IMPACT OF e-SAFETY APPLICATIONS ON CYCLISTS' SAFETY

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ABSTRACT

In the years to come urban areas in EU face the challenge of making transport sustainable in terms of environment and competitiveness. Cycling is a perfect means of transport in urban areas. Cycling is the most energy efficient and environmentally friendly transport mode, suitable especially for short distances. However, cyclists are considered as Vulnerable Road Users (VRUs). Often they are referred as road users who have a high casualty rate and should therefore be given special attention in road safety policy. VRUs can be, for instance, defined as users with lack of external protection towards other road users.

ICT can be used to develop intelligent applications assisting cyclists and other road users to avoid, prevent or mitigate accidents. This paper presents the results of an impacts assessment on the safety for cyclists of the eleven applications, realised in the framework of the EU co-funded project SAFECYCLE (www.safecycle.eu).

Eleven applications were selected as the most promising for cyclists' safety improvement and were analysed in term of benefits (i.e. accident reduction) and costs. The analysis allowed comparing the potential impacts of these applications in different EU countries, having different mobility and social characteristics.

The results of this study show the highest Benefit Cost ratio for the applications on internet or on nomadic devices. On the contrary, the applications being installed on other vehicles result in low Benefit Cost ratio, mainly due to the high costs necessary for installing them on a great number of vehicles.

Keywords: cyclists safety / cost-benefit analysis / e-safety / Vulnerable Road Users
Research domains: Transport safety / Intelligent transport systems

1. INTRODUCTION

Cyclists in Europe make around 50 million trips per day and this figure is increasing. Cycling is a crucial mode of transport in the common European challenge of making transport sustainable: cycling is energy efficient, environmentally friendly and very suitable for short distances. Cyclists are anyway considered as Vulnerable Road Users (VRUs), having a high casualty rate and a lack of external protection towards other road users. In 2009, around 2,100 cyclists were killed in road accidents in the EU-19 countries (around 7% of all fatalities) (ERSO, 2011). Therefore, actions to promote cycling in cities should go together with improving road safety.

Apart from the traditional measures like a dedicated cycling infrastructure, improving visibility and reducing speed of cars, decision makers also have to look at intelligent solutions to improve the safety of cyclists. ICT can be used to develop intelligent applications that assist cyclists and other road users to avoid, prevent, or mitigate accidents. Although isolated, ICT applications and services have been developed for cycling. However, there is no integrated approach to research activities in this domain at a national or international level. To fill in this gap, the SAFECYCLE project, co-funded by the European Commission (DG MOVE) was started in 2011[1]. The main objectives of SAFECYCLE were: (i) to identify e-safety applications that have the potential to enhance the safety of cyclists, (ii) to create knowledge and raise awareness about e-safety applications applied to cycling (policy, industry, users), (iii) to speed up the adoption of (new) e-safety applications in cycling.

E-safety is defined here as a vehicle-based intelligent safety system that could improve road safety in terms of exposure, crash avoidance, injury reduction and post-crash phases. A variety of measures are being promoted widely as “e-safety” measures, though the knowledge about e-safety is slowly evolving, including information on the costs and benefits of measures (European Commission, 2012). Different applications, being installed on board of bicycles, of other vehicles, of the road infrastructure, as well as nomadic and internet systems, can be identified that can enhance the safety of cyclists.

During the SAFECYCLE project, more than 120 applications for cyclists were identified (the search not only included Europe, but also other continents). Not all of the applications are in definition “intelligent”, but have the potential to increase safety in a smart manner. The list of e-safety applications was reduced to 30 applications that are representative of various categories. These applications were assessed through a SWOT analysis. Cycling, ITS and road safety experts filled in many SWOTs, resulting in a list of applications from most to less

[1] The project SAFECYCLE – ICT applications for safe cycling was finished in November 2012. Results can be found on the website: www.safecycle.eu

promising in relation to increasing road safety for cyclists. Eleven applications out of the 30 were then selected for the impact assessment based on the SWOT.

This paper presents the results of an impacts assessment on the safety for cyclists of the eleven applications. The bicycle safety situation in four European countries (The Netherlands, Belgium, Italy and Czech Republic) was used as a basis for the analysis. These countries represent a good mix of cycling experience.

Paper organization

This paper is comprised of four sections. The first section presents a background overview on cyclists' safety situation in Europe and on e-safety applications for cyclists. The second section outlines the development of the impact assessment method. The third section presents results on the assessment of two e-safety applications on cyclists' safety in different European countries. In the fourth section the results obtained for the eleven applications are discussed and conclusions are presented.

2. BACKGROUND

Safety of cyclists in Europe

According to the "Promotion of cycling" note for the European Commission (Martino et al., 2010), there are no reliable single international or European statistical reports showing modal share of bicycle use per country, related to all journeys. In Figure 1 the data available in each country (from different sources and years) are presented.

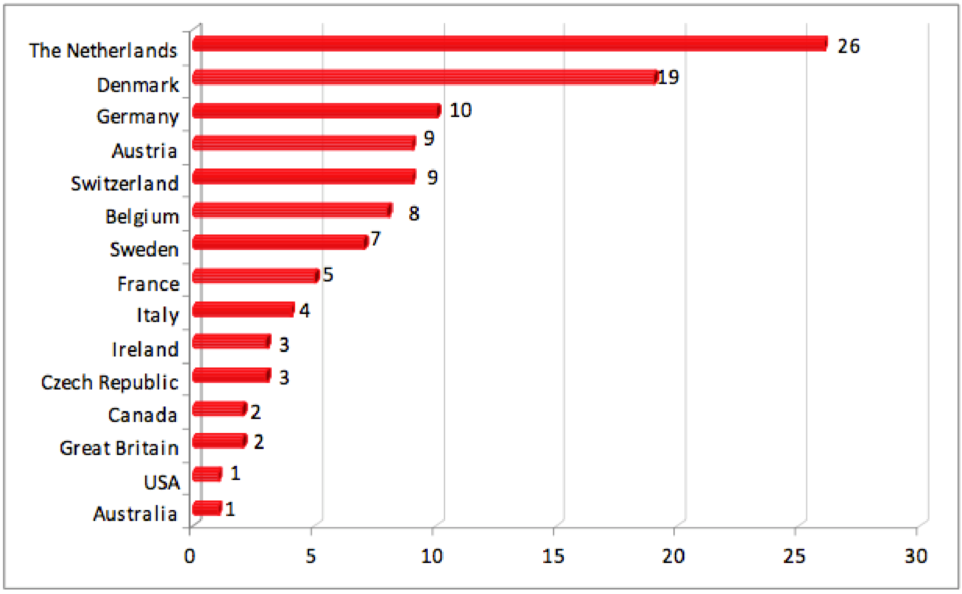

Figure 1: Bicycle modal share for all journeys per country[2]

In many European countries there is not a good road infrastructure network for cyclists. Cycle paths are poorly maintained, dirty and not entirely safe. Often, cyclists are expected to share the road with fast traffic. This makes cyclists feel unsafe and does not encourage them to use the bicycle as a means of transportation for commuting. Also, this has an effect on road safety figures for cyclists. During the last years, more cities, regions and national governments have started to take cycling as a means of transportation seriously and making cycling safer is one of the objectives. Data from Europe (Martino et al., 2010) suggests that countries that have invested the most in cycling tend to have the highest rates of cycling. These countries also have the lowest rates of cycling mortality, expressed as “risk in fatalities per billion cycling kilometers”. Due to a higher number of bicycle trips and kilometers cycled, cyclists are perceived and expected in traffic, which makes their coexistence with other road users mutually smoother and accidents are reduced. To improve this safety situation for cyclists (national) road safety policy with attention for infrastructure for cyclists, traffic control measures and training of children and adults (cyclists and non-cyclists) is needed.

Figure 2 indicates the deaths in traffic involving at least one bicycle, per million inhabitants in different countries in Europe. It is interesting to note that, for example, Czech Republic and The Netherlands have almost the same number of deaths per million inhabitants, but in The Netherlands share of cycling in the modal choice is about nine times higher than in Czech Republic.

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[2] **Sources:** Australian Bureau of Statistics (2007); Netherlands Ministry of Transport (2006); United States Department of Transportation (2003); Isfort Italian survey ‘Audimob’ (2006); Annex I: Literature search bicycle use and influencing factors in Europe– ByPad Project (2008). In: Martino et al. (2010)

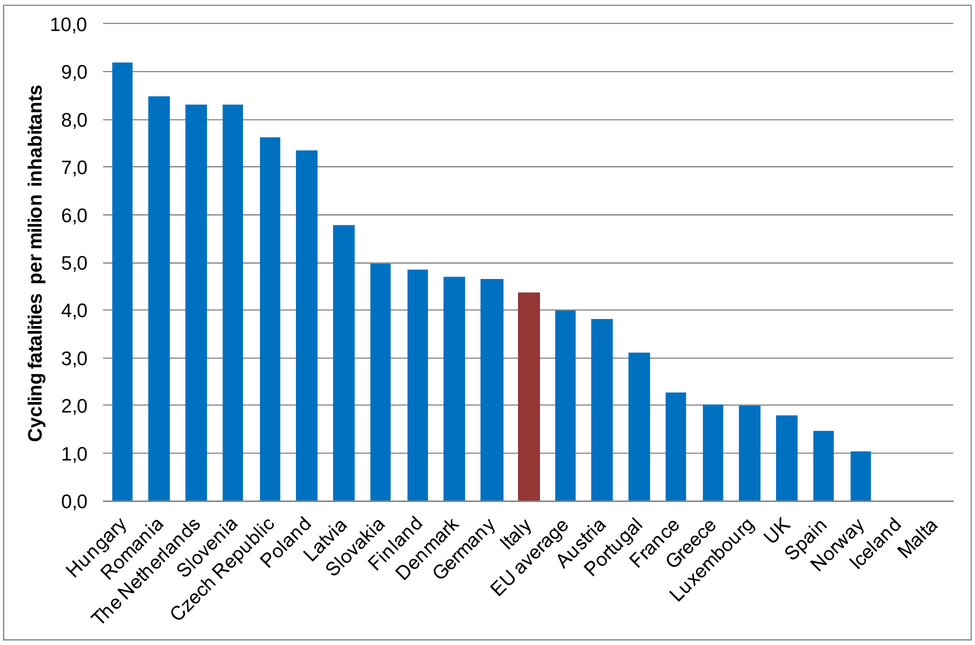

Figure 2: Deaths in traffic accidents involving at least a bicycle per million inhabitants in Europe – 2010 (CARE, 2012)

Across the EU-23 countries, the majority of cyclist fatalities are males (80%). The Netherlands and Belgium had the highest proportion of female cyclist fatalities (around 30%), while countries like Romania and Portugal had 8% or less female fatalities. These different proportions between males and females are probably due, from one hand, to a better way of driving (i.e. less risky behaviors) by females and, to the other hand, to a higher use of bicycle (and thus of distances covered) by males.

Also, across the EU-23 countries, there appears to be a large proportion of cyclists of 60 years or older who die as the cause of an accident (49%). Next to this, there appears to be a peak in fatalities of cyclists aged between 12 and 17. This is the age at which children increasingly undertake independent trips by bicycle and their exposure rate in traffic increases a lot (ERSO, 2011). Almost 60% of the bicycle fatalities in the EU-23 countries were killed in urban areas. Again, there are large differences ranging from over 75% in Spain to 24% in Romania (ERSO, 2011).

Overview of e-safety applications

E-safety applications in cycling can be used to provide intelligent systems that assist in avoiding, preventing or mitigating accidents with cyclists. The following dimensions can be identified: cyclists, bicycles, other vehicles, infrastructure, web applications (Internet and Nomadic). Each of these categories includes a large number of possible applications, already existing, under development or just prototype.

The cyclists' category refers to applications that are attached to the cyclist. Examples of these applications are:

- *BlinkHelmet*, a helmet with lights on right and left sides and on back. Tapping the helmet activates the direction indicators, which contributes to increase the cyclist visibility.
- *Airbag for cyclists*, a helmet containing an airbag that is activated by a fast and atypical movement of the head. This application aims at reducing the severity of injuries after an accident.

The bicycles category refers to applications that are attached to the bicycle or have their main focus on the bicycle. Examples of these applications are:

- The *Copenhagen Wheel*, a prototype of e-bike wheel that transforms a "normal" bicycle into an electrical one and allows use of measuring, tracking and communication devices. It aims at providing the cyclists with information on safety, health, routes.
- *Hindsight 35*, a prototype screen on the steering wheel providing information about situation behind the bicycle. It improves knowledge about what is going on behind the bicycle without moving the head.
- *Light Lane,* an existing application that projects, through a green laser, a cycle lane behind the bicycle. It increases the visibility of the bicycle.
- *Self powered laser*, an idea aiming, through a laser, at projecting a green light around the bicycle that turns red in case a car enters the safety zone of the bicycle. Its aim is to increase the bicycle visibility and to notify about risk of collision.

Other vehicles' category refers to applications that are integrated in or used by other vehicles. Examples of these applications are:

- *SaveCap* (being tested by the Dutch TNO), an airbag, installed on the bonnet and windows of cars, which protects the cyclists in case of collision. It aims at reducing the severity of injuries.
- *NextGenITS*, an Intelligent Speed Adaptation (ISA) under development that allows detection of bicycles through Vehicle-to-Vehicle and Vehicle-to-Infrastructure communication systems. This ISA allows to warn the drivers about the presence of cyclist and to adapt the vehicle speed or to brake. It aims at preventing collisions with cyclists.
- The *Blind Spot* system (existing) consists in a radar that detects moving objects in the blind spot area of the vehicle and gives an alarm to the driver. Some systems also block the vehicle's engine. *Blind Spot* is typically used on heavy vehicles (e.g. trucks or buses) where drivers have difficulties in viewing a cyclist.

Infrastructure category refers to applications that are integrated in infrastructure or have their main focus on infrastructure. An example of this application is *See-Mi*, an existing system allowing the bicycle to send a signal with a special reflector to a receiver at the intersection, showing the presence of a cyclist. It prevents blind spot accidents.

Web applications refer to systems that can be used through internet or nomadic devices (smart phone). Examples of web applications for cyclists are:

- *Citizens Connect*, developed in Boston (USA) with the aim of taking an active part in reporting dangerous situations (e.g. snow or ice). The reportings from cyclists are followed by actions from the Municipality.
- The *Routeplanner Gent*, allowing the cyclists to avoid potentially dangerous situations like tram tracks, cobble stones or very busy roads.

3. METHODOLOGY

Due to the lack of impact assessments and real case tests on applications for cyclists, the assessment of the e-safety applications selected has been mainly based on a literature review of impacts on safety of similar measures (i.e. having similar effects on cyclists safety). The assessment was thus not based on results of pilot demonstrations or Field Operational Tests. The aim was to provide a first picture about the possible benefits of ICT for the cyclists' safety.

For each of the eleven applications selected, a Cost Benefit Analysis (CBA) has been realized. This procedure allows for assessing the differences, in term of impacts, of the applications between the four selected countries. This especially allows understanding if (potentially) certain applications would be more cost effective to implement than others (i.e. if benefits are higher than costs).

Selected e-safety applications

From the total number of 120 identified applications, eleven most promising applications were identified and selected for the impact assessment by Tripodi et al. (2012). The selection was made during a brainstorming session among the project partners, in which opinions provided by experts and cyclists were compared and discussed. The final decision about the applications is the best compromise between the opinions provided and the type of application to be assessed (as far as possible the selection included at least one application per type – only the category "Cyclist" was excluded). **Error! Reference source not found.**1 shows the applications selected for the impact assessment. More information about these applications can be found in Zoer et al. (2012).

Table 1: List of most promising applications

Category	Name of application
Bicycle	
Physical problems	HindSight
Street projection	Light Lane Bike
Visibility	Bicycle braking light
Other vehicles	
Airbag	SaveCap - Car airbag for cyclists
Speed	ISA - Intelligent Speed Adaptation
Visibility	Lexguard blind spot system
Infrastructure	
Traffic light	Countdown traffic lights
	Traffic Eye Zürich
Visibility	LED-Mark
Internet (web)	
Route planner	Routeplanner Gent
Nomadic	
Monitoring and action	Citizens connect

Assessment of benefits

The benefits have been monetized based on values of social costs of accidents (i.e. benefits refers to reduction of all costs associated to the reduction of cycling accidents, injuries and fatalities, due to the use of an application). The potential reduction of accidents has been estimated through "Crash Reduction Factors" (CRFs). Since there is not a lot of research available about e-safety applications for safer cycling, the CRFs of similar or comparable applications (chosen based on the literature review) were used. The CRFs have been considered to be equal in the four selected countries. This assumption is made due to the lack of information and specific studies about the impacts of applications like those considered.

The social costs were differentiated based on the last national figures. This implicates that safety benefits in Czech Republic are much lower compared to the other countries, because of the lower costs of fatalities, injuries and accidents. The Table 2 shows the social costs considered for the four countries, as well as the EU average.

Table 2: Social costs of traffic accidents (2002)

Cost (€)*	Netherlands	Belgium	Italy	Czech Rep	EU ***
Accident**	€ 19,000	€ 16,000	€ 14,000	€ 4,800	€ 13,450
Injury	€ 236,000	€ 249,000	€ 183,000	€ 67,100	€ 183,775
Fatality	€ 1,782,000	€ 1,639,000	€ 1,430,000	€ 495,000	€ 1,336,500

* Social costs refer to official national data of 2002

** Only material damage

*** EU value is a mean value of the values of the four countries

The monetized benefits are thus obtained through the following formula:

$$Benefits^i = SC_A^i \cdot CRF_A \cdot N_A^i + SC_I^i \cdot CRF_I \cdot N_I^i + SC_F^i \cdot CRF_F \cdot N_F^i$$

where:

- $SC_A{}^i$ refers to the social cost of an accident for the country *i*.
- CRF_A refers to the Accident Reduction Factor of the application considered.
- $N_A{}^i$ refers to the number of accidents (related with the type of accident that can be saved using the application considered) for the country *i*.
- $SC_I{}^i$ refers to the social cost of an injury for the country *i*.
- CRF_I refers to the Injury Reduction Factor of the application considered.
- $N_I{}^i$ refers to the number of injuries (related with the type of accident that can be saved using the application considered) for the country *i*.
- $SC_F{}^i$ refers to the social cost of a fatality for the country *i*.
- CRF_F refers to the Fatality Reduction Factor of the application considered.
- $N_F{}^i$ refers to the number of fatalities (related with the type of accident that can be saved using the application considered) for the country *i*.

The number of accidents, injuries and fatalities associated to a specific type of accident (e.g. rear-end collisions, accident at intersection, accident at night, frontal accident, etc.) has been obtained based on the last available national or European figures on traffic accidents involving cyclists. Though one has to keep in mind that there are indications that especially (relatively light) injuries and accidents are under-registered (Methorst & Schepers, 2011). The SWOV (2012b) indicates that single sided accidents, especially without serious consequences, are very often not registered. Therefore the expected benefits might be higher than predicted in the analysis.

Assessment of costs

The costs have been calculated as the sum of implementation and maintenance costs. Assumption was made that costs for maintaining the application are 10% of the implementation costs per year. The implementation costs of an application are obtained through the following formula:

$$Implementation\_Costs^i = Unit\_Cost \cdot Unit\_Number^i$$

where:

- *Unit_Cost* is the cost for implementing (or buying) one application for the *Unit* considered (assumption was made that the unit cost is equal in all the countries considered).
- *Unit* is the dimension considered depending on the type of application (e.g. km of equipped roads for applications on the infrastructure, n° of traffic lights equipped, n° of vehicles equipped for applications on vehicles).

- *Unit_Number^i* is the number of *Unit* on which the application should be implemented in the country *i*.

Benefit Cost ratio

The ratio between benefits and costs was used to assess the usefulness of the applications against their costs for implementation and maintenance. Assumption was made that the expected duration of the applications is equal to ten years (irrespective of the application considered). The benefits and costs were actualized considering an interest rate equal to 10%.

Actualized benefits and costs have been obtained multiplying the benefits and costs per an *Equivalent Uniform Factor (EUF)* given by the following formula:

$$EUF = \frac{(1 + interest\_rate)^{duration} - 1}{interest_{rate} \cdot (1 + interest\_rate)^{duration}} = \frac{(1 + 0.1)^{10} - 1}{0.1 \cdot (1 + 0.1)^{10}} = 6.1$$

The actualized costs have been compared to the actualized social benefits, associated to the reduction of cycling accidents, injuries and fatalities, through the following formula (valid for the country *i*). This procedure allows for assessing the differences, in term of impacts, of the applications between the four selected countries. This especially allows understanding if (potentially) certain applications would be more cost effective to implement than others (i.e. if benefits are higher than costs) and in what countries applications could provide the highest benefits.

4. RESULTS OF COST-BENEFIT ANALYSIS

In the following paragraphs two examples of analysis for the applications selected are presented. These applications are representative of two of the four categories considered during the analysis: application for other vehicles, for bicycles, for infrastructure and on internet. The two applications presented here (*Lexguard* and *Light Lane Bike*) provide a good overview on how the Cost Benefit Analysis have been realized and about the assumptions and considerations made during the analysis. Detailed information for the other applications can be found in Zoer at al. (2012). The last paragraph provides an overview of the results obtained for all the applications.

Lexguard

The active blind spot system is equipped with synthetic sensor strips at the right side of the trailer and at the front and the right side of the truck. These strips “sense” and “see” if there is an object in the blind spot. In case of dangerous situations an automatic sound and light warning system is activated inside the truck on the display. The signal becomes more intense when cyclists are close to the truck.

The literature review about CRFs of this application did not provide indications about its effects on road safety. It seems that similar applications have not been studied yet. Some studies about blind spot countermeasures instead exist, even if not specifically referred to ICT applications.

Effects on blind spot accidents are reported in Elvik et al. (2009) with reference to convex mirror, aimed at covering all fields of vision behind cars. Convex mirrors were also found to reduce cars visibility and lead to an underestimation of the speed of passing cars. Elvik estimated a fatality decrease of 40%. A gradual implementation over ten years would result in a fatality decrease of 22%. The same percentage was assumed for injuries. The CRFs assumed for this application are thus:

- Fatal accidents: -22%.
- Injury accidents: -22%.
- Other accidents: 0% (no effects).

The application was considered to have impacts on the accidents involving cyclists while turning left or right (CARE, 2012). In the Netherlands 25% of the fatalities and 1.25% of the injuries are a result of blind spot accidents (SWOV, 2008). In Belgium the figures are 15% and 0.25% (Casteels & Godart, 2008). For Italy and Czech Republic the percentages of the Netherlands are used. Table 3 shows the lateral blind spot accidents in the four countries for the last year available (2009), as well as the estimated costs and benefits and the CBA results.

Table 3: Cost Benefit analysis for *Lexguard*

	Netherlands	**Belgium**	**Italy**	**Czech Rep**	**EU**
Accidents	4,237	4,694	10,633	2,142	60,300
Injuries	45	12	130	26	788
Fatalities	20	8	34	10	156
Unit cost (€)	2,700	2,700	2,700	2,700	2,700
N° of vehicles*	39,000	56,000	171,000	20,000	1,700,00
Costs (mln €)	712	1,022	3,121	365	31,024
Benefits (mln €)	63	39	97	9	477
CBA	**0.09**	**0.04**	**0.03**	**0.02**	**0.02**

* reference to average number of new trucks registered at country level in 2011 – source: EUROSTAT

The CBA of *Lexguard* is always lower than one. The Netherlands shows the most potential. The Cost Benefit ratio for the other three countries is comparable. Compared to other applications, an important issue is the costs of *Lexguard*. Naturally the assumptions made have influenced the CBA results. The hypothesis was made that all new trucks will be equipped with *Lexguard* and that all the cyclist accidents due to vehicle turning are influenced. Since not all vehicle-turning accidents happen because of blind spots, the fatal accident reduction could be lower than the estimated amount.

However, it is possible that the potential effect of *Lexguard* is higher than estimated. An Italian expert expects that the effect of *Lexguard* may be greater than the reference used. The main reason is that *Lexguard* issues a warning sound that activates the driver. Although the costs seem to outrun the benefits, chances are high that this application does reduce fatalities and injury. It is proven technology and it warns the driver onscreen and with sound in case there is a cyclist in the blind spot.

Light Lane bike

A green laser projects a cycle lane behind the bicycle, making the cyclist more visible so that other road users (car drivers) take account of the cyclist's presence. The literature review about CRFs for the light lane bicycle or similar applications did not provide indications about its effects on road safety. Effects on the use of lights are reported in Elvik et al. (2009) with reference to the use of taillights on all bicycles. The estimated effect is a decrease of accidents with 80%. It is assumed that the effect of the light lane bike is half the effect, leading to the following CRFs for this application:

- Fatal accidents: -40%.
- Injury accidents: -40%.
- Other accidents: -40%.

The application was considered to have impacts on the accidents involving cyclists at night. The Table 4 shows the rear-end accidents during night in the four countries for the last year available (2009), as well as the estimated costs and benefits and the CBA results. The Benefit Cost ratio is positive for all countries, but Belgium shows the highest potential. The effect is almost twice as high compared to Italy and three or four times higher than the Netherlands and Czech Republic. This means that night time accidents in Belgium happen relatively often compared to the other countries.

Table 4: Cost Benefit analysis for Light Lane Bike

	Netherlands	Belgium	Italy	Czech Rep	EU
Accidents*	776	866	2,809	648	12,760
Injuries*	720	866	2,684	635	13,324

Fatalitie*s	24	15	75	20	418
Unit cost (€)	15	15	15	15	15
N° of vehicles**	16,000,000	5,500,000	27,000,000	5,200,000	224,000,000
Costs (mln €)	387	133	654	125	5,420
Benefits (mln €)	559	624	1,568	136	7,813
CBA	**1.44**	**4.69**	**2.40**	**1.09**	**1.44**

* Figures of accidents for 2009 – source: CARE, 2012

** amount of bicycles per inhabitants in 2007 – source: Ministerie van Verkeer en Waterstaat & Fietsberaad (2009)

With regular lighting at roads, the effect of *Light Lane Bike* might be low. However, for rural areas of countries without well-developed cycling infrastructure the effects of *Light Lane Bike* could be substantial with regard to road safety benefits.

Synthesis of results

Table 5 shows the results of the Cost Benefit Analysis (i.e. the EU average values) for the eleven applications selected. It should be noted that the applications having the higher costs are those for other vehicles, which require a great monetary investment in order to be installed on a large number of vehicles (i.e. necessary in order that their impacts are significant). The applications on internet or on nomadic devices, on the contrary, require a very low monetary investment.

Table 5: Result of the Cost Benefit Analysis for the selected applications

Category	**Name of application**	**Costs (mln €)**	**Benefits (mln €)**	**CBA**
Bicycle				
Physical	HindSight	27,101	2,415	0.09
Street projection	Light Lane Bike	5,420	7,813	1.44
Visibility	Bike braking light	3,252	2,300	0.71
Other vehicles				
Airbag	SaveCap	51,744	2,302	0.04
Speed	ISA	103,548	2,521	0.02
Visibility	Lexguard	31,024	477	0.02
Infrastructure				
Traffic light	Countdown	363	9,219	25.38
	Traffic Eye Zürich	36	51	1.41
Visibility	LED-Mark	3,111	397	0.13
Internet (web)				
Route planner	Routeplanner Gent	44	334	7.67
Nomadic				
Monitoring	Citizens connect	44	334	7.67

In term of benefits, the various applications show a mixed picture, mainly related with the type of accidents on which they act. The applications on bicycle always show significant benefits, while that on internet or on nomadic devices have lower impacts on reduction of accidents. In general, the applications providing the higher benefits are *Countdown* and *Light Lane Bike*. The first is an infrastructural application that can reduce significantly the number of accidents and their severity at intersections. The second is an application for bicycles that increase the visibility of cyclists and reduce the rear-end collisions.

5. DISCUSSION AND CONCLUSION

The paper aimed at presenting the results of an analysis, realized in the framework of the European project SAFECYCLE, on the impacts of e-safety application on the safety of cyclists. The analysis focused on eleven e-safety applications of different type: for bicycle, installed on board of other vehicles, on the infrastructure, on internet or on nomadic devices.

Although the results of the CBA are based on many assumptions and best estimates, the outcomes are hinting towards some conclusions. Applications that require installations in all passenger cars, such as *SaveCap* and *ISA*, result in a very low Benefit Cost ratio. This is caused by the fact that the systems need to be installed in millions of vehicles and therefore are very costly in total. The same applies for applications that need to be installed in trucks, such as *Lexguard*. On a European-wide basis, this requires an investment of hundreds of millions of Euros. For the systems to be installed at the bicycles, two out of three seem to have a positive Cost Benefit ratio (i.e. *Bicycle braking light* and the *Light Lane Bike*). These are relatively cheap applications. On the other hand, the *HindSight* does not have a positive Cost Benefit ratio. The infrastructure-based systems show a mixed picture. The *Countdown traffic light* system has a very high Cost Benefit ratio, due to a high number of accidents saved thanks to this application.. The *Traffic Eye Zurich* also has a positive Cost Benefit ratio, even if the value is much lower than that of Countdown (less accident saved). For the *LED-Mark* system the expected costs are always higher than the expected benefits. Last but not least, it seems that the Internet applications, such as the *Routeplanner Gent* and the *Citizens Connect*, have the highest Benefit Cost ratio. Even if their potential in term of reduction of number of accidents is low, with relatively little investment many potential users can be reached, which seems to result in a very positive Benefit Cost ratio.

The results obtained through this analysis should anyway be considered as a starting point. There has not been a lot of research carried out about ITS and cycling. Comparable national statistics between countries are also hard to find. However, on a European level there are some comparable statistics, although not in depth, such as the CARE database and

EUROSTAT. Furthermore, many of the applications are in the development or prototype stage, which makes it hard to make an estimation of the price or the costs of an application. When looking at the different components of the Cost Benefit Analysis (CBA) there are differences in the social costs of accidents, injuries and fatalities. The social costs in the Czech Republic are much lower than in The Netherlands, Italy and Belgium. This influences the CBA heavily.

The analysis realized in this study was based on several assumptions regarding implementation costs and potential reduction of accidents. The results can thus only be considered a valid indication about the potentials of the e-safety applications for cyclists and about the differences that can exist in different contexts. Future research should be aimed at quantifying the effective effects of such systems on safety of cyclists (and on traffic accidents in general). To do this, demonstrations and Field Operational Tests would be necessary both to increase the awareness about these systems and to assess their impacts.

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