the accident data base (*FOD Economie*) (*AD SEI*). However, when the road safety situation and the traffic performance situation are allocated to a GIS-layer, a more detailed estimation of the influence of this measure on road safety can be made.

Walter et al. (2005) (in Departement Mobiliteit en Openbare Werken, 2008) estimate the effectiveness of an improved bicycle network as 50% for fatalities. In this report, it is assumed that the number of injury accidents, slight casualties, serious casualties and fatalities is halved on the road segments where the bicycle lanes are constructed.

Table 14 shows the calculation of the road safety situation on local roads when 400 kilometer new bicycle lanes are constructed.

Table 14 Calculation of road safety situation on local roads for measure 2011

		IAs	***SLC***	***SC***	***FATs***	***C***
2007	total	27 945.42	34 452.22	2 975.52	321.30	37 749.04
	bicycle	6 637.12	5 736.39	458.46	38.85	6 233.69
2011 baseline	total	26 865.82	33 086.14	2 859.29	308.57	36 254.01
	bicycle	6 380.71	5 509.67	440.67	37.31	5 987.65
	bicycle on selected segments	1 463.93	1 281.65	55.86	3.03	1 340.54
2011 measure	savings	731.97	640.82	27.93	1.51	670.27
	total	26 133.85	32 445.32	2 831.36	307.06	35 583.74

Values are summed over all Flemish municipalities
IAs = injury accidents, SLC = slight casualties, SC = serious casualties, FATs = fatalities, C = SLC + SC + FATs

5.2.5 2012: 600 kilometer new bicycle lanes & Section speed control

In 2012 an additional 600 kilometer of new bicycle lanes are installed, of which 200 kilometer is located on secondary roads and 400 kilometer on local roads. The procedure to estimate the effects on the road safety situation is similar to the assessment of the measure in 2011 (paragraph 0). The results for local roads are shown in Table 15.

Table 15 Calculation of road safety situation on local roads for bicycle lanes 2012

		IAs	***SLC***	***SC***	***FATs***	***C***
2007	total	27 945.42	34 452.22	2 975.52	321.30	37 749.04
	bicycle	6 637.12	5 736.39	458.46	38.85	6 233.69
2012 baseline	total	25 886.26	32 137.93	2 804.54	304.15	35 246.62
	bicycle	5 595.23	4 822.72	408.83	35.46	5 267.01
	bicycle on selected segments	773.83	672.98	44.83	1.25	719.06
2012 measure	savings	386.91	336.49	22.41	0.62	359.53
	total	25 499.35	31 801.45	2 782.13	303.52	34 887.09

Values are summed over all Flemish municipalities
IAs = injury accidents, SLC = slight casualties, SC = serious casualties, FATs = fatalities, C = SLC + SC + FATs

In addition to the construction of new bicycle lanes, suppose three highway segments are equipped with a section speed control system in 2012:

- E19 Antwerpen < > Rumst
- E40 Aalter < > Oosterzele
- E314 Diest < > Leuven

The number of injury accidents and casualties in 2007 on these highway segments is determined by means of the accident data base (*FOD Economie*, *AD SEI*). These numbers are augmented with the underreporting factors (paragraph 3.) and the updated baseline prognosis for 2012 is estimated. Based on this baseline prognosis the number of injury accidents and casualties involving speeding at the base is estimated. According to the literature (Staten-Generaal van de Verkeersveiligheid, 2007) approximately 20 to 35% of the road accidents have an excessive or inappropriate speed as a main causal factor. In addition, Shinar (2007) found that speeding plays an important role in at least 30% of all fatalities. In this report, it is assumed that speeding is a main causal factor in 20% of all injury accidents, in 20% of the slight casualties, in 25% of the serious casualties and 30% of the fatalities. The results of these calculations are shown in Table 16.

The effectiveness of the section speed control system is assessed on the baseline speeding accidents and casualties. According to Stefan (2006) section speed control reduces the number of injury accidents with 33.3%, the number of slightly injuries with 32.2% and the number of serious and fatal injuries with 48.8%. These effectiveness factors are also used for the reduction casualties per severity level.

Table 16 Calculation of road safety situation on highways for section speed control (SSC) 2012

		IAs	SLC	SC	FATs	C
2007	total	4 156.30	5 351.69	823.91	77.70	6 253.31
	segments SSC	651.00	803.70	153.40	11.55	968.65
2012 baseline	total	3 620.61	4 643.60	719.79	68.63	5 432.02
	segments SSC	581.09	712.56	136.21	10.44	859.20
	speeding on segments SSC	116.22	142.51	34.05	3.13	179.70
2012 measure	savings	38.70	45.89	16.62	1.53	64.03
	total	3 581.91	4 597.71	703.18	67.10	5 367.99

Values are summed over all Flemish municipalities
IAs = injury accidents, SLC = slight casualties, SC = serious casualties, FATs = fatalities, C = SLC + SC + FATs

5.2.6 2013: 550 kilometer new bicycle lanes

In 2013, the last 550 kilometer of a total of 1750 kilometer of new bicycle lanes are supposed to be constructed on local roads. In the 55 municipalities with the highest estimated accident risk per kilometer on local roads in 2013, 10 kilometer of bicycle lanes is constructed. The assessment of the effects on the road safety situation are similar to the procedure of 2011 (paragraph 0) and 2012 (paragraph 0). Table 17 shows the results of these calculations.

Table 17 Calculation of road safety situation on local roads for measure 2013

		IAs	SLC	SC	FATs	C
2007	total	27 945.42	34 452.22	2 975.52	321.30	37 749.04
	bicycle	6 637.12	5 736.39	458.46	38.85	6 233.69
2013 baseline	total	25 260.77	31 503.91	2 756.10	300.68	34 560.69
	bicycle	5 159.59	4 444.26	382.80	34.51	4 861.57
	bicycle on selected segments	1 196.99	1 042.27	65.33	4.64	1 112.24
2013 measure	savings	598.50	521.13	32.67	2.32	556.12
	total	24 662.28	30 982.78	2 723.43	298.36	34 004.57

Values are summed over all Flemish municipalities
IAs = injury accidents, SLC = slight casualties, SC = serious casualties, FATs = fatalities, C = SLC + SC + FATs

5.2.7 2014: Mandatory bicycle helmets for children

The last measure which is taken into account in this computational model is the mandatory use of bicycle helmets for children in Flanders. The bicycle helmet is a passive safety measure so the severity (and not the chance) of the accidents is affected.

Similar to the assessment of the previous measures, the updated baseline prognosis for 2013 is made and the number of children (younger than 12 year) who are involved in injury accidents with their bicycle are determined by means of the accident data base (*FOD Economie*, *AD SEI*). It is important to note that the majority of the bicycle accidents occur on intersections (Departement Mobiliteit en Openbare Werken, 2008). This is an explanation for the fact that the number of fatalities on road segments with cycling children is very low in 2007.

In this report, it is assumed that when the bicycle helmet was not mandatory 10% (Lammar, 2005) of the children wear a bicycle helmet, in 2014. Due to this measure, the percentage of children who wear a helmet during cycling is supposed to increase to 80%.

In this report, the head injury risks of Table 18 are used. As an example: 44% of the serious casualties who do not wear a helmet have a head injury (based on Elvik et al., 2009). When someone wears a helmet, the risk of serious head injury decreases with 60% (Elvik et al., 2009) to a percentage of 26.4%.

Table 19 shows the results of the assessment of this measure. Remember that the majority of the bicycle accidents occur on intersections. The mandatory use of bicycle helmets for children will thus also decrease the number of casualties on intersections.

Table 18 Head injury risk per severity level with and without a helmet

	Without helmet	***With helmet***
Slight casualties	20% (assumption)	12% (= 0.20 * 0.60)
Serious casualties	44% (based on Elvik et al., 2009)	26.4% (= 0.44 * 0.60)
Fatalities	50% (assumption)	30% (= 0.50 * 0.60)

Table 19 Calculation of road safety situation on local roads for measure 2014

		IAs	*SLC*	*SC*	*FATs*	*C*
2007	total	27 945.42	34 452.22	2 975.52	321.30	37 749.04
	children with bicycle	n.d.	383.82	21.62	0.00	405.44
2014 baseline	total	24 434.30	30 696.37	2 698.26	295.60	33 690.23
	children with bicycle	n.d.	337.16	18.88	0.00	356.04
	children with bicycle without helmet (90%)	n.d.	303.45	16.99	0.00	320.44
	children with bicycle with helmet (10%)	n.d.	33.72	1.89	0.00	35.60
	children with bicycle without helmet with head injury	n.d.	60.69	7.48	0.00	68.17
	children with bicycle with helmet with head injury	n.d.	4.05	0.50	0.00	4.54
	total children with bicycle with head injury	n.d.	64.74	7.97	0.00	72.71
2014 measure	children with bicycle without helmet (20%)	n.d.	67.43	3.78	0.00	71.21
	children with bicycle with helmet (80%)	n.d.	269.73	15.10	0.00	284.83
	children with bicycle without helmet with head injury	n.d.	13.49	1.66	0.00	15.15
	children with bicycle with helmet with head injury	n.d.	32.37	3.99	0.00	36.35
	total children with bicycle with head injury	n.d.	45.85	5.65	0.00	51.50
	savings	n.d.	18.88	2.33	0.00	21.21
	total	24 434.30	30 677.49	2 695.93	295.60	33 669.02

Values are summed over all Flemish municipalities
IAs = injury accidents, SLC = slight casualties, SC = serious casualties, FATs = fatalities, C = SLC + SC + FATs
n.d.: data not determined from accident database because measure does not influence the number of injury accidents

6. SAVINGS

6.1 Methodology

When the effectiveness of the regional and locational measures is calculated, the number of saved injury accidents, slight casualties, serious casualties and fatalities can be determined. The number of saved quantities results from the difference between the corresponding baseline and measure prognoses. For example, the saved number of IAs on category c in a specific year t equals to the difference between the number of IAs according to the updated baseline prognosis and the measure prognosis in that year. If $BP\_IAs_{c,t}$ and $MP\_IAs_{c,t}$ denote the number of IAs in the baseline prognosis and measure prognosis respectively, then the corresponding number of saved injury accidents, $S\_IAs_{c,t}$ is obtained as follows:

$$S\_IAs_{c,t} = BP\_IAs_{c,t} - MP\_IAs_{c,t}$$

The saved number of slight casualties, serious casualties and fatalities is calculated using the same procedure.

6.2 Application

In this stage of the computational model, an overview of the savings of the set of measures is given. In paragraph 5.2 , we provided the procedure for the assessment of the measures and we gave an illustration of the effects on one road type. In this paragraph, the results for the three road types are given. It is important to note that the description of the methodology and the inventory of the data needs are the main focus of this report. We implemented the model using an illustration which is based on the most recent data sets available at the start of this study (end of 2010). The results of this example are highly affected by the assumptions made during the assessment process. Therefore, we want to emphasize that the obtained numbers have no actual meaning and further development of an as realistic as possible assessment for Flanders is needed.

Before we give a summary of the savings computed in the model, we provide a short summary of the main assumptions which were made during the computational process. By means of this list, we would like to stress the fact that the results of this illustration have no actual meaning because they are highly affected by the several assumptions that had to be made during the assessment process. Whereas the assumptions for each road safety measure are described in the measurement information cards (see appendix 11.1), the main assumptions are listed below:

- Reference year
  - A certain road safety measure is always applied to all road segments of a certain road category in a certain municipality.
  - Two corrections for underreporting are used:
    - The Flemish correction factor which adjusts for the different numbers of PV's and VOF's
    - The internationally recognized underreporting factors of Elvik and Mysen (1999)
- Baseline prognosis
  - Because the traffic performance data per road type for 1985-2007 contains no data per municipality, we have to assume that all road segments belonging to a particular road type have the same growth rate for traffic performance as that category, thus the growth rate is independent on the municipality.
  - Because the Flemish injury accident data from 1985-2007 makes no distinction between the three road types or between road segments and intersections, we assume that the autonomous risk change is independent

on the road type and the accident location (i.e. road segment or intersection).

- Measurement prognosis: see measurement information cards (appendix 11.1).

When we compare the road safety situation of 2015 with the reference year 2007, we establish that the number of injury accidents and casualties is reduced with respectively, 4 649 and 5 800. This reduction is partly caused by the growth in traffic performance and the change in autonomous risk (2 408 injury accidents; 3 312 casualties) and partly by the road safety measures (2 241 injury accidents; 2 488 casualties). The number of savings per road type are illustrated in Figure 7 and Figure 8.

In the case that no measures are taken between 2008 and 2014 (i.e. the baseline prognosis or business-as-usual presented in paragraph 4.) the number of injury accidents and casualties decreases respectively with 2 475 and 3 390 between 2007 and 2015, due to the growth in traffic performance and the change in autonomous risk. The evolution in the number of injury accidents and casualties per road type for both the baseline prognosis and the measurement prognosis is shown in Figure 9.

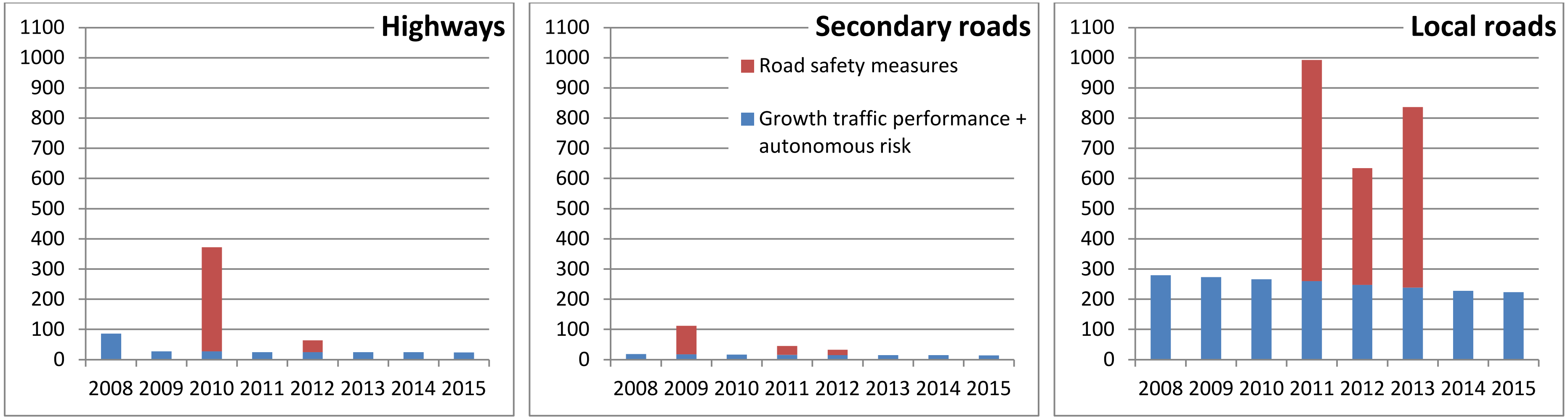

Figure 7 Totally saved injury accidents

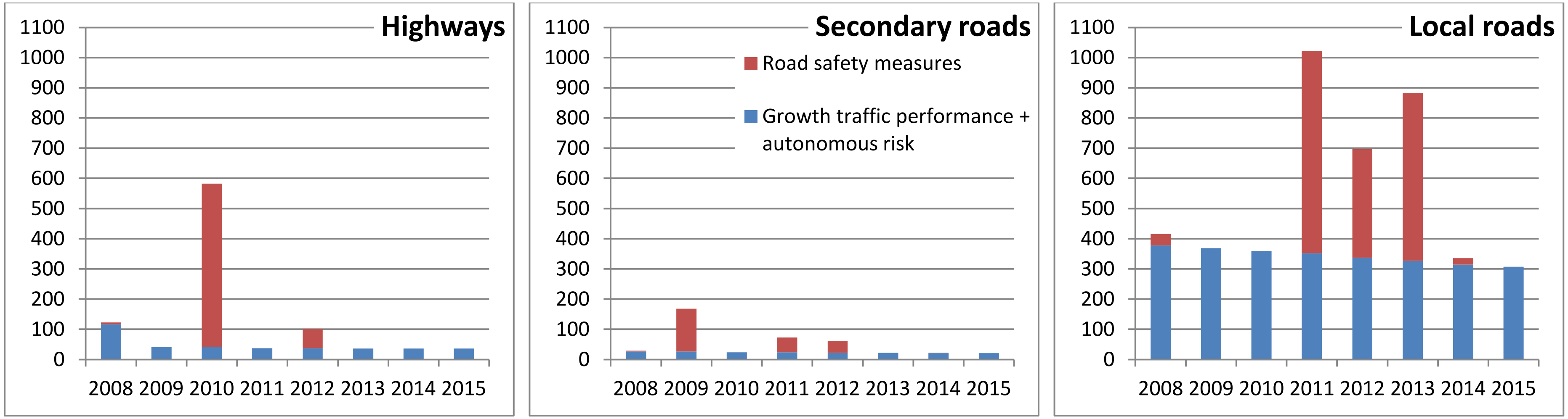

Figure 8 Totally saved casualties

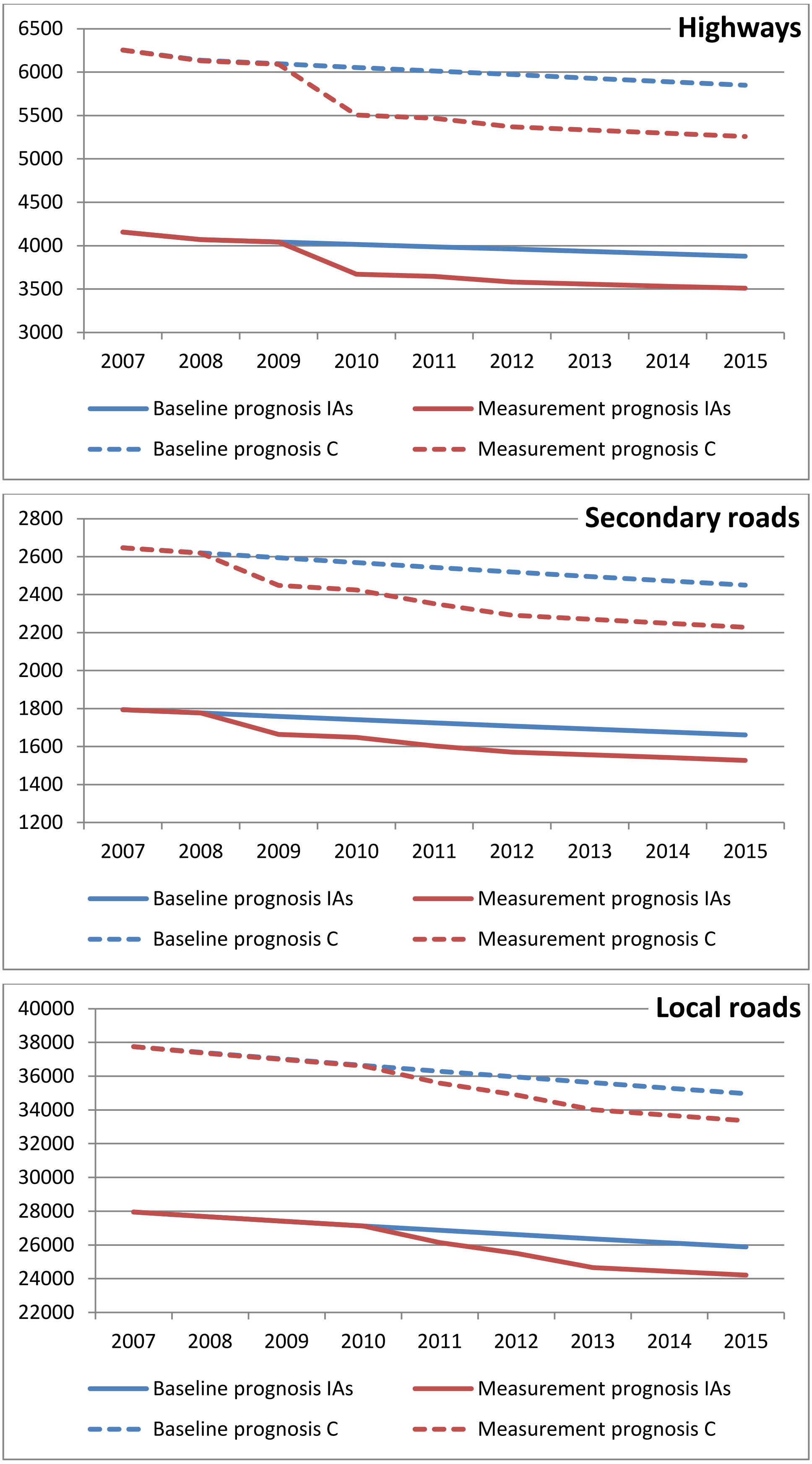

Figure 9 Evolution of the road safety situation per road type (2007-2015)

7. COST-BENEFIT ANALYSIS

7.1 Methodology

In order to determine the benefits of the applied regional and locational measures, the value of an injury accident, a slight casualty, a serious casualty and a fatality must be expressed in euros. A cost-benefit analysis is one of the tools used to assess the possible measures by comparing their profitability. This analysis allows the comparison of measures with a different life span and justifies the choice between possible combinations of measures. Here, we focus on two criteria namely: net cash value (NCV) and cost-benefit ratio (CBR).

7.1.1 Benefits

The benefits $B_{c,t}$ in year t on category c, are the products of the number of saved quantities and the values in euros corresponding to a particular road safety quantity. Let W_{IAs}, W_{SLC}, W_{SC} and W_{FATs} denote the monetary value of an injury accident, a slight casualty, a serious casualty and a fatality respectively. Then, $B_{c,t}$ is given by:

$$B_{c,t,} = \left(S\_IAs_{c,t} * W_{IAs}\right) + \left(S\_SLC_{c,t} * W_{SLC}\right) + \left(SC_{c,t} * W_{SC}\right) + \left(FATs_{c,t} * W_{FATs}\right)$$

The total sum of benefits over all categories, C, in year t is obtained by summing the benefits on all categories in that year i.e. $B_{C,t} = \sum_{c=1}^{C} B_{c,t}$.

7.1.2 Costs

The total cost per year is determined by summing the cost of regional and locational measures. Measure costs on road categories are calculated per kilometre while those of intersection categories are estimated per piece. In the following sections an explanation of how the costs of regional and locational measures are calculated is given. The calculations for regional costs are presented first and those of locational costs will follow.

a. Costs of a regional measure

Suppose a set m contains j regional measures i.e. m=1, 2,…, j and the cost of measure j in year t is denoted by $R_{j,t}$. If these measures are applied in year t, on category c, the total cost $R_{c,t}$ of the applied regional measure set on category c in year t equals the total cost of all measures as follows:

$$R_{c,t} = \sum_{j=1}^{j} R_{j,t}$$

The total cost, R_t, of all regional measures in year t on all road categories C equals:

$$R_t = \sum_{c=1}^{C} R_{c,t}$$

b. Costs of a locational measure

Let a set m contain n locational measures i.e. m=1, 2,…, n that are introduced at locations belonging to category c in year t. Let $L_{n,t}$ be the cost of locational measure n applied in year t. The total cost $L_{c,t}$ of the applied locational measures on category c in year t then equals:

$L_{c,t} = \sum_{1}^{n} L_{n,t} * l_m$ with

l_m = length of the road segment if the measure is applied on a road segment

l_m = 1 if the measure is applied on an intersection

The total cost, L_t, of all locational measures applied in year t on all road categories equals:

$$L_t = \sum_{c=1}^{C} L_{c,t}$$

The overall costs in year t are determined by summing the cost of regional and locational measures: $R_t + L_t$.

7.1.3 Benefits versus costs

a. The cash value of costs (CVC)

The CVC is obtained by expressing the total costs in year t of all the applied measures in terms of the nominal value of the reference year using a discount rate R as below:

$CVC = \sum_{t=1}^{t} \frac{R_t + L_t}{(1+R)^t}$ with

R	= discount rate for the entire calculation period
L_t	= cost of locational measures in year t
R_t	= cost of regional measures in year t
t	= last year of the calculation period

b. The cash value of benefits (CVB)

The CVB is calculated by expressing the total benefits over all categories C in year t in terms of the nominal value of the reference year using a discount rate R as follows:

$CVB = \sum_{C=1,t=1}^{C,t} \frac{B_{C,t}}{(1+R)^t}$

c. The net cash value (NCV)

The NCV is the difference between the cash value of costs (CVC) and the cash value of benefits (CVB) and is computed by the following expression:

$NCV = CVB - CVC$

A set of measures is profitable when the NCV is positive. However, when the NCV is used large measure sets (with large costs and benefits) are given preference as they have higher NCV than smaller measure sets.

d. The cost-benefit ratio (CBR)

The cost-benefit ratio is the ratio between the cash value of costs and benefits and indicates how much higher the costs are compared to the benefits and it is computed as:

$CBR = CVC/CVB$

It is possible to have negative benefits in a cost-benefit analysis. The negative benefits should not be added to the costs but should be deducted from the positive benefits. Adding negative benefits to the costs would wrongfully lead to a lower CBR. This is one of the disadvantages of the CBR (Janssen, 2005). Another limitation of the CBR is that all effects need to be expressed in monetary terms. On the other hand, a cost-benefit analysis has the advantage of taking into account both the intended effects such as the construction costs and side effects for example noise nuisance (Vlakveld, Wesemann, Devillers, Elvik, & Veisten, 2005). Further, the CBR is useful for comparing the profitability of measures with varying costs (Janssen, 2005). The NCV and the CBR rank projects according to their net benefit. Thus, it remains a practical tool for the comparison of several possible measures (Ampe, Geudens, & Macharis, 2008).

Apart from the cost-benefit analysis, there are other evaluation tools. These are briefly described with their advantages and disadvantages. The first method used for measure assessment is the cost-effectiveness analysis (CEA). This method is often used to determine the effectiveness of measures. This is done using a ratio of saved victims versus the cost attached to the measure. This method only includes the intended effects (safety effects in this case) and the costs incurred to attain these effects. However, in order to make policy decisions it is required to have insight into all relevant social effects and not only the intended ones (Vlakveld et al., 2005).

Another tool is the cost utility analysis (CUA). This is comparable to the CEA. The only difference is that the CUA uses quality adjusted life years as a basic concept. While in the CEA counting is done in amount of life years, the CUA uses a weighting for the life years in terms of quality of life. This tool takes into account the severity of an injury and the disability related to the injury. One barrier to this tool is that the kind of medical data required is not always available (Ampe et al., 2008).

In case of multiple decisions, methods that handle several criteria are required. One of the options is the multi-criteria analysis or multi-criteria decision analysis (MCDA). A MCDA groups several methods and techniques, structures the decision problem and supports decision making (Ampe et al., 2008).

7.2 Application

In this report, the cost-benefit analysis is illustrated for one of the six measures: the implementation of the dynamic congestion warning system on 12 highway segments. The cost-benefit analyses for the other road safety measures is not illustrated because detailed cost values for each measure are presently not available. Before the NCV and the CBR can be calculated, the costs and benefits should be known. Therefore, the savings should be valued in a monetary value (euro). In this report, the Belgian monetary values determined by De Brabander and Vereeck (2007) and De Brabander (2006) are used:

- Injury accident: € 6 516
- Slight injury: € 20 943
- Serious injury: € 725 512
- Fatality: € 2 004 799

Based on the number of saved injury accidents and casualties due to the dynamic congestion warning system and the monetary values above, the benefits of this measure amount to 69 789 432 euro.

$$B_{highway,2010} = (344.64\ saved\ IAs * €6\ 516) + (471.17\ saved\ SLC * €20\ 943) + (64.52\ saved\ SC * €725\ 512) + (5.42\ saved\ FATs * €2\ 004\ 799) = €69\ 789\ 432$$

The total cost of the installation is estimated at 48 700 000 euro (see Appendix 11.1.3).

In addition, the discount rate of 4,5%[12] should be taken into account to compute the cash value of the costs and benefits. For the calculation of the cash values, it is assumed that the reference year (2007) is year 0. The dynamic congestion warning system was implemented in 2010, thus this is year 3. Because only one measure is considered in the illustration of the cost-benefit analysis, it is assumed that only this measure is implemented. Therefore the cash value of the benefits and the costs is:

$$CVB = \frac{69\ 789\ 432}{(1+0.045)^3} = 61\ 156\ 242.26$$

$$CVC = \frac{48\ 700\ 000}{(1+0.045)^3} = 42\ 675\ 644.62$$

In conclusion, the cost-benefit analysis of the implementation of the dynamic congestion warning system results in a positive net cash value of 18 480 598 euro. In addition, the cost-benefit ratio is 1.43 which means that every euro which is invested, brings almost 1.5 euro in. Both parameters show that this measure is socially and economically justified. It should be noted that this cost-benefit analysis is rather limited because only the costs of the installation and the benefits of the saved injury accidents and casualties

[12] Average discount rate in Belgium in 2007 (European Commission, 2012).

in 2010 are taken into account. The fact that less accidents occur will for instance decrease the number of hours lost due to congestion, and as a result the emissions and the noise nuisance will also decrease. In addition, this cost-benefit analysis considers only the costs and benefits in 2010. Therefore, future costs and benefits, such as maintenance and long term road safety effects are disregarded.

8. LIMITATIONS AND FUTURE RESEARCH

Despite the advanced development of the model there are some aspects that should be taken into account in future research and use.

Firstly, detailed data sets about the traffic performance and the road safety situation are the basis of the model. The data sets should make a distinction between intersections and road segments and between different road types (e.g. highways, secondary roads and local roads) and intersection types. In addition, these data should be available for each municipality. As described in paragraph 0, the integration of a localized accident data base and the traffic performance data set into a GIS-lay may generate large opportunities for a detailed and more realistic assessment of the methodology. As an example, a more detailed distinction could be made between road segments and intersections inside or outside an urban area[13]. However, it is important to note that this more detailed categorization for the road safety situation requires also more detailed information concerning the traffic performance and, if meaningful, the effectiveness of the road safety measure for each of the categorization types. Furthermore, it takes time before all data are available. For this study, road safety data per road type and per municipality for 2007 was used because this data was – relatively easily – available at the start of the data needs inventory (which occurred by the end of 2010). By using this data set, a measure will always affect the road safety situation in the involved municipality on all road segment locations of the involved road type and thus not only one street. Another data issue we have to consider is the reference year. In small regions as Flanders, it might be a good idea to use mean accident values for several years rather than a single year to correct for the regression-to-the-mean issue. It is worth noting that, due to the rather limited level of realism, the results of this illustration are highly affected by the assumptions made during the assessment process. Therefore, we emphasized that the obtained numbers have no actual meaning and further development of an assessment for Flanders is needed. To summarize: the model is only as strong as its weakest link. Based on this study, the government can decide to elaborate more on the development of detailed data sets concerning the road safety situation and the traffic performance situation. However, one must keep in mind that this elaboration is only useful when the selected road safety measures are distinguished to such detailed level.

Secondly, it should be clearly defined which measures will be implemented where and when. The exact allocation of a road safety measure to a certain location or road segment might be facilitated by a GIS-application. Furthermore, possible interaction effects when different, dependent, road safety measures are combined should be considered. In addition, more detailed information about the costs and benefits should be known to support the cost-benefit analysis.

Lastly, there are often no Flemish effectiveness figures available so we have to focus on international studies. Furthermore, these effectiveness figures are susceptible to a wide range. In addition, international literature should be consulted to determine the accident profile. It is worth noting that, due to the limited information available for Flanders, the results of this illustration are highly affected by the assumptions made during the assessment process[14]. More effort could be devoted to fulfilling all data needs.

To conclude, a detailed GIS-application based on this methodology might increase the realism of this Flemish model and might result in a good tool to support policy decisions.

[13] This distinction might be useful because the differences in road environment and road users present have an influence on the accident risk (Van Hout and Brijs, 2008).
[14] See paragraph 6.2 for a list of the general assumptions and appendix 11.1 for the assumptions made concerning the road safety measures.

9. CONCLUSION

The Flemish computational model which is described and illustrated in this report shows the opportunity to calculate the effects of a set of road safety measures by means of five stages. The model starts with the description of the traffic performance and safety situation in the reference year (2007). Afterwards the baseline prognosis and the measure prognosis are computed. The baseline prognosis contains the road safety situation before the impact of measures is taken into account but with the inclusion of the change in traffic performance and the change in autonomous risk. However, in the measure prognosis the safety effects of the selected road safety measures are calculated by taking the safety effectiveness of the measures into account. Based on these prognoses the number of saved injury accidents and casualties is calculated and a cost-benefit analysis can be conducted.

The ~~model~~ proposed methodology provides policy makers the possibility to predict the extent to which the proposed measures would contribute to the attainment of road safety objectives that are set. In addition, the results from the cost-benefit analysis help in judging the profitability of the measures.

It is important to note that the description of the methodology and the inventory of the data needs is the main focus of this report. In addition, we implemented the model with an illustration which is based on the most recent data sets available at the start of this study (end of 2010). This study illustrated the methodology by considering the traffic performance and road safety situation on highway, secondary and local road segments in Flanders. 2007 was the reference year and a prognosis of the road safety situation on road segments in Flanders by 2015 was obtained when on the one hand, a set of six road safety measures from the road safety plan Flanders would be implemented and on the other hand, general trends such as the growth in traffic performance and the change in autonomous risk are accounted for. The resulting number of saved injury accidents and casualties was computed but it needs to be stressed that these results are highly affected by the assumptions made during the assessment process[15]. Therefore we want to emphasize that the obtained numbers have no actual meaning and further development of an as realistic as possible assessment for Flanders is needed. The illustration is thus a proof of concept.

[15] See paragraph 6.2 for a list of the general assumptions and appendix 11.1 for the assumptions made concerning the road safety measures.

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11. APPENDIX

11.1 Measurement information cards

11.1.1 Campaign usage child restraints

<table>
<tr><td>Measurement description</td><td>A regional campaign is organized in Flanders to raise the usage of child restraints. The measure has thus an influence on the number of casualties below an age of 12 years who were passenger of a car (or truck).

This measure is a pure assumption and is not based on any policy document.</td></tr>
<tr><td>Year of implementation</td><td>2008</td></tr>
<tr><td>Road category</td><td>Regional: highways, secondary roads and local roads</td></tr>
<tr><td>Effectiveness</td><td>Slight injury reduction: 20% (assumption based on Schoon and van Kampen, 1992)

Serious injury reduction: 30% (Schoon and van Kampen, 1992)

Fatality injury reduction: 50% (Schoon and van Kampen, 1992)</td></tr>
<tr><td>Other assumptions</td><td>- The campaign decreases the percentage of children who are not restrained in the car from 37% to 16%. This assumption is based on the Dutch evaluation on the percentage of children who were restrained in 2006[16] and 2008 (SWOV, 2010).
<table>
<tr><th>Year</th><th>The Netherlands (SWOV 2010)</th><th>Flanders (VV-plan)</th></tr>
<tr><td>2006</td><td>28%</td><td>37%</td></tr>
<tr><td>2007</td><td>20%</td><td>26.4%</td></tr>
<tr><td>2008</td><td>12%</td><td>15.9%</td></tr>
</table>
Recently, a national behavioral survey concerning the usage of child restraint systems was organized in Belgium (BIVV, 2012). The results for Flanders show that 11% of the children was not restrained. In addition, 14% of the children was not correctly restrained. Furthermore, the study shows that the percentage of children who are not restrained increases gradually with their age. Therefore, an optimal model might include different percentages for different age categories.</td></tr>
</table>

[16] Since 2006, a new European measure obligated children (smaller than 1.35m) to be restrained in a child seat.

11.1.2 100 fixed speed cameras

Measurement description	Some secondary roads in Flanders are equipped with extra fixed speed cameras. In total, 100 cameras are installed. This measure is a pure assumption and is not based on any policy document.
Year of implementation	2009
Road category	Local: secondary roads
Effectiveness	Injury accident reduction: 35% (Erke et al., 2009) Slight injury reduction: 30% (assumption based on Erke et al., 2009) Serious injury reduction: 35% (assumption based on Erke et al., 2009) Fatality injury reduction: 39% (Erke et al., 2009)
Other assumptions	- It is a locational measure applied in 100 different municipalities; only a small region around the speed camera is affected by the measure. Due to data restrictions, it is assumed that the speed cameras have an influence on the road safety situation on all secondary roads in the municipality in which the camera is installed. In an ideal situation, traffic performance data and road safety data would be available for each location on the Flemish road network. This detailed data provides the possibility to calculate the impact of locational measures per kilometer and not per municipality. - Speeding is a main causal factor in 20% of all injury accidents, in 20% of the slight casualties, in 25% of the serious casualties and 30% of the fatalities. - The 100 municipalities with the 100 highest injury accident risk per kilometer road are selected for the installation of the 100 fixed speed cameras. It is assumed that the road safety situation in the other municipalities is not influenced by this measure.

11.1.3 Dynamic warning congestion warning system

Measurement description	Several highway segments in Flanders are equipped with a dynamic warning congestion system. The selection of the highway segments on which the system is installed, is done in consultation with the Flemish Government: - E34 Zelzate < > Antwerpen (€ 2,5mio) - E17 Rekkem < > Antwerpen (€7,6mio) - E19 Meer < > Machelen (€ 5,4mio) - A12 Zandvliet < > Stroombeek-Bever (€ 4,8mio) - E40 Jabbeke < > Brussel (€5,6mio) - E403 Aalbeke < > Moorsele (€0,9mio) - R4 Destelbergen < > Merelbeke (€0,9mio) - R0 volledig (€7,6mio) - E40 Haasrode < > St.-Stevens-Woluwe (€1,1mio) - E313 Hasselt-West > Geel-Oost en Ranst > Hasselt-West (€3,7mio) - E314 Houthalen < > Heverlee (€ 5,5mio) - E34 Turnhout < > Ranst (€2,6mio)
Year of implementation	2010
Road category	Local: highways
Effectiveness	Injury accident reduction: 30% Slight injury reduction: 30% Serious injury reduction: 30% Fatality injury reduction: 30% (Assumption based on the road safety plan Flanders (Departement Mobiliteit and Openbare Werken, 2008)
Other assumptions	- Parts of the E313 highway are only in one travel direction equipped with the dynamic congestion warning system. However, the assessment of the road safety situation is based on both travel directions. It is therefore possible that the effect on the road safety situation is slightly overestimated for this highway segment.

11.1.4 New bicycle lanes

Measurement description	Some secondary roads and local roads are equipped with 1750km new bicycle lanes. This measure is a pure assumption and is not based on any policy document.
Year of implementation	2011: 200km on secondary roads + 400km on local roads 2012: 200km on secondary roads + 400km on local roads 2013: 550km on local roads
Road category	Local: secondary roads and local roads
Effectiveness	Injury accident reduction: 50% (assumption based on Walter et al., 2005) Slight injury reduction: 50% (assumption based on Walter et al., 2005) Serious injury reduction: 50% (assumption based on Walter et al., 2005) Fatality injury reduction: 50% (Walter et al., 2005)
Other assumptions	- The municipalities with the highest accident risk for bicyclists per kilometer road are selected: the top 20 for the secondary roads and the top 40 for the local roads. In each municipality, 10km of new bicycle lanes are constructed on the concerning road type. - It is assumed that in the selected municipalities half of the bicycle accidents and casualties occur on road segments which will be equipped with the new bicycle lanes. This is a rough estimation because the exact accident location is not included in the used accident data base (FOD Economie, AD SEI).

11.1.5 Section speed control

Measurement description	Three highway segments are equipped with a section speed control system: - E19 Antwerpen <> Rumst - E40 Aalter <> Oosterzele - E314 Diest <> Leuven This selection is a pure assumption and is not based on any policy document.
Year of implementation	2012
Road category	Local: highways
Effectiveness	Injury accident reduction: 33.3% (Stefan, 2006) Slight injury reduction: 32.2% (Stefan, 2006) Serious injury reduction: 48.8% (Stefan, 2006) Fatality injury reduction: 48.8% (Stefan, 2006)
Other assumptions	- Speeding is a main causal factor in 20% of all injury accidents, in 20% of the slight casualties, in 25% of the serious casualties and 30% of the fatalities.

11.1.6 Mandatory bicycle helmets for children

<table>
<tr><td>Measurement description</td><td>In 2014 the bicycle helmet becomes mandatory for children below the age of 12.
This measure is a pure assumption and is not based on any policy document.</td></tr>
<tr><td>Year of implementation</td><td>2014</td></tr>
<tr><td>Road category</td><td>Regional</td></tr>
<tr><td>Effectiveness</td><td>Risk reduction of serious head injury: 60% (Elvik et al., 2009)</td></tr>
<tr><td>Other assumptions</td><td>- It is assumed that when the bicycle helmet was not mandatory 10% (Lammar, 2005) of the children wear a bicycle helmet in 2014. Due to this road safety measure, the percentage of children who wear a helmet during cycling is supposed to increase to 80%.
- The head injury risks of Table 20 are used. As an example: 44% of the serious casualties who do not wear a helmet have a head injury (based on Elvik et al., 2009). When someone wears a helmet, the risk of serious head injury decreases with 60% (Elvik et al., 2009) to a percentage of 26.4%.
Table 20 Head injury risk per severity level with and without a helmet
<table>
<tr><th></th><th>Without helmet</th><th>With helmet</th></tr>
<tr><td>Slight casualties</td><td>20% (assumption)</td><td>12% (= 0.20 * 0.60)</td></tr>
<tr><td>Serious casualties</td><td>44% (based on Elvik et al., 2009)</td><td>26.4% (= 0.44 * 0.60)</td></tr>
<tr><td>Fatalities</td><td>50% (assumption)</td><td>30% (= 0.50 * 0.60)</td></tr>
</table>
</td></tr>
</table>

11.2 Traffic situation in 2007 based on data of 2005

The traffic situation in the reference year 2007 per road type and per municipality is unknown. However, we can calculate these values based on the traffic performance (TP) per road type and per municipality in 2005 (*Afgelegde afstanden in het verkeers – per wegtype en per gemeente 2005*: FOD Economie, AD SEI) and the overall traffic performance for Flanders per road type in 2005 and 2007 (*Afgelegde afstand door motorvoertuigen*: FOD Economie, AD SEI). The difference in traffic performance in terms of percentage between 2005 and 2007 is calculated and this adjustment factor is applied on the traffic situation per road type and per municipality in 2005. This calculation for municipality m can be summarized as follows:

$$Adjustment\ factor = \frac{TP_{Flanders,2007}}{TP_{Flanders,2005}}$$

$$TP_{m,2007} = TP_{m,2005} * Adjustment\ factor$$

An example for ten municipalities is given in Table 22.

Table 21 Adjustment factor

Road type	***Overall TP* 2005***	***Overall TP* 2007***	***Adjustment factor***
Highways	20.46	22.05	1.078
Secondary roads	21.74	22.01	1.012
Local roads	12.34	12.57	1.019

** Traffic performance (TP) in billion vehicle kilometer per year*

Table 22 Example of calculation of traffic performance (TP)* per road type and per municipality

Municipality	***TP* 2005*** *(FOD Economie, AD SEI)*			***TP* 2007*** *(own calculations)*		
	Highways	*Secondary roads*	*Local roads*	*Highways*	*Secondary roads*	*Local roads*
Aalst	317.5	260.9	167.5	342.2	264.0	170.7
Aalter	385.8	98.1	47.1	415.8	99.3	48.0
Aarschot	164.7	115.3	62.8	177.6	116.7	64.0
Aartselaar	0.8	95.8	39.9	0.8	96.9	40.7
Affligem	190.4	25.8	13.4	205.2	26.1	13.6
Alken	0.0	61.6	22.0	0.0	62.3	22.4
Alveringem	0.0	33.4	11.5	0.0	33.8	11.7
Antwerpen	1,428.0	829.3	1,537.8	1,539.3	839.3	1,567.0
Anzegem	0.0	51.1	23.3	0.0	51.7	23.7
Ardooie	80.0	36.1	15.8	86.2	36.5	16.1

** TP in million vehicle km per year*