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EFFECTIVENESS OF ROAD SAFETY INTERVENTIONS IN SPAIN

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A mi familia

A la meva família

A miña familia

“Caminante, no hay camino.

El camino se hace al andar.”

Antonio Machado

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LA TESIS... Cuando te piensas que nunca la terminarás, cuando te persigue día y noche, cuando estás con tus amigos y te acuerdas de que mañana se acaba el plazo para entregar las correcciones a la segunda revisión del artículo, en la décima revista a la que lo has enviado... Y, de repente, ¡llega el día en que tienes que entregarla! Ese día que te pensaste que nunca llegaría, finalmente ha llegado.

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EXECUTIVE SUMMARY

Road traffic injuries are an important public health problem in Spain. In 2004, the Spanish government established road safety as a political priority, and created the Road Safety Strategic Programme 2005-2008, which proposes a series of actions aimed to reduce the burden of traffic injuries in Spain.

The objectives of the present thesis are to review the road safety interventions which have proven to be effective in reducing road traffic deaths and injuries, and to assess the impact on traffic morbidity and mortality of overall road safety interventions implemented in Spain from the year 2004 on and of specific road safety interventions implemented, specifically the penalty points system, the reform of the Penal Code and speed cameras.

The design of all the intervention evaluation studies consisted in interrupted time-series studies. The number of injury crashes, drivers involved in injury collisions, and people injured in traffic collisions in Spain between the years 2000-2008 were the study populations. Police and hospital registries were used as sources of information. Quasi-Poisson regression models were adjusted, controlling for time trend and seasonal patterns.

The studies included in the present thesis suggest that the prioritisation of road safety in the year 2004 changed the trend of road traffic injuries in Spain, being especially effective in reducing the number of

seriously injured people. Among the interventions included in the Road Safety Strategic Programme 2005-2008, speed cameras, the penalty points system, and the criminalisation of a set of road behaviours - by means of reforming the Penal Code – were assessed for effectiveness and were observed to reduce the burden of traffic injuries in Spain. Nevertheless, the literature review included in the thesis identified several effective road safety interventions, such as the graduated licensing system, that have not been implemented as yet, and which could further reduce the number of people injured on the Spanish roads.

Important efforts and enough resources will be needed to maintain the level of road safety achieved. Furthermore, additional effective road safety measures should be implemented to reduce the still unacceptably high number of people injured or killed on the Spanish roads every day.

RESUMEN EJECUTIVO

Las lesiones por tráfico son un importante problema de salud pública en España. En 2004, el gobierno español estableció la seguridad vial como una prioridad política, y creó el Plan Estratégico de Seguridad Vial 2005-2008, que propone una serie de medidas dirigidas a disminuir el impacto de las lesiones por tráfico en España.

Los objetivos de la tesis son revisar las intervenciones de seguridad vial que se han demostrado efectivas en reducir las lesiones y mortalidad por tráfico y evaluar el impacto en morbilidad y mortalidad por tráfico del conjunto de medidas implementadas en España a partir del año 2004 y de algunas de las medidas implementadas, concretamente el permiso por puntos, la reforma del Código Penal y los radares.

El diseño de todos los estudios de evaluación consistió en estudios de series temporales interrumpidas. Las poblaciones de estudio fueron el número de colisiones, conductores involucrados en colisiones con lesionados y personas lesionadas por tráfico en España entre los años 2000 y 2008. Las fuentes de información fueron bases de datos de policía y hospitalarias. Se ajustaron modelos de regresión Quasi-Poisson, controlando la tendencia temporal y la estacionalidad.

Los estudios incluidos en la tesis sugieren que la priorización de la seguridad vial en el año 2004 supuso un cambio en la tendencia de las lesiones por tráfico en España, y fue especialmente efectiva en reducir

el número de lesionados graves. Entre las intervenciones incluidas en el Plan Estratégico de Seguridad Vial 2005-2008, se evaluó la efectividad de los radares, el permiso por puntos y la criminalización de una serie de comportamientos de tráfico – mediante la reforma del Código Penal –, medidas que redujeron el impacto de las lesiones por tráfico en España. Sin embargo, la revisión de la literatura incluida en la tesis identificó diversas medidas efectivas de seguridad vial, como el permiso de conducir gradual, que todavía no han sido implementadas y que podrían reducir todavía más el número de personas lesionadas en las carreteras españolas.

Será necesario realizar esfuerzos importantes y adjudicar suficientes recursos para mantener el nivel de seguridad vial alcanzado. Además, se deberán implementar más medidas efectivas de seguridad vial para reducir el todavía inaceptablemente elevado número de personas lesionadas o muertas en las carreteras españolas cada día.

PREFACE

This thesis consists of five papers, one of which is a literature review and the remaining papers intervention evaluation studies. Three of these papers have been published in Gaceta Sanitaria, The Journal of Epidemiology and Community Health, and Injury Prevention, a fourth paper is in press in The American Journal of Public Health, and a fifth paper is under review in the Bulletin of the World Health Organisation.

The thesis is structured as follows: a summary in English and in Spanish, an introduction, a chapter explaining the methodology used in the thesis, the results of the thesis (5 papers), a chapter in which the results are discussed, a list of conclusions, a series of recommendations based on the findings and conclusions of the thesis, and an appendix, which shows the impact in the media of one of the studies of the thesis.

The studies included in the present thesis are the results of the research project “Evaluation of road safety strategies in Spain: gender, age, and geographical inequalities”, supported by the Agencia de Evaluación de Tecnologías Sanitarias (AETS) (Plan Nacional de Investigación Científica, Desarrollo e Innovación Tecnológica (I+D+I) e Instituto de Salud Carlos III-Subdirección General de Evaluación y Fomento de la Investigación) [PI07/90157], and with Catherine Pérez as the lead researcher.

CONTENTS

A. INTRODUCTION

Road transport is essential to society, since it allows both people and goods to move from one location to another. As such, it plays an important role in the economic development of the countries. However, it involves several drawbacks. In the first place, it is among the main sources of air pollution, which is one of the main risk factors for respiratory and cardiovascular illnesses. It also discourages the use of healthier modes of transport, such as walking or cycling, therefore contributing to physical inactivity and increasing the levels of cardiovascular disease, diabetes, and obesity, among others. In addition, road transport also contributes to climate change and increased noise levels. However, one of its most evident setbacks is the great number of road traffic injuries and deaths that take place every year worldwide.

1. THE ROLE OF PUBLIC HEALTH IN ROAD SAFETY ISSUES

The concept of Health in All Policies indicates that the health of the population is largely dependent on policies from sectors other than solely the health sector (HiAP, 2006). The transport sector is a clear example. Several of the decisions made from this area are mainly aimed to improve the mobility of the population in detriment of its health consequences (e.g. air pollution, road traffic injuries).

Historically, road safety has been regarded as being mainly the responsibility of the transport sector. However, many other sectors are involved (e.g. health, police, justice and others). Given the complexity of traffic injuries, road safety should not be the responsibility of only one sector. The public health sector can contribute to improve road safety in several aspects (Peden, 2004):

1) Surveillance of road traffic injuries. The numbers of road traffic crashes and of people injured should be registered in a high-quality database. This will allow to determine the impact of traffic injuries in a specific region, analyse the differences across regions, and compare their magnitude with other public health issues. In addition, road traffic injuries should be followed-up in time so as to monitor injury trends. These databases should also be used to assess the effect of road safety interventions. Inequalities due to gender, age, social class, type of road user, and others should be kept in mind when planning the information to be included in these databases.

2) Performing research into the causes and associated factors of road traffic injuries. Scientific studies assessing these issues should be performed, in order to gather relevant information needed to prioritise and decide the road safety interventions to be implemented.

3) Designing, implementing, and evaluating road safety interventions. Although the design and implementation of road safety interventions mainly belongs to the transport and police sectors,

the public health sector can take part in these tasks by providing these sectors with evidence-based advice. In addition, the effectiveness of road safety interventions in reducing road traffic injuries should always be assessed by means of rigorous intervention studies. Furthermore, before implementing any measure, it would be highly recommendable to perform a health impact assessment.

4) Convincing policy-makers of the need for prioritising road traffic injuries. Public health workers should develop the abilities needed to convince policy-makers that, given the preventable nature of road traffic injuries and their impact on population's health, they should be included in the political agenda.

5) Persuading policy-makers to implement evidence-based effective road safety interventions. Public health workers should identify effective road safety interventions and convince policy-makers that only those proven to be effective should be implemented.

2. DEFINING ROAD TRAFFIC INJURIES

An injury is a lesion occurred in the body at the organic level, resulting from an acute exposure to energy (mechanical, thermal, electrical, chemical or radiant) in amounts that exceed the threshold of physiological tolerance. In some cases (e.g. drowning, strangulation, freezing), the injury results from the insufficiency of a vital element (Baker, 1984).

Injuries can be unintentional (road traffic injuries, poisoning, falls, fires, drowning and others) or intentional (self-inflicted, interpersonal violence, war and others) (Begg, 2002).

A road traffic injury is an injury due to traffic crashes originating, terminating or involving a vehicle partially or fully on a public highway (WHO, 2002).

3. MAGNITUDE OF THE PROBLEM

Worldwide, 5 million people die from injuries every year, accounting for 9% of deaths and 12% of the burden of disease. Half of injury-related deaths occur between the ages of 15 and 44 years, the most economically productive members, and they are twice in men than among women. More than 90% of these injury-related deaths take place in low- and middle-income countries (López, 2006) (Peden, 2002a).

Road traffic injuries are the primary cause of injury-related deaths worldwide, accounting for 25% of the injury-related mortality and for 22% of the injury-related burden of disease. They are the ninth most common cause of mortality and burden of disease. Every year, 50 million people are injured and 1.2 million people die from road traffic collisions, 90% of which in low- and middle-income countries. Mortality due to traffic crashes is particularly high among men (mortality is almost 3 times higher than among women) and among young adults (subjects between 15 and 44 years account for over 50%

of road traffic fatalities). In addition, the burden of disease derived from traffic injuries is also higher among young adults, who account for 60% of the overall number of DALYs lost (Peden, 2002a) (Peden, 2004) (WHO, 2008) (WHO, 2009).

Specifically, road traffic injuries are the leading cause of death for ages 15-29, second for ages 5-14 and the third for ages 30-44. Among males, they are the third cause of death for ages 5-14 and the second for 15-44, after HIV/AIDS. Among females, they are the fifth, fourth and sixth cause of death for ages 5-14, 15-29 and 30-44, respectively. In high-income countries, they are the leading cause of death for ages 5-29 and the second for ages 30-44, after self-inflicted injuries. A similar pattern is observed when stratifying by sex, except for ages 30-44 in females, for whom it is the third cause, after self-inflicted injuries and breast cancer (Peden, 2002b) (WHO, 2009).

In addition, road traffic injuries are the second leading cause of burden of disease for ages 5-14, the third for ages 15-29 and the fourth for ages 30-44. Among males, they are the second cause for ages 5-44, after HIV/AIDS for ages 15-44 and after childhood diseases for ages 5-14. Among females, they rank fifth, 13th and 11th for ages 5-14, 15-29 and 30-44, respectively.

It is predicted that, in 2030, without appropriate action, road traffic injuries will be the eighth leading cause of mortality and the fourth leading cause of burden of disease worldwide (Mathers, 2006). However, these projections differ by world region: between 2000 and 2020, road traffic mortality will increase over an 80% in low- and

middle-income countries, whereas they will decrease by about a 30% in high-income countries (Peden, 2004).

The economic cost of road traffic injuries has been estimated to be 1% of the gross national product in low-income countries, 1.5% in middle-income countries and 2% in high-income countries. Moreover, they also involve social costs and suffering (Peden, 2004).

In Europe (in the 27 member states of the European Union), 78 road traffic fatalities per million inhabitants were observed during the year 2008. In Spain, during the same year, 134,047 people were injured and 3,100 were killed (68 fatalities per million inhabitants), placing Spain in the 8th position and, for the first time, below the mean fatality rate of the European Union (CARE, 2010).

Road traffic injuries are the fifth leading cause of mortality in Spain, being the primary cause among individuals from 1-39 years, the third for individuals from 40-59 years and the fifth for individuals from 60-69 years (Peiró, 2006). In addition, they are the primary cause of potential years of life lost in men, and the second in women (Cubí, 2008) (Llàcer, 2001).

The economic costs of road traffic crashes in Spain have been estimated to be of 6.280 million euros (1.4% of the Gross National Product), 30% of which are due to administrative costs, 19% to premature death, 26% to premature disability, 21% to property damage and 4% to medical costs (Bastida, 2004).

Notwithstanding these facts, road traffic mortality in Spain has experienced a trend change during the last years. Whereas between the years 2000-2003 the number of traffic fatalities remained relatively stable at around 5,300 annual deaths, traffic mortality showed a trend change in the year 2004, being the death toll reduced from 5,399 fatalities in the year 2003 to 3,100 in the year 2008.

4. EPIDEMIOLOGICAL MODEL

William Haddon suggested replacing the descriptive concept of road traffic injuries, according to which they are regarded as accidents – and, therefore, unavoidable - for an etiological concept, which is based on a causal model that allows to identify the factors involved in the collision, and thus considers road traffic injuries as preventable. According to this model, injuries are caused by the interaction between the causal agent (energy), which is transferred by means of a vector (the vehicle) to the host, and by other factors related to the host and to the environment (Figure 1).

Figure 1. Causal model

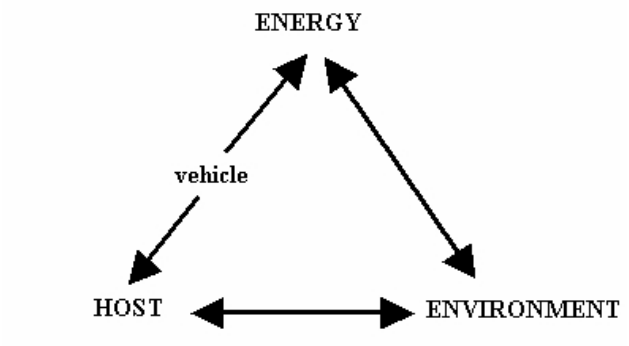
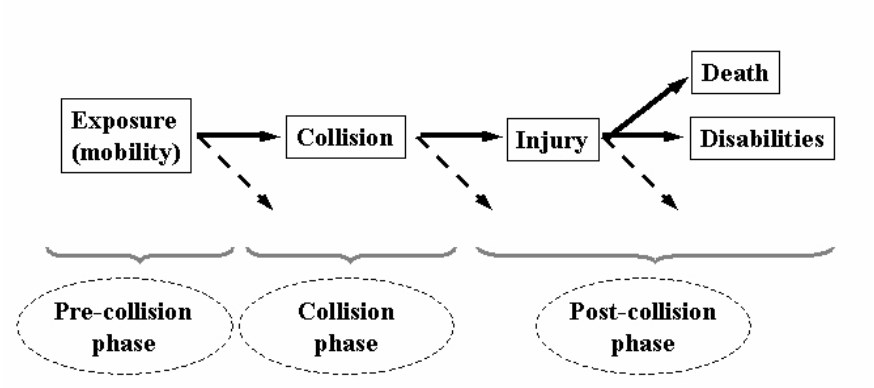


Figure 2 graphically displays the time sequence of road traffic injuries. The mobility of the individuals entails an exposure to the risk of sustaining road traffic injuries. Accordingly, some of these individuals will be involved in a road traffic collision. Depending on the amount of energy transferred in the collision, and to other factors related to the host, the vehicle, and the environment, the collision might lead to a road traffic injury, from which subjects might recover or, otherwise, lead to transitory or permanent disabilities or death. This sequence can be divided into three phases: the pre-collision phase, in which a set of factors contribute to the occurrence of the crash (i.e., they increase the crash probability), the event phase, in which certain factors contribute to the generation of injury once a crash has occurred, and the post-event phase, in which a series of factors have an influence on survival and disabilities once injury has occurred.

Figure 2. The sequence of road traffic injuries.



Adapted from Seguí-Gómez et al (Seguí-Gómez, 2007)

Haddon unified the agent-host-environment model with the three phases of road traffic injuries, and created the Haddon matrix, which allows to identify the factors involved in road traffic collisions

according to the phase in which they are involved (Figure 3) (Haddon, 1968). The matrix considers two types of environmental factors: physical factors (e.g. road design) and social factors (e.g. traffic laws).

Figure 3. The Haddon matrix.

	Individual factors	Vehicle factors	Environmental factors	
			Physical	Social
Pre-collision phase				
Collision phase				
Post-collision phase				

The Haddon matrix also allows to classify road safety interventions. In the pre-collision phase, interventions aim to reduce exposure to risk and to prevent road traffic crashes from occurring (i.e. primary prevention). In the collision phase, they aim to reduce the probability of injury once the collision has occurred (i.e. secondary prevention). Finally, in the post-collision phase, they aim to reduce the consequences of injury - disability and mortality - (i.e. tertiary prevention). In each of these three phases, interventions can focus on modifying individual, vehicle or environmental factors.

With regard to the type of road safety interventions that can be implemented, in the 1990's Widome defined the classical three "E"s for interventions (Widome, 1991): 1) education, which implies influencing behaviour and raising awareness of injury risk; 2) engineering, which implies designing or redesigning products (i.e., vehicles, infrastructure and others) in order to reduce their risk of

injury or to make them less injurious; 3) enforcement of road safety legislation and regulation (e.g. safety standards).

Also, Haddon suggested ten strategies for injury prevention (Haddon, 1995): 1) to prevent the creation of the hazard - energy, in the case of road traffic injuries – (e.g. to reduce the exposure to risk); 2) to reduce the amount of hazard (e.g. to reduce speed); 3) to prevent the release of the hazard (e.g. to improve brakes); 4) to modify the rate of release of the hazard from its source (e.g. restraints); 5) to separate the hazard from that which is to be protected by time and space (e.g. pedestrian sidewalks); 6) to separate the hazard from that which is to be protected by a physical barrier (e.g. bike helmets); 7) to modify relevant qualities of the hazard (e.g. crash cushions); 8) to make what is to be protected more resistant to damage from the hazard (e.g. to reduce osteoporosis); 9) to begin to counteract damage done by the hazard (e.g. to improve access to emergency care); 10) to stabilize, repair and rehabilitate the object of damage (e.g. to improve health care quality). Strategies 1 to 3 belong to the pre-collision phase, strategies 4 to 8 to the collision phase, and strategies 9 and 10 to the post-collision phase.

5. SOCIAL COGNITIVE MODEL

Compliance of road users with traffic rules is one of the main components of road safety. Understanding which factors motivate human behaviour, and how these factors are interrelated is of prime importance to design effective road safety interventions. Behavioural science has been increasingly applied to injury prevention in recent

years. There are a large number of behaviour change theories that attempt to explain human behaviour with regard to different health-related behaviours, such as the health belief model (Becker, 1974) or the theory of reasoned action (Ajzen, 1980). However, most of these theories have not been applied in the field of injury prevention.

The social cognitive theory attempts to integrate several of the most relevant components of the previous behavioural theories into one comprehensive behavioural model (Bandura, 1986) (Simons-Morton, 2006). One of the main contributions of this theory is that it considers three interrelated constituents: person, behaviour and environment. The person refers to the cognitive, affective and biological aspects, and takes into account the uniqueness of humans, given their unique personality, experiences, cognitive capabilities, and genetic characteristics; the behaviour refers to the intentional or unintentional actions carried out by the person; and the environment can both refer to the physical environment or to the social environment (e.g., policy, neighbourhood, school, and family and peer relationships). Therefore, the characteristics of the environment are processed by the person who initiates an action (behaviour) which can influence the environment, at the same time that the experience of performing such action provides information which is cognitively and emotionally processed by the person, and which will be processed in a different way depending on the person's previous experiences. Several constructs constitute this theory, the most relevant of which are the following:

1) Environment. This construct includes physical items, such as equipment and facilities, as well as social items, including policies,

enforcement practices, the influence of family and friends, and general social norms. While some features in the environment can act as facilitators for a certain behaviour, others can act like barriers.

2) Situation. It refers to the uniqueness of people, and the different ways in which one same environment can be experienced and interpreted by different individuals.

3) Reinforcement. This construct has an influence on the likelihood of performing a specific behaviour. A positive reinforcement, or reward, will increase the likelihood of a certain behaviour, while a negative reinforcement will decrease it. Some consequences may be more reinforcing than others, and there may be several reinforcements taking place at the same time. However, this construct is characterised by its great complexity, since it also depends on how it is cognitively interpreted by the person, being it possible for a negative reinforcement to increase the likelihood of the behaviour.

4) Observational learning. People can learn through the reinforcement experience of others, and how they experience such reinforcement. They can also learn through modelling, observing a behaviour performed by individuals which have an influence on them, which can modify their own perceptions about social norms and outcome expectations.

5) Behavioural capability. It refers to the knowledge and skills of the person. Although they are necessary to perform a certain behaviour, they are not sufficient.

6) Outcome expectations. This construct refers to the anticipated consequences of behaviour. In other words, the individual's prediction of the consequences that will come about after performing a certain behaviour. Such prediction is based on personal experience and observed experience in others, and can vary depending on the social influences of the subject and the specific context in which the behaviour takes place. The strength with which these expectations will influence behaviour will depend on the likelihood of the different consequences predicted, their intrinsic value and their relative value (compared with the remaining consequences).

7) Self-efficacy. It refers to the person's beliefs about his or her ability to perform the behaviour successfully. It depends on a series of factors, such as the person's behavioural capability or the environmental facilitators and barriers.

It must be pointed out that, according to the social cognitive theory, although behavioural capability (i.e. skills and knowledge) is an important factor, many other factors play an important role in the person's final decision of undertaking or not a specific action.

6. ROAD SAFETY AND GENDER

The rationale for studying road safety issues separately in men and women lies behind the fact that they are exposed to different injury risk situations in traffic, have different risks for injury given a certain traffic crash, and behave differently in traffic.

Although women account for a smaller proportion of traffic injuries, they have a higher risk for being injured or killed given a certain physical impact (Awadzi, 2008) (Laapotti, 2003) (Evans, 2001). This could be explained by sex differences in terms of certain physiological characteristics such as the resistance of the body to withstand impacts or differences in its size and weight, and their interaction with vehicle safety design (location of and operation of the airbag or safety belt design, among others) (Ulfarsson, 2004). However, gender does not seem to have an influence in mortality adjusted for severity at admission (Hernández-Tejedor, 2008).

In terms of the type of road user, whereas females are more frequently injured as passengers than their male counterparts, males are more frequently injured as drivers and as motorcycle users (Tavris, 2001), reflecting their choice of more dangerous means of transport than women (Martin, 2004). Also, women tend to drive smaller and lighter cars than men, which will ensure less protection in a traffic crash than bigger and heavier vehicles (Welsh, 2001).

As regards traffic behaviour, female drivers are known to show a more positive attitude towards road safety, to have higher levels of

compliance with traffic norms, and to commit less traffic offenses than males (kilometrage controlled) (Laapotti, 2003) (Keskinen, 2003) (Iversen, 2004). Whereas female gender has been observed to predict seatbelt use (Lerner, 2001), male gender is a strong predictor of risky driving (Oltedal, 2006). Men report engaging in risky driving behaviours more often than women do (Keskinen, 2003) (Jelalian, 2000), they score higher in driver aggression, thrill seeking, and risk acceptance (Turner, 2003) (Jonah, 1997), and are more likely to report inappropriate behaviour in traffic (Iversen, 2004). For example, men have been observed to drive under the influence of drugs or alcohol more frequently than women (Calafat, 2008). In another study performed at a hospital in Wisconsin, although men and women were approximately equally represented in collisions with another motor vehicle, loss of control was approximately twice as frequent in males as in females (Tavris, 2001). Furthermore, whereas excessive speed and driving under the influence of alcohol are the main reasons for loss of vehicle control among male drivers, driving on slippery roads is the main cause among female drivers (Laapotti, 1998) (Laapotti, 2004). With respect to the elderly, a higher percentage of men have been observed to continue to drive at night with poor vision – a behaviour which can be considered as being of relatively high-risk - (Brabyn, 2005). As regards pedestrians' behaviour, male pedestrians cross on a red light more frequently than female pedestrians (Rosenbloom, 2009), while women are less likely to intend to cross since they perceive more risk (Holland, 2007). Riskier attitudes towards traffic among males can already be observed among children: boys tend to engage in riskier behaviours than girls, they also attribute more injuries to bad luck and rate dangerous situations with lower risk of injury compared to their

female counterparts (Barton, 2007) (Morrongiello, 1998). In general, boys have more impulsive behaviours that imply a higher risk of injury (Schwebel, 2005).

Differences in high-risk behaviours between men and women are not explained by the innate differences in the biological sex. Rather, they depend on the individual's socialization of gender roles, that is, the individuals' perceptions of the societal expectations with regard to gender role. Such roles are based on gender stereotypes, a set of beliefs about the characteristics that male and female individuals should have in terms of physical appearance, attitudes, interests, psychological traits, social relationships, and occupations, and which can vary depending on the social and cultural traits of each society at a particular moment in time (Morrongiello, 2004) (Granié, 2009) (Courtenay, 2000). In particular, risk-taking behaviours are generally considered a typical masculine feature. In fact, the subject's conformity with masculine stereotypes can predict injury-risk behaviours, including risk-taking in driving. As an example, whereas being male only predicted certain violations, the masculinity score positively predicted the number of offences and aggressive violations, and the femininity score negatively predicted the number of crashes, offences, and aggressive violations. Specifically, the combination of high levels of masculinity and low levels of femininity were related to the highest levels of crashes and aggressive violations. Therefore, whereas being a skilful and fearless driver is considered a masculine feature, being a safe driver is seen as a neutral or feminine characteristic (Özkan, 2005) (Sibley, 2009). Furthermore, conformity to gender stereotypes does not only explain why males and females

differ in risk-taking, but they can also help to understand differences within male groups and female groups in risk-taking.

Gender role socialization actually begins at very young ages. Parents' contribution to gender identity development and gender-role learning has an influence on the sex differences found in children's risk-taking. For instance, mothers expect more risky behaviours of sons than of daughters, they are more concerned about injuries to daughters, and believe they can have greater influence on the risk-taking behaviour of daughters (Morrongiello, 2004). In addition, whereas girls are encouraged to be nurturing and polite, boys are encouraged to be autonomous, adventuresome, and independent, generally receive less direct supervision than same-age girls, and are permitted to take greater risks (Morrongiello, 2004) (Morrongiello, 1998).

All of the aforementioned differences between men and women in terms of road safety entail the need for approaching the problem of traffic injuries taking these differences into account.

7. ROAD SAFETY POLICY

Several key organizations influence road injury policy: the government and legislative bodies, the police, industry, the media, injury control professionals, NGOs and special groups of interest and citizens (Peden, 2004). Road safety policy making should take into consideration the interests and opinions of all of these organizations. In addition, a strong and sustained political will is required to achieve road safety

targets and ensure that road safety is given enough priority, including appropriate funding, necessary legislative changes, a capable bureaucracy and the involvement of other stakeholders (OECD, 2006) (ECORYS, 2005) (ETSC, 2006).

According to the European Community Treaty, the European Commission has the power to legislate in order to adopt measures aiming to improve road safety. The European Commission, as stated in the White Paper on European transport policy (White Paper, 2001), established the target of reducing road traffic fatalities in the European Union by 50% by the year 2010 (compared to the year 2001). The Road Safety Action Programme describes the specific measures put forward by the Commission aimed to achieve this target, which are focused on road user behaviour (mainly through police enforcement), on vehicle safety and on road infrastructure (RSAP, 2003). One of these measures consists in developing the European Road Safety Observatory, whose function is to coordinate the collection and analysis of road safety data from the state members and to provide best practice guidelines for road safety policy making (ERSO, 2007).

The year 2004, the theme of the World Health Day was “Road safety is no accident”. It was precisely this year that the World Health Organization (WHO) and the World Bank launched a report on road traffic injury prevention whose main aims were (1) to increase the level of awareness and commitment of road injuries, (2) to shift from the current perception of injuries as the unavoidable consequence of mobility to the idea that they are preventable through action at different levels, (3) to provide policy-makers with scientific

information about effective interventions aimed to prevent traffic injuries, and (4) to foster the creation of effective partnerships between the wide range of governmental and non-governmental institutions in charge of road traffic safety (Peden, 2004). Of particular importance in this report is the "systems approach". This approach, based on the recognition of the vulnerability of the human body and the fallibility of humans in traffic, suggests that the implemented road safety measures should try to compensate for these facts through action at the different levels of prevention (prevention of the collision, prevention of injury given a collision and prevention of the consequences of injury) and by the promotion of collaboration between the different sectors involved in road safety. To reduce the burden of traffic injuries, the authors of the report suggest that every country should (1) identify a governmental lead agency in charge of road safety, (2) elaborate a diagnosis of their current situation in terms of the burden of road injuries, the policies that have been implemented and their capacity for prevention, (3) elaborate a national and multisectoral road safety strategy and plan of action, (4) allocate enough financial and human resources to put into practice the suggested actions, and (5) implement actions for the three phases of the Haddon Matrix and assess their effectiveness.

The recommendations of this report were endorsed by the United Nations in its resolution 58/289: "Improving global road safety" (UN 58/289, 2004). Afterwards, the World Health Assembly adopted resolution WHA 57.10: "Road safety and health", in which they requested the WHO member states to prioritise road safety as a public

health issue and reduce their burden of road injury by implementing effective interventions (WHO 57.10, 2004).

At the European level, the WHO Regional Committee for Europe resolution RC55/R9: "Prevention of injuries in the WHO European Region" provides a framework for injury prevention in the European Region (RC55/R9, 2005). Several organisations are working on injury prevention in Europe. The International Transport Forum is an inter-governmental organisation in which stakeholders from the government, politics, industry, researches and civil society from the Organisation for Economic Co-operation and Development (OECD) countries have the chance to discuss about the role of transport in the economy and in society. The European Transport Safety Council (ETSC), an independent non-profitmaking organisation linked to the European Commission, aims to reduce the number and severity of road traffic crashes in Europe by providing impartial expert advice about evidence-based effective road safety measures. Also, the European Road Safety Observatory, created the year 2004, among other functions collects road safety data from the state members, with which it maintains the Community database on Accidents on the Roads in Europe (the CARE database).

Following the approval of the Road Safety Action Programme, the Spanish government established road safety as a political priority, and created the Road Safety Special Measures 2004-2005 (DGT, 2005) and the Road Safety Strategic Programme 2005-2008 (DGT, 2006a). The main goal of this Programme was to reduce road fatalities by 40% by

the year 2008, compared with the year 2003. To achieve this objective 182 actions are proposed, included in 10 strategic areas (Table 1).

Table 1. Strategic areas and lines of the Road Safety Strategic Programme 2005-2008.

Strategic areas	Strategic lines
Road safety education	Promotion of road safety education Drivers' licenses: improvement of procedures related with road safety training Drivers' reeducation and awareness-raising
Road safety awareness	Enhancement of road safety awareness in the society Preventive actions carried out by the health sector
Surveillance and control	Improvement of the resources and actions undertaken to enforce road safety behaviours Promotion of the reforms needed to increase the effectiveness of the penalising procedures
Vehicle safety	Enhancement of vehicles' safety devices Improvement of vehicle registries to provide more and better data on vehicle fleet
Road infrastructures and improvement of road safety information and management	Improvement of road traffic information and management Upkeep, improvement, and building of infrastructures to improve road safety Improvement of infrastructures with respect to black spots Performance of audits, studies and normative to improve road safety
Road safety in the field of transport and labour	Education, awareness-raising and enforcement of professional drivers with respect to road safety Other measures aimed to promote road safety among professional drivers and in the labour sector
Assistance to the victims and their families	Improvement of the assistance provided to road traffic victims and their families
Road safety research and analysis	Improvement of the process of collection, processing, analysis and diffusion of road safety information
Participation of society	Promotion of the National Road Safety Council as a permanent forum of participation
Coordination between administrations	Improvement of the coordination between administrations in road safety issues

8. JUSTIFICATION

In Spain, prior to road safety prioritisation on the year 2004 other interventions had been implemented. Most of them consisted in passing road safety normative, such as the establishment of illegal blood alcohol concentration levels, speed limits, or making compulsory to use passive safety devices. Also, road infrastructure and health care delivery in emergency settings were improved (Villalbi, 2006). However, with respect to road safety enforcement, most of the interventions which focused on ensuring compliance with traffic legislation were set up from the year 2004 on: the number of speed cameras installed on non-urban roads (excluding Catalonia and the Basque Country) increased from 4 to 295 cameras between the years 2004 and 2009, and the number of alcohol checkpoints performed over the number of registered drivers increased from an 11.1% in the year 2003 to a 22.1% in the year 2008. Also, the penalty point system was implemented the 1st of July 2006, and a Penal Code reform became effective on the 1st of December 2007, which considers as crimes certain road traffic behaviours such as driving without a license or after having lost all license points and exceeding speed limits or blood alcohol concentration limits over specific thresholds (DGT, 2006b) (DGT, 2007).

Given the large amount of human and economic resources that have been invested in improving road safety, it is of prime importance to ensure that only effective interventions are implemented. As such, the impact on traffic morbidity and mortality of the set of interventions set up recently in Spain should be assessed. Likewise, additional road

safety measures with proven international effectiveness should also be implemented.

B. HYPOTHESES AND OBJECTIVES

1. HYPOTHESES

The following hypotheses were formulated:

1. The package of road safety interventions implemented following road safety prioritisation the year 2004, included in the Road Safety Special Measures 2004-2005 and the Road Safety Strategic Programme 2005-2008, have been effective in reducing the number of people injured and killed on the Spanish roads.

2. Specific road safety interventions implemented in Spain, such as the penalty points system, the reform of the penal code and the installation of speed cameras, have been effective in reducing the number of people injured and killed on the Spanish roads.

2. OBJECTIVES

2.1. General objectives:

1. To review the road safety interventions which have proven to be effective in reducing road traffic deaths and injuries, based on the scientific evidence.

2. To assess the impact of overall road safety interventions implemented recently in Spain on morbidity and mortality.

3. To assess the impact of specific road safety interventions implemented recently in Spain on morbidity and mortality.

2.2. Specific objectives:

1.1 To review the literature to determine which road safety interventions have been proven effective in reducing road traffic injuries, based on literature reviews.

2.1 To assess the impact of including road safety in the political agenda in Spain in the year 2004 (i.e., the package of road safety interventions implemented afterwards) on morbidity and mortality, taking into account injury severity and type of road user, by age and gender.

3.1 To assess the impact of the penalty points system in Spain, introduced on the 1st of July 2006, on morbidity and mortality, taking into account injury severity, type of road user, road type and time of collisions, by age and gender.

3.2. To assess the impact of the reform of the Penal Code in Spain, which became effective the 1st of December 2007, on morbidity and mortality, taking into account injury severity, type of road user, road type and time of collisions, by age and gender.

3.3 To assess the impact of installing fixed speed cameras in the city of Barcelona on morbidity and mortality, by age and gender.

The following papers are included in the thesis, each of them covering one of the specific objectives:

- Objective 1.1: (PAPER 1) "Evidence-based effectiveness of road safety interventions: a literature review". This paper was published the year 2009 in *Gaceta Sanitaria*.

- Objective 2.1: (PAPER 2) "Road safety in the political agenda: the impact on road traffic injuries". This paper was published the year 2010 in the *Journal of Epidemiology and Community Health*.

- Objective 3.1: (PAPER 3) "Impact of the penalty points system on road traffic injuries in Spain: a time-series study". This paper was accepted for publication the year 2010 in the *American Journal of Public Health*.

- Objective 3.2: (PAPER 4) "Criminalisation of road traffic offences as a road safety measure: its impact on road traffic injuries. A time series study". At the moment this thesis was printed, this paper was under review in the *Bulletin of the World Health Organisation*.

- Objective 3.3: (PAPER 5) “Effectiveness of speed enforcement through fixed speed cameras: a times series study”. This paper was published the year 2009 in *Injury Prevention*.

C. METHODS

In this section the methodology used in the four intervention evaluation studies (i.e., assessment of road safety prioritisation, the penalty points system, and the reform of the Penal Code at the national level, and of the speed cameras in Barcelona) included in the present thesis is described. Although most of it has been explained in the papers, certain details are provided which could not be included due to the word number limit of the scientific journals. The methodology used in each study is summarised in Table 2. The methodology used in the literature review of effective interventions is described in the paper.

1. STUDY DESIGN AND POPULATION

The design of all the intervention evaluation studies consisted in interrupted time-series studies. In other words, a time series was considered which was separated into two sub-series (i.e., interrupted) by the introduction of an intervention at a specific moment in time (Figure 4).

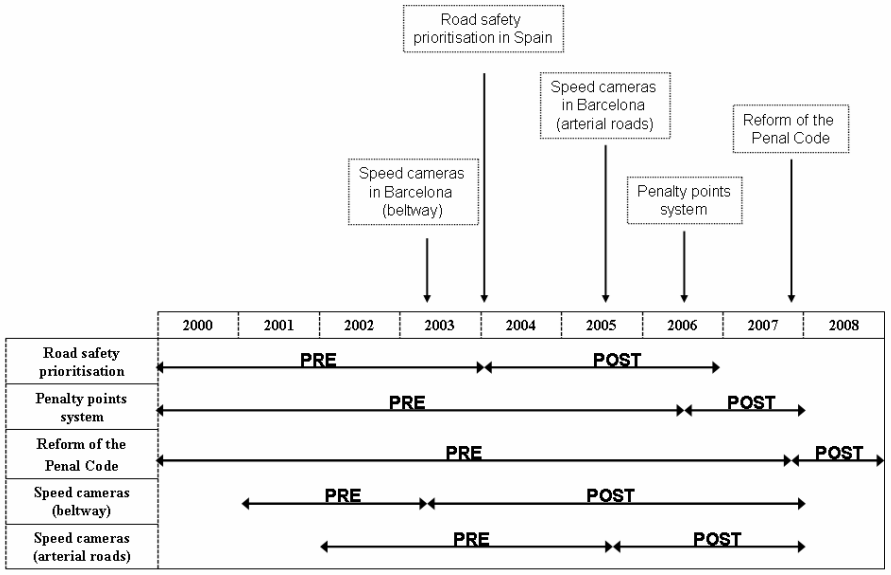
The study population for the study assessing the effectiveness of speed cameras in Barcelona consisted of injury crashes and people injured in road traffic crashes in the city of Barcelona between January 2002 and December 2007 for the arterial roads, and between January 2001 and December 2007 for the beltway. For the remaining studies, the study population consisted of people injured in road traffic crashes in Spain

between January 2000 and December 2006 (December 2007 for the penalty points system study and December 2008 for the penal code reform study). In addition, drivers involved in injury crashes in Spain were also considered in the studies assessing the effectiveness of the penalty points system and the criminalisation of certain road behaviours.

Table 2. Characteristics of the methodology used in the evaluation studies included in the thesis.

Study	Study design	Study population	Period of study	Sources of information	Statistical analysis
Road safety prioritisation	Interrupted time-series design	People injured in road traffic crashes in Spain	Pre-intervention period: 2000 – 2003 Post-intervention period: 2004 – 2006	a) The traffic crashes database of the Dirección General de Tráfico (DGT) b) The hospital discharge registry (CMBD-AH)	Poisson regression models adjusted for over-dispersion (quasi-Poisson), controlled for time trend and seasonality
Penalty points system	Interrupted time-series design	a) Drivers involved in injury crashes in Spain b) People injured in road traffic crashes in Spain	Pre-intervention period: 2000 – June 2006 Post-intervention period: July 2006 – 2006	The traffic crashes database of the Dirección General de Tráfico (DGT)	
Reform of the Penal Code	Interrupted time-series design	a) Drivers involved in injury crashes in Spain b) People injured in road traffic crashes in Spain	Pre-intervention period: 2000 – November 2006 Post-intervention period: December 2006 – 2007	The traffic crashes database of the Dirección General de Tráfico (DGT)	
Speed cameras (beltway)	Interrupted time-series design	a) Injury crashes in Barcelona b) People injured in road traffic crashes in the city of Barcelona	Pre-intervention period: 2001 – March 2003 Post-intervention period: April 2003 – 2007	The local police accident database (Guàrdia Urbana)	
Speed cameras (arterial roads)	Interrupted time-series design with comparison group	a) Injury crashes in Barcelona b) People injured in road traffic crashes in the city of Barcelona	Pre-intervention period: 2002 – July 2005 Post-intervention period: August 2005 – 2007	The local police accident database (Guàrdia Urbana)	

Figure 4. Time the interventions assessed in the thesis were introduced and pre- and post-intervention periods of the studies assessing their effectiveness. Spain 2000-2008.



PRE: Pre-intervention period; POST: Post-intervention period

2. SOURCES OF INFORMATION

Three databases were used:

1) In the study assessing the effectiveness of speed cameras in Barcelona, the local police accident database was used. This database contains the road traffic collisions involving people injured occurred in the city of Barcelona. A specific unit of the local police (Guàrdia Urbana) is in charge of collecting these

collisions since the year 2002, which has led to improve the exhaustiveness of the data.

2) The three remaining studies used the traffic crashes database of the Dirección General de Tráfico (DGT) (General Directorate for Traffic). This database contains data about those road traffic collisions occurred in Spain and which involved people injured. Different police officers are in charge of reporting and collecting information about these collisions. The national police force reports those collisions that occur on non-urban roads, with the exception of Catalonia and the Basque Country, where the road safety competences are transferred (since 1997 in Catalonia and 1982 in the Basque Country) and in which the *Mossos d'Esquadra* and the *Ertzaintza*, respectively, are in charge of this task. With respect to collisions that occur on urban roads, they are collected by local police officers. All these collisions are compiled by the DGT and included into their traffic crashes database. This database is, thus, subject to quality differences in the collection of road traffic crashes between the different police officers involved.

   This database, as well as the local police accident database, includes information about the time and location of the collision, the type of vehicle involved, and the characteristics of the subjects involved (sex, age, type of road user – driver, passenger, pedestrian -, and injury severity collected according to police criteria – slight, serious, dead -). People injured are considered seriously injured if they have been admitted to hospital for 24 hours or longer. These databases only include fatalities occurred within the first 24 hours,

although a road traffic fatality is generally defined as a death occurring within 30 days from the day of the collision.

3) The hospital discharge registry (CMBD-AH) was used in the study that assessed the effectiveness of prioritising road safety. This database includes information of the patient: sex, age, and diagnosis. The type of vehicle could not be used since the E code was missing or had unspecific information in a high number of cases (it was missing in 47% of the cases between the years 2000 and 2007 and had unspecific information – which did not allow to know the type of road user - in 92% of the remaining cases). Injury diagnoses were coded using the International Classification of diseases, Ninth Revision, Clinical Modification (ICD-9-CM). Cases were selected if they satisfied all of the following criteria: 1) one or more injury diagnostic (800 to 959.9 codes of the ICD9-CM); 2) presence of an E-code of external cause due to a road traffic collision (E810-819 or E826) or of a "road traffic collisions insurance company" as the financing regimen; 3) emergency admission. The injury severity for each subject was calculated based on the Injury Severity Score (ISS, range 1–75) (Baker, 1974), which was carried out using the ICDMAP-90 software (ICDMAP-90, 1996).

3. VARIABLES

3.1. Dependent variables

The number of people injured due to a road traffic collision was one of the dependent variables in all the studies. The number of injury crashes was also analysed in the speed cameras study, and the number of drivers involved in injury collisions in the studies assessing the penalty points system and the reform of the Penal Code.

3.2. Stratification variables

The following variables were used to stratify the dependent variables:

- Sex
- Age: 0-13 years, 14-15 years [allowed to ride mopeds], 16-17 years [also allowed to ride motorcycles up to 125 cc], 18-29 years [allowed to drive any type of vehicle], 30-44 years, 45-64 years, 65-74 years, >74 years).
- Severity according to the police database: unharmed [only regarding drivers], slight, serious - hospitalized more than 24 hours -, fatal – in the first 24 hours –.
- Severity according to the hospital database: classified using the Injury Severity Score [ISS], obtained with medical criteria, as follows: slight - ISS 1 to 3 -, moderate - ISS 4 to 8 -, serious - ISS 9 to 24 -, critical - ISS >24 -.
- Type of road user: car user, motorcycle user, moped user, pedestrian.
- Road type: urban, non-urban.

- Time of collision: weekday during daytime – Monday thru Friday from 7.00 to 19.59, weekday during nighttime – Monday thru Tuesday from 20.00 to 6.59 -, weekend during daytime – Saturday and Sunday from 7.00 to 19.59 -, weekend during nighttime – Friday thru Sunday from 20.00 to 6.59 -.
- Traffic density: fluent, congested.
- Number of vehicles involved in the crash: single-vehicle collisions, multi-vehicle collisions.

3.3. Explanatory variables

The explanatory variable (the intervention of interest) consisted in a dummy variable that compared the post-intervention period with the pre-intervention period. The moment the intervention was introduced indicated the cut-point which divided the two periods.

3.4. Adjusting variables

The following variables were used to adjust for the presence of other factors which could be explaining the results:

- Socio-economic variables: unemployment rate, and the gross national product.
- Other interventions or regulations implemented during the study period: the new motorcycle regulation which allows car drivers with more than three years of experience to ride motorcycles up to 150 cc without needing to pass a motorcycle riding examination (passed on October 2004), the penalty points system (introduced the 1st of July 2006), the new protocol for police data collection

aimed to improve the reporting of road traffic crashes in Spain (operating since July 2005), and the political prioritisation of road safety (January 2004). A dummy variable was created to compare the periods before and after their introduction.

- Exposure-adjusting variables: gasoline and gas-oil consumption, vehicle fleet and the number of new vehicle registrations were used as *proxies* for exposure.

4. STATISTICAL ANALYSIS

Interrupted time-series analyses were carried out, with month as the unit of analysis, using Poisson regression models adjusted for over-dispersion (quasi-Poisson) (Yannis, 2007). Generalized linear models were used, which allow to extend the linear modeling to data which follows a distribution from the exponential family by means of a link function (Poisson, in this case). These models often bear over-dispersion, which may produce an underestimation of the standard errors, leading to statistically significant associations where no such association exists. To solve this problem, standard errors were scaled using the inverse square root of the Person χ^2 (Hardin, 2007).

Since appropriate exposure denominators (i.e. kilometres travelled by vehicle) are not available (information is only available for non-urban roads), the absolute number of people injured was compared throughout the time series. This type of analysis (without denominators) assumes that exposure has remained stable throughout the study period. Given that this assumption might be unrealistic, in an

attempt to control for exposure, certain analyses were also performed using as a denominator the monthly car, motorcycle and moped fleet and the monthly number of new car, motorcycle and moped registrations. Additionally, others analyses were performed including gasoline and gas oil consumption as a covariate in the models.

Potential confounding by time trend and seasonal patterns were controlled for using a linear trend and sine and cosine functions (Stolwijk, 1999). Thus, the model for each outcome can be summarized as follows:

$$\ln\left[E\left(Y_t\right)\right] = \beta_0 + \beta_1 t + \beta_2 X_t + \beta_3 X_t t + \\ + \sum_{k=1}^{6}\left[\beta_{4k}\sin\left(\frac{2k\pi t}{T}\right) + \beta_{5k}\cos\left(\frac{2k\pi t}{T}\right)\right] + \beta_6 P_t t + \sum_j\left(\beta_{7j} Z_{jt}\right) + \varepsilon_t$$

where t is the time period (t=1 for the first month of the series, t=2 for the second month, etc.), X_t identifies the pre- and post-intervention periods (X_t=1 for the post-intervention period), which can be multiplied by the time trend (*t*) to take into account the differences in the time trend before and after the intervention (Langbein, 2006), k takes values between 1 and 6 (for example, k=1 for annual seasonality; k=2 for six-monthly seasonality), T is the number of periods described by each sinusoidal function (for example, T=12 months), P_t the dummy variable for road safety prioritisation - included in the studies which assess the effect of the penalty points system and the criminalisation of certain road behaviours -, Z_{jt} other co-variables introduced (socio-economic variables, new protocol for police data collection), j the number of co-variables introduced, and ε the error term. The exposure denominators where included in the models as an offset. Only those

terms which were statistically significant were included in the final model.

Relative risks (RR) and their 95% confidence intervals (95% CI) were derived from the adjusted models. Not reaching $ß_3$ statistical significance, the RR derived from the model ($ß_2$) would indicate the mean change in the overall number of people injured between the post- and the pre-intervention periods, controlling for time trend and seasonality. On the contrary, being $ß_3$ statistically significant, two different RRs would be obtained, one corresponding to mean change ($ß_2 + ß_3 t_0$, where t_0 identifies the month in which the intervention took place), indicating the change in the mean number of people injured during the first month of the post-intervention period compared with the previous month (adjusting for time trend and seasonality) (short-term effect), and another corresponding to trend change ($ß_3$), obtained from the interaction between the intervention and the time period, and which would indicate the change in the time trend between the two periods (long-term effect) (Langbein, 2006). The RR for the mean change in the latter case should not be confused with the mean change in the overall number of people injured throughout the whole post-intervention period obtained in the previous case.

In order to facilitate the interpretation of trend changes, the relative risk is expressed in terms of percentages: time trends in the pre- and post-intervention periods are indicated as the mean percentage increase/decrease in the monthly risk of being injured in that period, and trend change is indicated as the mean percentage increase/decrease in the monthly risk of being injured in the post-intervention period

compared with that in the pre-intervention period. (i.e. the difference between the post- and the pre-intervention period time trends).

The number of prevented people injured attributable to the interventions was also estimated. It was calculated from the difference between the observed and expected numbers of people injured in the post-intervention period. The expected number was predicted with the statistical models by projecting the trends of the pre-intervention period into the post-intervention period had the intervention not been implemented.

Statistical analyses were carried out using Stata statistical software, release 9 (StataCorp, 2005).

D. PAPERS

PAPER 1: LITERATURE REVIEW

Novoa AM, Pérez K, Borrell C. Efectividad de las intervenciones de seguridad vial basadas en la evidencia: una revisión de la literatura. Gac Sanit. 2009 Nov-Dec;23(6):553.e1-553.e14.

Available at:
http://www.elsevier.es/revistas/ctl_servlet?_f=7064&ip=79.159.191.195&articuloid=13145417&revistaid=138

Novoa AM, Pérez K, Borrell C. Efectividad de las intervenciones de seguridad vial basadas en la evidencia: una revisión de la literatura. Gac Sanit. 2009; 23(6): 553.e1-553.e14.

PAPER 2: ROAD SAFETY PRIORITISATION

Novoa AM, Pérez K, Santamariña-Rubio E, Marí-Dell'olmo M, Cozar R, Ferrando J, Peiró-Pérez R, Tobías A, Zori P, Borrell C. Road safety in the political agenda: the impact on road traffic injuries. J Epidemiol Community Health. 2010 Jun 15.

Available at:
http://jech.bmj.com/content/early/2010/06/15/jech.2009.094029.abstract

Novoa AM, Pérez K, Santamariña-Rubio E, Marí-Dell'Olmo M, Cozar R, Ferrando J, et al. Road safety in the political agenda: the impact on road traffic injuries. J Epidemiol Community Health. 2011; 65(3): 218-25.

PAPER 3: THE PENALTY POINTS SYSTEM

Novoa AM, Pérez K, Santamariña-Rubio E, Marí-Dell'Olmo M, Ferrando J, Peiró R, Tobías A, Zori P, Borrell C. Impact of the penalty points system on road traffic injuries in Spain: a time-series study. American Journal of Public Health (in press).

Pending official publication as of Nov. 1, 2010

Available at:

http://ajph.aphapublications.org/

Novoa AM, Pérez K, Santamariña-Rubio E, Marí-Dell'Olmo M, Ferrando J, Peiró R, et al. Impact of the penalty points system on road traffic injuries in Spain: a time-series study. Am J Public Health. 2010; 100(11): 2220-7.

PAPER 4: THE REFORM OF THE PENAL CODE

Novoa AM, Pérez K, Santamariña-Rubio E, Borrell C. Criminalisation of road traffic offences as a road safety measure: its impact on road traffic injuries. A time-series study. (Under review in the Bulletin of the World Health Organisation).

CRIMINALISATION OF ROAD TRAFFIC OFFENCES AS A ROAD SAFETY MEASURE: ITS IMPACT ON ROAD TRAFFIC INJURIES. A TIME SERIES STUDY

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ABSTRACT

Objectives: To determine the effect of criminalising a series of traffic behaviours - following the reform of the Spanish penal code - on the numbers of drivers involved in injury collisions and of people injured in traffic collisions in Spain.

Methods: An evaluation study was performed using an interrupted time-series design. The dependent variables - the number of drivers involved in injury collisions and the number of people injured in traffic collisions in Spain 2000-2008 – were stratified by sex, age, injury severity, type of road user, road type and time of collision. The road traffic crashes database of the General Directorate for Traffic was used. The intervention was the reform of the penal code passed in December 2007. The explanatory variable (intervention) compared the post- (December 2007–December 2008) with the pre-intervention period (January 2000–November 2007). Quasi-Poisson regression models were fit, controlling for time trend, seasonality and previous interventions.

Findings: The results of the present study show a reduction in the number of drivers involved in injury collisions [RR=0.92 (0.89-0.96) in men and RR=0.99 (0.94-1.03) in women] following the reform of the penal code in Spain. In addition, 9,789 men ($p<0.001$) and 2,114 women ($p=0.15$) were prevented from being injured. Larger reductions were observed among young male drivers and among male motorcycle or moped riders.

Conclusions: The present study suggests that criminalising certain traffic behaviours can improve road safety, reducing both the number of drivers involved in injury collisions and the number of people injured in road traffic collisions.

Key words: accidents, traffic; effectiveness; evaluation studies; intervention studies; legislation; policy making; wounds and injuries.

BACKGROUND

Although the rate of road traffic injuries in Spain is decreasing, they still constitute a major public health problem. During the year 2008, they accounted for 134,047 people injured and 3,100 deaths[1]. During recent years, several measures have been implemented to reduce the burden of traffic injuries. In 2004, the Spanish government established road safety as a political priority, and created the Special Road Safety Measures 2004-2005[2] and the Strategic Road Safety Programme 2005-2008[3], which comprise a number of interventions based mainly on the enforcement of traffic regulations, which have been observed to reduce traffic injuries by 9% and 11% in men and women, respectively[4]. In addition, the introduction of a penalty points system on July 2006 was associated with an 11% and 12% reduction in the number of men and women seriously injured in traffic collisions, respectively[5].

Legislation alone is unlikely to be effective in deterring road users from performing certain behaviours, and requires rigorous enforcement in order to be successful, whose effectiveness depends on its ability to create a significant deterrent effect (i.e., the perceived risk and fear of the consequences of performing a certain behaviour), which in turn depends on the surveillance level, on the severity of the penalty, and on the swiftness with which it is administered. A public awareness campaign can increase its effectiveness[6-8].

In Spain, although regulated by Spanish traffic law, the number of injuries and fatalities attributable to speeding and drunk driving is still extremely high. One year after the introduction of the penalty points system, the main traffic offences involving the removal of points were speeding (39.3%), non-compliance with wearing passive restraint devices (15.5%) and drunk driving (11.6%)[9]. In order to further reduce road

injuries caused by these behaviours, the penal code was modified on December 1st 2007, criminalising several traffic offences, mainly speeding over the limit, drunk driving, reckless driving and driving without a driver's license. The penalties for committing these violations vary according to the severity of the offence, and can include imprisonment, a fine, community service or license suspension (Table 1). Prior to this reform, the penal code also considered speeding and drunk driving as crimes, although the strictness of the penalties was much lower and it did not specify the speed or blood alcohol levels above which such behaviours were to be considered as a crime, leaving to the judge to subjectively decide such matters. Thus, the reform of the penal code eliminates the subjectivity of the previous penal code, and incorporates stricter penalties, including compulsory imprisonment in certain cases. An important publicity campaign was launched in all news media and it was included in the media agenda, giving rise to intense public debate.

The effectiveness of criminalising road users' behaviour has only been assessed with regard to driving under the influence of alcohol[10-15]. To our knowledge, the effect on road safety of the inclusion of other behaviours in the penal code has not been evaluated to date.

The present study sets out to determine the effect of criminalising several road behaviours on the numbers of drivers involved in injury collisions and of people injured in traffic collisions in Spain. Differences in effectiveness according to gender, age, injury severity, type of road user, road type and time of collision will also be assessed. The study's hypothesis is that the criminalisation of these behaviours will reduce the burden of traffic injuries in Spain, in the context of a previously existing downward trend resulting from several effective road safety interventions implemented during previous years.

METHODS

Study design and population

Using an interrupted time-series design, an evaluation study was performed in two study populations: 1) drivers (injured or unharmed) involved in traffic collisions resulting in injury to self or to others (i.e., injury collisions) and 2) people injured in traffic collisions, in Spain 2000-2008.

Sources of information

The Road Traffic Crashes Database of the Dirección General de Tráfico (General Directorate for Traffic) (DGT) was analysed. It includes information for injury collisions about the characteristics of the collision, the vehicle, and the subjects involved. In Spain, this information is collected by the national (non-urban roads) and local (urban roads) police forces, and sent to the DGT.

Data on national fuel consumption, used as a *proxy* for exposure, was obtained from the Ministry of Public Works.

Variables

The dependent variables were the number of drivers involved in injury collisions and the number of people injured in traffic collisions. Analyses were stratified by gender[16], age, injury severity (classifications assigned by police) (unharmed [drivers only], slight, serious non-fatal [hospitalised for more than 24 hours], fatal), type of road user (car, motorcycle or moped user, pedestrian [only for people injured]), road type (urban, non-

urban), and time of collision (weekday-daytime, weekday-night-time, weekend-daytime, weekend-night-time).

The main explanatory variable was the reform of the penal code. A dummy variable was created to compare the post- (1st of December 2007-31st of December 2008) with the pre-intervention period (1st of January 2000–30th of November 2007).

To adjust for the effect of road safety prioritisation in 2004 and the introduction of the penalty points system in July 2006, two additional dummy variables were included in the models which compared the periods before and after these interventions were introduced.

A variable representing national fuel consumption, which reflects the motorised mobility of the population (i.e., the distance travelled by the overall number of vehicles in Spain) was included in the analyses to adjust for exposure changes during the study period.

Statistical analysis

Time-series analyses were carried out using Poisson regression models adjusted for over-dispersion (quasi-Poisson)[17]. The number of drivers (and of people injured) per month was compared throughout the time series, controlling for time trend and seasonal patterns using linear trend and sine and cosine functions[18]. The model for each outcome can be summarised as follows:

$$\ln\left[E\left(Y_t\right)\right] = \beta_0 + \beta_1 t + \beta_2 X_t + \sum_k \left[\beta_{3k} \sin\left(\frac{2k\pi t}{T}\right) + \beta_{4k} \cos\left(\frac{2k\pi t}{T}\right)\right] + \beta_5 P_t t + \sum_j \left(\beta_{6j} Z_{jt}\right) + \varepsilon_t$$

where t is the time period (t=1 for the first month of the series, t=2 for the second, etc.), X_t identifies the pre- and post-intervention periods (X_t=1 for the post-intervention

period), k takes values between 1 and 6 (k=1 for annual seasonality; k=2 for six-monthly seasonality, etc.), T is the number of periods described by each sinusoidal function (e.g., T=12 months), P_t the dummy variable for road safety prioritisation, multiplied by the time trend (*t*) (i.e., an interaction term) to take into account the differences in the time trend before and after the year 2004[19], Z_{jt} other co-variables introduced (the penalty points system and the national fuel consumption), j the number of co-variables introduced, and ε the error term. Relative risks (RR) and their 95% confidence intervals (95% CI) were derived from the adjusted models. They indicate the difference between the number of drivers (or people injured) involved in injury collisions in the post-intervention period and that in the pre-intervention period, taking into account time trend and seasonality. Percentage change in the number of drivers (or people injured) between the two periods were computed from the RRs.

The number of people prevented from being injured attributable to the reform of the penal code was calculated as the difference between the number of people observed in the post-intervention period and the number predicted by the statistical models.

Statistical analyses were carried out using Stata statistical software, release 10[20].

RESULTS

Between the years 2000 and 2008 1,504,272 drivers were involved in injury collisions in Spain (annual median 168,912), most being male drivers (81.2%) between 18 and 44 years of age (70.8%). In addition, 1,327,291 people were injured in traffic collisions (annual median 147,636), most being men (65.5%) between 18 and 44 years of age

(65.2%). Table 2 shows the distribution of these subjects by sex, age, injury severity, type of road user, road type and time of collision.

Drivers involved in injury collisions

Figure 1 depicts the observed and expected numbers of male and female drivers (overall and for seriously or fatally injured drivers) involved in injury collisions throughout the study period. The graphs show a clear reduction in the number of male drivers involved in injury collisions compared with the expected numbers; notably, no such reduction was observed among female drivers.

Male drivers

For male drivers the overall risk of having an injury collision in the post-intervention period was reduced by 8% (RR=0.92; 95% CI 0.89-0.96). The largest reductions in risk were observed among seriously (15% reduction) and fatally injured drivers (11%); no reduction was observed among unharmed drivers (Table 3).

With respect to driver age, reductions in risk were observed for all drivers under 65 years of age, with greater reductions among those under 30 years of age.

The criminalisation of unsafe traffic behaviours showed a greater reduction in risk on non-urban roads (14% reduction). In fact, on urban roads, drivers' risk of being involved in an injury collision was only reduced for serious or fatal collisions (8%). In addition, the effect for each type of driver differed by road type. Among motorcycle and moped riders, a reduction in risk was observed on both road types, although the effect was larger on non-urban roads. However, car drivers only showed a reduction in risk on non-urban roads.

Finally, a reduction in risk was observed for both day-time and night-time collisions, and this reduction was even more marked for collisions that occurred at weekends.

Female drivers

Among female drivers, there was no significant change in overall risk of having an injury collision in the post-intervention period (RR=0.99; 95% CI 0.94-1.03). Although a trend towards a reduction in risk was observed for most of the subgroups analysed, especially for serious or fatal collisions, significant reductions were only observed on non-urban roads, among car drivers on non-urban roads, and among serious or fatal collisions at weekend during the daytime (Table 3).

People injured in traffic collisions

The number of people prevented from being injured in traffic collisions following the reform of the penal code showed a similar pattern of decrease to that observed for risk of injury collisions among drivers. No effect was observed among pedestrians or among children under 14 years of age.

During the 13 months of the post-intervention period, the observed number of men injured was 9.7% lower than that expected had the penal code not been reformed ($p<0.001$), a 3.9% lower in women ($p=0.15$) (Table 4).

The most marked reductions in the number of people prevented from being injured were observed among men, among individuals between 14 and 30 years of age, motorcycle or moped users, and for collisions that occurred at weekends during the daytime.

DISCUSION

The results of the present study show a reduction in both the number of drivers involved in injury collisions and the number of people injured in traffic collisions following the reform of the penal code in Spain. Greater reductions were observed among young male drivers, especially among motorcycle and moped riders.

The riskier driving behaviour observed among men and young drivers and the fact that the reform of the penal code criminalises several of these unsafe behaviours could partly explain the greater reductions in risk observed among young male drivers[21,22]. Since female and older drivers are generally more compliant road users, the association of stricter penalties to traffic law violation is not expected to reduce their risk of being involved in traffic collisions as much as among less compliant drivers.

The greater reductions observed among motorcycle and moped riders could be partly due to the generally younger age of these road users and to the fact that riders of powered two-wheel vehicles, especially moped users, are generally less compliant with road safety legislation[23].

In addition, a greater reduction was observed on non-urban roads, which might be explained by different compliance levels on urban and non-urban roads in terms of speeding and drunk driving, both included among the criminalised behaviours. A similar reasoning could apply to the greater reduction observed among drivers involved in collisions during the weekend.

The regulation of traffic behaviour is an essential component of road safety policy. However, its effectiveness depends on the intensity with which the laws are enforced. For instance, compliance with traffic regulations in Santa Fe, Argentina, was observed

to be extremely low[24]. In Spain, special attention has been given to enforcement of traffic behaviour since 2004. Following the reform of the penal code, the number of prosecutions increased from 43,296 in 2007 to 87,755 in 2008, most of which were related to driving without a license and to drunk driving.

In concert with strict enforcement, punishing traffic offences with strict penalties can increase the deterrent effect of the law. In Spain, in addition to the larger monetary fines, the reform of the penal code introduced the possibility of temporary or indefinite loss of one's license and, most importantly, the possibility of imprisonment for up to 5 years.

Comparison with previous studies

No previous studies have assessed the effect on rates of traffic injuries of criminalising a set of traffic behaviours. However, several authors have evaluated the effect of considering drunk driving – one of the behaviours included in the reform of the penal code in Spain - as a criminal offence. The results observed in these studies vary greatly, ranging from no effect to a 73% reduction in the number of alcohol-related crashes attributable to this measure. Asbridge and collaborators observed an 18% decrease in the number of fatally injured drunk drivers in Canada after the criminal law was passed[14]. In Taiwan, Chang and Yeh observed a 72.6% reduction in the number of collisions in which drivers made a positive alcohol breath test[10]. Criminalising drunk driving showed a smaller effect in the United States of America (a 6% reduction[13], a 5% reduction[11] and no reduction[12] in the number of alcohol-related fatalities), which could be due to the fact that these studies included several variables for criminal law in the models, which might have diminished the real effect of the measure due to correlation. Finally, in a study performed in Norway and Sweden, the authors did not observe an

increase in the number of traffic fatalities following a reduction in the severity of their criminal laws[15]. However, the authors did not analyse alcohol-related injuries, nor did they adjust for the effect of other coexisting laws aimed to reduce drunk driving.

The results from these studies suggest that one of the road behaviours criminalised in Spain - drunk driving - contributes to reducing the number of alcohol-related crashes, which is consistent with the results observed in the present study. The smaller effect observed in the present study compared with some of the previous studies may be partly due to the fact that much of the traffic injury reduction observed in recent years – due mainly to road safety prioritisation and the penalty points system – was already adjusted for in the models. Thus, the burden of traffic injuries in Spain, especially that for serious injuries, has been following a downward trend since 2004, to which the criminalisation of certain traffic behaviours has added a further reduction. This is particularly notable among motorcycle riders, who showed the smallest reductions in risk following previous road safety interventions[4,5].

Limitations and strengths

Since the intervention was nationwide, no comparison group was available with which to compare the results of the present study. However, time trend, seasonality, fuel consumption and previous road safety interventions were accounted for. In addition, although it may add evidence to the results, a comparison group is not essential in time series analyses, as percent change is compared between time points in the same series[19].

In order to control for exposure changes throughout the study period, national fuel consumption was accounted for in the models, which reflects the motorised mobility of the population. Nonetheless, since age-, sex-, and user-type-stratified information was not available, it was necessary to assume that mobility changes during the study period

were similar across the different subgroups. The number of kilometres travelled by all vehicles was not used since information was only available for non-urban roads, and neither was the number of vehicle registrations because it does not appropriately capture mobility changes: whereas this variable showed a constantly increasing time trend, a decrease in fuel consumption was observed during the year 2008, probably attributable to the economic crisis.

Although Spain is currently undergoing an important economic crisis, its influence on the results of the present study is expected to have been small, since the study period only includes information up to the year 2008, whereas the crisis's negative consequences became especially important during the years 2009 and 2010 (mean unemployment rates of 18.0% and 20.0%, respectively, whereas it was of 8.3% in 2007 and of 11.3% in 2008).

To our knowledge, this is the first study to assess the impact of criminalising road traffic behaviours other than just drunk driving. Although it was not possible to separately analyse the effect of each of the road behaviours penalised, the overall effect of the reform of the penal code was assessed, both on the number of drivers involved in injury collisions, which allows to analyse its effect on the population to whom it is directed and on which the penalties will be applied, and on the number of people injured, which allows to examine the overall effect of the intervention on the Spanish population.

In addition, Poisson regression models were used, which give similar estimates with a similar goodness of fit compared with ARIMA models, and allow the calculation of relative risks, which provide a straightforward interpretation of the intervention's effectiveness[25,26].

Moreover, a large sample size was available, which allowed to stratify the analysis by relevant variables such as age, sex, type of road user, road type, and time of collision. Finally, the long pre-intervention period provided analytical stability.

Conclusions

In conclusion, the results of the present study suggest that criminalising certain road traffic behaviours can be effective in terms of road safety, reducing both the numbers of drivers involved in injury collisions and of people injured in road traffic collisions. The results of the present study can probably be generalised to other countries with an efficient administration and where enforcement is given enough priority.

WHAT THIS PAPER ADDS

What is already known on this subject

- The effectiveness of traffic law enforcement depends on its ability to create a significant deterrent effect, which depends mostly on the surveillance level, but also on the severity of the penalty and on the swiftness with which it is administered.
- The effectiveness of criminalising road users' behaviours has only been assessed with regard to driving under the influence of alcohol.
- To date, the inclusion of other behaviours in the penal code has not been evaluated in terms of road safety.

What this study adds

- The present study suggests that criminalising certain road traffic behaviours can be effective in terms of road safety, reducing both the numbers of drivers involved in injury collisions and of people injured in road traffic collisions.

- In Spain, 11,903 people injured and 375 deaths due to road traffic collisions were prevented in the 13 months after the reform of the penal code was passed.

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NOTE

This paper will be included in the thesis of one of the authors (Ana M Novoa), performed at the Pompeu Fabra University (UPF).

CONTRIBUTORS

AMN and KP designed the study. AMN performed the statistical analyses. All of the authors contributed in the interpretation and the discussion of the results. AMN wrote the first draft of the paper. All of the authors critically revised the manuscript and approved the final version of the manuscript.

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COMPETING INTERESTS

None declared.

ETHICAL APPROVAL

The present study was approved by the ethics committee “Comitè Ètic d’Investigació Clínica – IMAS”, of the Institut Municipal d’Assistència Sanitària (IMAS).

REFERENCES

1. Dirección General de Tráfico. Ministerio de Interior. Anuario estadístico de accidentes 2008. Madrid: Dirección General de Tráfico; 2009.

2. Dirección General de Tráfico. Ministerio de Interior. Plan Estratégico de Seguridad Vial 2005-2008. Medidas Especiales de Seguridad Vial 2004-2005. Madrid: Dirección General de Tráfico; 2005.

3. Dirección General de Tráfico. Ministerio de Interior. Plan Estratégico de Seguridad Vial 2005-2008. Plan de Acciones Estratégicas Claves 2005-2008. Madrid: Dirección General de Tráfico; 2006.

4. Novoa AM, Pérez K, Santamariña-Rubio E, Marí-Dell'Olmo M, Cozar R, Ferrando J *et al*. Road safety in the political agenda in Spain: the impact on road traffic injuries. J Epidemiol Community Health. 2009 Dec 3. [Epub ahead of print]

5. Novoa AM, Pérez K, Santamariña-Rubio E, Álvaro A, Ferrando J, Marí-Dell'Olmo M *et al*. Impact of the penalty points system on road traffic injuries in Spain: a time-series study. American Journal of Public Health (in press).

6. Zaal D. Traffic law enforcement: a review of the literature. Monash university Accident Research Centre; 1994. Report N. 53.

7. Peden M, Scurfield R, Sleet D et al., editors. World report on road traffic injury prevention. Geneva: World Health Organization; 2004.

8. World Health Organization. Global status report on road safety: time for action. Geneva: World Health Organization; 2009.

9. Rodríguez JI. Balance de 3 años del permiso por puntos. Tráfico y Seguridad Vial. 2009;196:12-8.

10. Chang HL, Yeh CC. The life cycle of the policy for preventing road accidents: an empirical example of the policy for reducing drunk driving crashes in Taipei. Accid Anal Prev. 2004 Sep;36(5):809-18.

11. Villaveces A, Cummings P, Koepsell TD, Rivara FP, Lumley T, Moffat J. Association of alcohol-related laws with deaths due to motor vehicle and motorcycle crashes in the United States, 1980-1997. Am J Epidemiol. 2003 Jan 15;157(2):131-40.

12. Whetten-Goldstein K, Sloan FA, Stout E, Liang L. Civil liability, criminal law, and other policies and alcohol-related motor vehicle fatalities in the United States: 1984-1995. Accid Anal Prev. 2000 Nov;32(6):723-33.

13. Wagenaar AC, Maldonado-Molina MM, Erickson DJ, Ma L, Tobler AL, Komro KA. General deterrence effects of U.S. statutory DUI fine and jail penalties: long-term follow-up in 32 states. Accid Anal Prev. 2007 Sep;39(5):982-94.

14. Asbridge M, Mann RE, Flam-Zalcman R, Stoduto G. The criminalization of impaired driving in Canada: assessing the deterrent impact of Canada's first per se law. J Stud Alcohol. 2004 Jul;65(4):450-9.

15. Ross HL, Klette H. Abandonment of mandatory jail for impaired drivers in Norway and Sweden. Accid Anal Prev. 1995 Apr;27(2):151-7.

16. Kunkel SR, Atchley RC. Why gender matters: being female is not the same as not being male. *Am J Prev Med*. 1996; 12: 294-296.

17. Yannis G, Antoniou C, Papadimitriou E. Road casualties and enforcement: distributional assumptions of serially correlated count data. *Traffic Inj Prev*. 2007; 8: 300-8.

18. Stolwijk AM, Straatman H, Zielhuis GA. Studying seasonality by using sine and cosine functions in regression analysis. *J Epidemiol Community Health*. 1999; 53: 235-238.

19. Langbein LI, Felbinger CL. The quasi experiment. In: Langbein LI. *Public program evaluation: a statistical guide*. New York: ME Sharpe; 2006. p.106-33.

20. Stata Corporation. Stata Statistical Software, release 10. College Station, TX: Stata Corporation; 2005.

21. Fergusson D, Swain-Campbell N, Horwood J. Risky driving behaviour in young people: prevalence, personal characteristics and traffic accidents. *Aust N Z J Public Health*. 2003; 27: 337-42.

22. Turner C, McClure R. Age and gender differences in risk-taking behaviour as an explanation for high incidence of motor vehicle crashes as a driver in young males. Inj Control Saf Promot. 2003 Sep;10(3):123-30.

23. Dirección General de Tráfico (DGT). Observatorio General de Seguridad Vial. *Uso del casco en conductores y acompañantes de vehículos a motor de dos ruedas*. Madrid: Investigación, Marketing e Informática; 2005.

24. Beltramino JC, Carrera E. [Traffic law compliance in the city of Santa Fe, Argentina]. Rev Panam Salud Publica. 2007 Aug;22(2):141-5.

25. Tobias A, Díaz J, Saez M, Alberdi JC. Use of poisson regression and box-jenkins models to evaluate the short-term effects of environmental noise levels on daily emergency admissions in Madrid, Spain. *Eur J Epidemiol*. 2001; 17: 765-71.

26. Kuhn L, Davidson LL, Durkin MS. Use of Poisson regression and time series analysis for detecting changes over time in rates of child injury following a prevention program. *Am J Epidemiol*. 1994; 140: 943-55.

Table 1. Criminalised offences included in the reform of the penal code, and their associated penalties.

Offence	Prison term	Economic fine[a]	Community service	License suspension
Exceeding speed limits: by >60km/h on urban roads by >80km/h on non-urban roads	3-6 months*	6-12months*	31-90 days	1-4 years
Driving under the influence of alcohol (BAC >1.2gr/l) or other drugs	3-6 months*	6-12 months*	31-90 days	1-4 years
Reckless driving[b] AND putting the lives of others or their safety at risk	6-24 months			1-6 years
Reckless driving[b], showing contempt for the lives of others AND putting the lives of others or their safety	2-5 years	12-24 months		6-10 years AND vehicle requisition
Reckless driving[b], showing contempt for the lives of others WITHOUT putting the lives of others or their safety at risk	1-2 years	6-12 months		6-10 years AND vehicle requisition
Criminalised offences AND injury to others	2.5-4 years			Definitive suspension
Refusing to undergo alcohol or other drugs tests	6-12 months			1-4 years
Driving without a driver's license	3-6 months*	12-24 months*	10-40 days	
Generating road traffic risk[c]	6-24 months*	12-24 months*	10-40 days	

BAC: Blood alcohol concentration

*Offenders can choose between one or the other.

a. Between 60-1,200 euros/month depending on the economical and personal circumstances.

b. Punishable speeding or driving under the influence of alcohol or other drugs.

c. Includes leaving obstacles on the road, spilling slippery or flammable substances, modifying or destroying road signs or not restoring road safety when obliged.

Table 2. Distribution of drivers involved in injury collisions and of people injured in traffic collisions by age, injury severity, type of road user, road type, and time of collision, in men and women. Spain 2000-2008.

	DRIVERS[a]		PEOPLE INJURED[b]	
	Men (%) (n=1,185,232)	**Women (%)** (n=275,392)	**Men (%)** (n=843,885)	**Women (%)** (n=444,465)
Age (years)				
0-13	--	--	3.3	5.0
14-15	0.8	0.6	1.7	1.9
16-17	2.8	1.8	5.0	3.7
18-29	35.5	40.0	39.0	35.6
30-44	33.6	38.0	28.2	25.8
45-64	21.7	17.5	16.2	18.3
65-74	4.1	1.6	4.1	5.7
>= 75	1.5	0.5	2.5	4.0
Injury severity				
Unharmed	45.1	36.4	--	--
Slight	43.3	55.8	78.8	85.1
Serious	9.8	7.0	17.8	13.1
Fatal (24 hours)	1.8	0.8	3.4	1.8
Type of road user				
Car driver/user	74.6	83.2	59.2	71.4
Motorcycle rider/user	10.8	3.7	13.8	4.5
Moped rider/user	14.6	13.1	19.8	11.8
Pedestrians	--	--	7.2	12.3
Road type				
Urban	52.0	55.9	45.5	48.1
Non-urban	48.0	44.1	54.5	51.9
Time of collision				
Weekday daytime	53.2	61.2	48.4	51.8
Weekday night-time	14.1	12.5	14.9	12.6
Weekend daytime	16.9	14.6	18.2	19.8
Weekend night-time	15.8	11.7	18.5	15.8

a. Gender was not available for 57,239 (3.8%) drivers, injury severity for 92,201 (6.6%) drivers, and type of road user for 43,937 (2.9%) drivers.

b. Gender was not available for 38,941 (2.9%) people injured and type of road user for 34,528 (2.6%).

Table 3. Adjusted relative risks[a] (95% CI) for DRIVERS of being involved in injury collisions during the post-intervention period compared to the pre-intervention period by injury severity, type of road user, road type, and time of collision, in men and in women. Spain 2000-2008.

	MEN						WOMEN					
	OVERALL			SERIOUS OR FATAL			OVERALL			SERIOUS OR FATAL		
	Monthly median	RR	95% CI	Monthly median	RR	95% CI	Monthly median	RR	95% CI	Monthly median	RR	95% CI
Overall	11036	0.92***	0.89-0.96				2498	0.99	0.94-1.03			
Injury severity												
Unharmed	4597	0.96	0.91-1.01				891	0.99	0.92-1.06			
Slight	4481	0.91***	0.87-0.95				1329	0.99	0.95-1.04			
Serious	1014	0.85***	0.80-0.91				171	0.92	0.83-1.02			
Fatal	190	0.89*	0.81-0.97				19	0.81	0.63-1.06			
Age												
14-15 years	79	0.82**	0.72-0.94	18	0.82	0.63-1.08	15	0.81	0.61-1.06	2	0.72	0.31-1.71
16-17 years	290	0.83***	0.76-0.90	56	0.90	0.76-1.06	45	0.86	0.71-1.03	5	0.74	0.43-1.26
18-29 years	3755	0.89***	0.86-0.93	419	0.79***	0.74-0.85	989	1.00	0.96-1.06	75	0.90	0.79-1.04
30-44 years	3555	0.94**	0.91-0.98	367	0.86***	0.80-0.93	925	1.00	0.95-1.06	62	0.92	0.79-1.07
45-64 years	2295	0.96*	0.92-1.00	226	0.92	0.83-1.01	417	0.98	0.92-1.04	33	0.96	0.80-1.16
65-74 years	426	1.02	0.96-1.09	57	1.01	0.85-1.20	57	1.26**	1.08-1.48	4	1.84*	1.10-3.09
75 years and over	160	1.06	0.97-1.16	27	1.12	0.92-1.34	11	1.24	0.97-1.60	1	0.94	0.41-2.16
Type of road driver by road type												
Urban roads												
Overall drivers	5740	0.99	0.93-1.04	300	0.92*	0.85-0.99	1404	1.04	0.98-1.10	48	0.99	0.84-1.18
Car driver	3324	1.02	0.97-1.08	69	1.01	0.86-1.18	1008	1.06	0.99-1.14	17	1.07	0.80-1.43
Motorcycle rider	600	0.87***	0.81-0.95	77	0.86*	0.76-0.97	67	0.90	0.79-1.02	4	0.92	0.61-1.38
Moped rider	1017	0.90***	0.85-0.96	129	0.88	0.78-1.00	270	0.96	0.88-1.04	24	0.89	0.69-1.14
Non-urban roads												
Overall drivers	5279	0.86***	0.81-0.91	900	0.83***	0.78-0.90	1120	0.93*	0.87-0.99	140	0.89*	0.79-1.00
Car driver	3447	0.89**	0.83-0.96	69	1.01	0.86-1.18	995	0.93*	0.87-0.99	17	1.07	0.80-1.43
Motorcycle rider	600	0.87***	0.81-0.95	77	0.86*	0.76-0.97	67	0.90	0.79-1.02	4	0.92	0.61-1.38
Moped rider	1017	0.90***	0.85-0.96	129	0.88	0.78-1.00	270	0.96	0.88-1.04	24	0.89	0.69-1.14
Time of collision												
Daytime weekday	5773	0.94*	0.90-0.99	529	0.92**	0.86-0.97	1511	0.99	0.93-1.04	103	0.95	0.84-1.08
Night-time weekday	1538	0.95	0.88-1.02	184	0.86*	0.77-0.97	313	1.02	0.94-1.11	25	0.97	0.78-1.20
Daytime weekend	1843	0.86**	0.77-0.95	253	0.74***	0.65-0.85	362	0.97	0.85-1.10	34	0.79*	0.64-0.98
Night-time weekend	1711	0.88*	0.80-0.98	227	0.85**	0.75-0.96	299	0.98	0.87-1.10	25	0.93	0.73-1.18

*p<0.05; **p≤0.01; ***p≤0.001

RR: Relative risk; 95% CI: 95% Confidence intervals of RR

a. Adjusted by time trend, seasonality, the effect of road safety prioritisation in Spain in the year 2004, the introduction of the penalty points system in July 2006, and the national fuel consumption. Pre-intervention period: 1st January 2000 – 30th November 2007; Post-intervention period: 1st December 2007 – 31st December 2008.

Table 4. Number of PEOPLE prevented from being INJURED during the post-intervention period and percent change (95% CI) with respect to the expected number, by injury severity, type of road user, road type, and time of collision. Spain 2000-2008.

	MEN						WOMEN					
	OVERALL			SERIOUS OR FATAL			OVERALL			SERIOUS OR FATAL		
	Prevented (n)[b]	% change[a]	95% CI	Prevented (n)[b]	% change[a]	95% CI	Prevented (n)[b]	% change[a]	95% CI	Prevented (n)[b]	% change[a]	95% CI
Overall	9789***	9.7	5.3; 14.1				2114	3.9	-1.6; 9.4			
Injury severity												
Unharmed	7228***	8.7	3.9; 13.6				1640	3.4	-2.2; 9.0			
Slight	2373***	15.2	9.1; 21.3				553*	10.0	1.9; 18.1			
Serious	330**	12.5	4.0; 21.1				45	7.0	-8.8; 22.8			
Fatal												
Age												
0-13 years	-166	-6.1	-16.2; 4.1	7	1.9	-16.5; 20.3	191	8.2	-3.3; 19.6	22	8.9	-14.1; 31.5
14-15 years	197**	14.2	3.6; 24.8	49	17.3	-3.9; 38.4	106	12.9	-1.6; 27.5	2	2.1	-33.7; 38.9
16-17 years	702***	16.6	8.6; 24.5	138*	17.6	3.7; 31.5	61	3.7	-6.7; 14.1	22	11.2	-10.2; 32.0
18-29 years	4088***	12.1	7.2; 16.9	1228***	20.9	13.3; 28.4	465	2.8	-3.0; 8.6	281**	16.2	5.1; 27.3
30-44 years	2526***	8.4	3.6; 13.2	897***	16.0	9.2; 22.7	-82	-0.6	-7.2; 6.0	165	11.5	-0.2; 23.2
45-64 years	715*	4.4	0.0; 8.6	240	7.2	-1.2; 15.6	292	3.1	-2.8; 9.0	95	7.7	-2.0; 17.4
65-74 years	-176	-5.4	-11.9; 1.1	3	0.4	-10.4; 11.1	-200	-8.6	-16.6; -0.6	-43	-9.6	-25.5; 6.3
75 years and over	-156	-6.3	-13.9; 1.3	-73	-11.2	-23.6; 1.1	-157	-8.2	-17.0; 0.5	-36	-7.0	-22.4; 8.3
Type of road user												
Car user	3552*	7.4	1.0; 13.8	816*	11.5	2.6; 20.4	1135	3.2	-4.0; 10.4	253	7.5	-2.4; 17.3
Motorcycle user	3674***	18.2	10.3; 26.1	1067***	23.8	13.2; 34.4	547**	14.5	4.2; 24.7	69	15.6	-9.0; 40.3
Moped user	1757***	12.8	7.1; 18.4	387***	16.5	7.9; 25.2	464*	8.9	1.7; 16.2	69	14.3	-1.9; 30.8
Pedestrians	-140	-2.5	-9.5; 4.6	134	8.2	-2.6; 18.9	-110	-1.9	-9.4; 5.6	107	7.8	-1.9; 17.6
Road type												
Urban roads	1488	3.4	-2.3; 9.1	463**	9.4	2.7; 16.2	-832	-3.3	-9.1; 2.5	51	2.5	-7.8; 12.9
Non-urban roads	8328***	14.5	8.3; 20.7	2242***	16.8	9.6; 24.0	3016*	10.2	1.8; 18.6	548**	13.2	3.2; 23.3
Time of collision												
Daytime weekday	3440**	6.7	2.1; 11.3	713**	9.0	2.9; 15.1	486	1.6	-4.3; 7.6	24	0.8	-8.1; 9.8
Night-time weekday	848	6.3	-1.7; 14.4	300*	12.0	1.5; 22.5	22	0.4	-9.2; 9.9	36	5.1	-11.4; 21.7
Daytime weekend	3483**	17.7	6.6; 28.7	1209***	27.0	13.6; 40.4	1113	10.2	-2.3; 22.7	371**	23.9	6.9; 40.9
Night-time weekend	2080*	12.4	2.4; 22.5	542**	15.8	3.5; 28.2	540	6.9	-5.4; 19.2	166*	17.1	0.4; 33.6

*p<0.05; **p≤0.01; ***p≤0.001

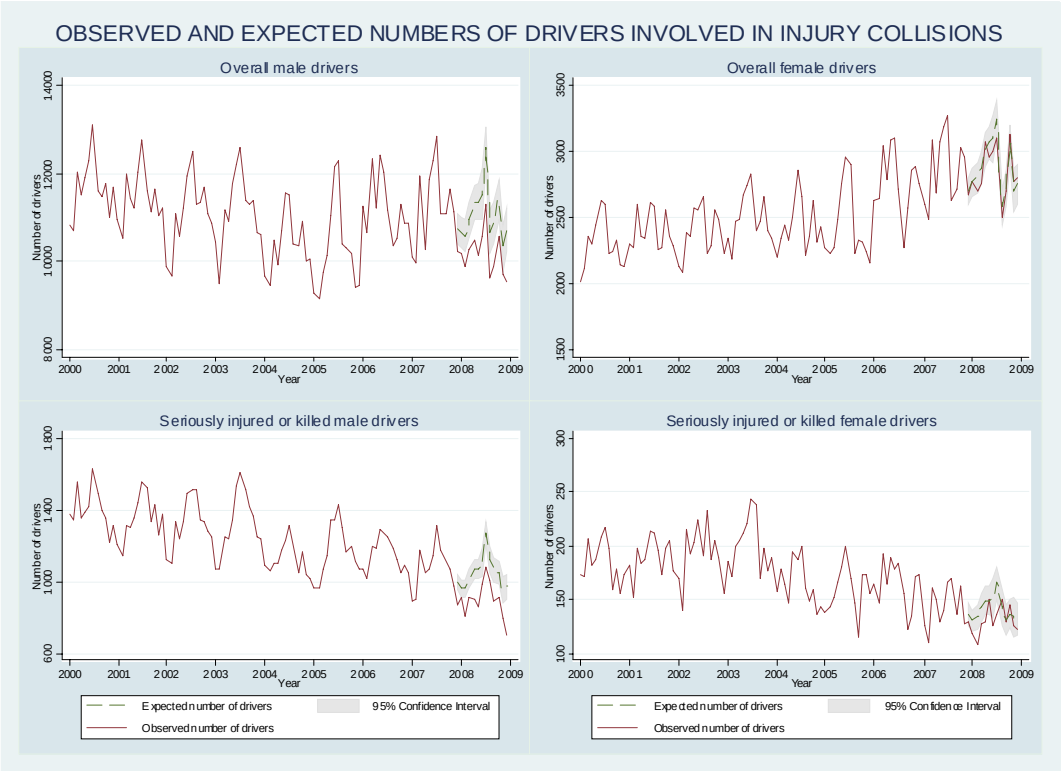
% change: percent change; 95% CI: 95% Confidence intervals of percent change

a. Calculated as the number of people injured prevented over the expected number of people injured in the post-intervention period.

b. Negative numbers indicate an excess of people injured in the post-intervention period compared to the expected numbers had the intervention not been implemented.

Pre-intervention period: 1st January 2000 – 30th November 2007; Post-intervention period: 1st December 2007 – 31st December 2008.

Fig 1. Observed and expected numbers of drivers involved in injury collisions by sex and injury severity. Spain 2000-2008.



PAPER 5: SPEED CAMERAS IN BARCELONA

Novoa AM, Pérez K, Santamariña-Rubio E, Marí-Dell'Olmo M, Tobías A. Effectiveness of speed enforcement through fixed speed cameras: a time series study. Inj Prev. 2010 Feb;16(1):12-6.

Available at:
http://injuryprevention.bmj.com/content/16/1/12.abstract

Novoa AM, Pérez K, Santamariña-Rubio E, Marí-Dell'Olmo M, Tobías A. Effectiveness of speed enforcement through fixed speed cameras: a time series study. Inj Prev. 2010; 16(1): 12-6.

E. DISCUSSION

The studies included in the present thesis suggest that the prioritisation of road safety in the year 2004 changed the trend of road traffic injuries in Spain, being especially effective in reducing the number of seriously injured people. Among the interventions included in the Road Safety Strategic Programme 2005-2008 (DGT, 2006a), speed cameras, the penalty points system, and the criminalisation of a set of road behaviours - by means of reforming the Penal Code – were assessed for effectiveness and were observed to reduce the burden of traffic injuries in Spain. Nevertheless, the literature review included in the thesis identified several effective road safety interventions, such as the graduated licensing system, that have not been implemented as yet, and which could further reduce the number of people injured on the Spanish roads.

1. SUMMARY OF THE PAPERS INCLUDED IN THE THESIS

The first general objective (i.e. to review the road safety interventions which have proven to be effective in reducing road traffic deaths and injuries, based on the scientific evidence) was covered in paper 1: "Evidence-based effectiveness of road safety interventions: a literature review". The objective of this work consisted in identifying and summarizing the available evidence about the effectiveness of road safety interventions in reducing road traffic collisions, injuries and deaths. All those literature reviews published in a scientific journal,

which assessed the effectiveness of one or more road safety interventions and whose outcome measure was road traffic crashes, injuries or fatalities were included. The review showed that there are effective interventions for the three phases of the traffic crash (before, during and after the collision) and for all the factors involved (the individual, the vehicle, the infrastructures and the social environment). The non-effective road safety interventions identified are mainly those based exclusively on the education of road users. It is concluded that the most successful interventions are those that reduce or eliminate the hazard and which do not require knowledge, cooperation, or behaviour change from the individuals (i.e. those interventions focused on the vehicle or on physical environmental factors). Legislation and regulation are effective to a lesser extent, as they require compliance with such rules, which entails modifying individuals' behaviour. Finally, those interventions focused on the individuals, such as education, are the least effective of all.

The second and third general objectives were covered in the evaluation studies included in the thesis (papers 2 to 5). Table 3 and Table 4 summarise the main findings of these studies.

The second general objective (i.e. to assess the impact of overall road safety interventions implemented recently in Spain on morbidity and mortality) was covered in paper 2: "Road safety in the political agenda in Spain: the impact on road traffic injuries". The objective of paper 2 was to assess the effectiveness of introducing road safety onto the political agenda in the year 2004 – and the overall effect of the road safety measures implemented thereafter - on the number of road traffic

injured people in Spain. Differences in the effectiveness with respect to gender, age, injury severity and type of road user were also assessed. An interrupted time-series design was used. The study suggested that prioritising road safety is effective in reducing the number of road traffic injured men and women in Spain. Injury reduction was observed across all injury severity categories, age groups and road users, except for pedestrians.

The third objective (i.e. to assess the impact of specific road safety interventions implemented recently in Spain on morbidity and mortality) was covered in papers 3 (the penalty points system), 4 (the reform of the Penal Code) and 5 (speed cameras): "Impact of the penalty points system on road traffic injuries in Spain: a time-series design study" "Criminalisation of road traffic offences as a road safety measure: its impact on road traffic injuries. A time series study", and "Effectiveness of speed enforcement through fixed speed cameras: a time series study". Paper 3 aimed to assess the effectiveness of the penalty points system introduced in Spain the 1st of July 2006 in reducing road traffic injuries in Spain. Again, an interrupted time-series design was used. The results showed that the penalty points system reduced both the number of drivers involved in injury collisions and the number of people injured in road traffic collisions in Spain, especially among the seriously injured or killed and among those drivers and locations where little interventions had been implemented previously or where the implemented interventions had not been effective. Paper 4 aimed to determine the effect that the reform of the penal code, which considered as crimes a set of road safety behaviours and which was passed the 1st of December 2007, had

on the numbers of drivers involved in injury collisions and of people injured in road traffic collisions in Spain. An interrupted time-series design was also used in this study. Both the numbers of drivers involved in injury collisions and of people injured in road traffic collisions were reduced following the reform of the penal code in Spain, especially among young male drivers and among male motorcycle or moped riders. Paper 5 assessed the effectiveness of fixed speed cameras installed in the city of Barcelona in reducing the numbers of crashes and people injured. Specifically, the speed cameras installed on the arterial roads were evaluated and those installed on the beltway were re-assessed to determine their long-term effectiveness. The study confirmed the long-term effectiveness of the speed cameras installed on the beltway, whose short-term effectiveness had been previously observed (Pérez, 2007). However, it did not show any effect of the speed cameras on the arterial roads, suggesting that speed enforcement through fixed speed cameras is effective on medium-high-speed roads, although effectiveness cannot be generalized to roads with lower speed limits and traffic lights.

Table 3. Prevented[a] numbers of men and women injured in road traffic collisions in the post-intervention period[b] following road safety prioritisation, the penalty points system and the reform of the Penal Code in Spain.

		Men		Women	
		n	%[c]	n	%[c]
Road safety prioritisation	**Overall**	9,850	3.5	14,779*	9.3
	Injury severity				
	Slight	3,311	1.5	10,136*	7.5
	Serious	5,414*	10.2	4,299*	19.2
	Fatal (24 hours)	1,167*	11.5	475*	16.1
Penalty points system	**Overall**	7,720*	5.2	2,787	3.5
	Injury severity				
	Slight	4,494	3.5	1,706	2.5
	Serious	2,699*	10.8	1,074*	11.7
	Fatal (24 hours)	471*	10.6	-16	-1.5
Reform of the Penal Code	**Overall**	9,789*	9.7	2,114	3.9
	Injury severity				
	Slight	7,228*	8.7	1,640	3.4
	Serious	2,373*	15.2	553*	10.0
	Fatal (24 hours)	330*	12.5	45	7.0

*$p<0.05$

a. Negative numbers indicate an excess of people injured in the post-intervention period compared to the expected, according to the numbers observed in the pre-intervention period.

b. Length of the post-intervention periods: 36 months (road safety prioritisation), 18 months (penalty points system), and 13 months (reform of the Penal Code)

c. Calculated as the number of prevented people injured over the expected number of people injured in the post-intervention period.

Table 4. Prevented[a] numbers of people injured in road traffic collisions in the post-intervention period[b] following the installation of speed cameras in Barcelona.

	n	%[c]
Beltway		
Overall	1,219*	26.1
Arterial roads - Enforced stretches		
Overall	-38	-36.9
Arterial roads – Non-enforced stretches		
Overall	-6	-0.1

*p<0.05

a. Negative numbers indicate an excess of people injured in the post-intervention period compared to the expected, according to the numbers observed in the pre-intervention period.

b. Length of the post-intervention period: 4 years and 9 months (beltway) and 2 years and 5 months (arterial roads)

c. Calculated as the number of prevented people injured over the expected number of people injured in the post-intervention period.

2. OVERALL ASSESSMENT OF THE ROAD SAFETY POLICIES IMPLEMENTED IN SPAIN SINCE 2004

2.1. The impact of prioritising road safety

The burden of road traffic injuries in Spain at the beginning of the new millennium was extremely high. The year 2000, 155,557 people were injured and 5,776 were killed in traffic collisions on Spanish roads. The fatality rate was of 144 fatalities per million inhabitants, which placed Spain above the mean for the European Union (117 fatalities per million inhabitants for the 27 member countries) and ranking in the 17th position. Starting the new millennium, the European Commission focused its attention on the problem of road traffic injuries, and established the target of reducing traffic fatalities in the European Union by 50% by the year 2010 (compared to the year 2001) (White Paper, 2001). A set of measures – described in the Road Safety Action

Programme - were proposed to achieve this target (RSAP, 2003). However, this seemed to have little or no effect in Spain: in the year 2003, still 156,034 people were injured and 5,399 were killed (130 fatalities per million inhabitants), placing Spain in the 19th position compared to the 27 state members of the European Union. A possible explanation for the stagnation of traffic injury figures in Spain could be that the interventions implemented hitherto were mostly based on passing road traffic normative (e.g., the establishment of illegal blood alcohol concentration levels, speed limits, or making compulsory to use passive safety devices), whereas little resources were allocated on enforcing these laws.

Coinciding with United Nations' endorsement of the recommendations of the report on road traffic injury prevention launched by the WHO and the World Bank, and the WHO's request to its member states to prioritise road safety as a public health issue, the year 2004 the Spanish government – also coinciding with a change of the political party in power - finally introduced road safety onto the political agenda. This decision was followed by development of the Road Safety Special Measures 2004-2005 (DGT, 2005) and the Road Safety Strategic Programme 2005-2008 (DGT, 2006a), whose goal was to achieve a 40% reduction in road fatalities by the year 2008 (compared to 2003). Several road safety interventions have been implemented since then, many of which focused on increasing the levels of enforcement of road traffic normative. For instance, the number of speed cameras installed increased from 4 to 295 between the years 2004 and 2009, the number of alcohol checkpoints performed over the number of registered drivers increased from an 11.1% in 2003 to a 22.1% in 2008 (DGT, 2006b)

(DGT, 2007). Also, the penalty points system was introduced the 1st of July 2006, and the reform of the Penal Code became effective the 1st of December 2007. Measures other than enforcement were also implemented, such as passing further traffic normative: on 2004 standardized child safety seats and bicycle helmets on non-urban roads were made compulsory, and on 2006 the life period for school buses was set at a maximum of ten years (Rodríguez, 2009). Also, a significant part of the budget was allocated on educating road users and increasing awareness in society, which are the first two strategic areas of the Road Safety Strategic Programme. The effect of the pack of measures implemented following road safety prioritisation was assessed in paper 2. In addition, the effect a set of specific measures (the penalty points system, the reform of the Penal Code, and speed cameras) was assessed in papers 3, 4, and 5.

The findings set out in this thesis indicate that the set of measures implemented following road safety prioritisation considerably reduced the burden of road traffic injuries in Spain. Specifically, in 2008, 3,100 people were killed in road traffic collisions, which implies that road fatalities have been reduced by 43.8% compared to the figures in 2001, placing Spain very close to the target of halving the number of deaths by 50% in 2010, compared to 2001, as set in the White Paper. Also, road fatalities have been reduced by 42.6% compared to 2003, therefore achieving the target set out in the Road Safety Strategic Programme 2005-2008 (DGT, 2006a). Reanalysing the effect of road safety prioritisation for the years 2000-2008, the number of fatalities prevented between the years 2004-2008, taking into account the confounding effects of time trend and seasonality, is of 4,058 people

(an 18.8% less of what was expected had road safety not been prioritised).

The results observed in paper 2 (road safety prioritisation) show that, following road safety prioritisation, there was a significant change in the trend of traffic fatalities, which reflects the accumulative effect of the road safety measures progressively implemented throughout the study period. Compared with these results, a mean change in the number of fatalities was observed in papers 3 (penalty points system) and 4 (reform of the Penal Code), which is consistent with the implementation of a specific intervention in a specific moment in time.

2.2. The need for assessing road safety interventions

All road safety interventions implemented should be assessed for effectiveness. What is more, even if a specific intervention has been proven effective previously, new evaluation studies should confirm it is effective in the specific context in which it is being implemented. The results obtained in paper 5 (speed cameras) support this fact. Although the effectiveness of speed cameras in reducing road traffic collisions and injuries had been previously established in two systematic reviews (Pilkington, 2005) (Wilson, 2006), the results observed in paper 5 (speed cameras) suggest that, although the speed cameras installed on the beltway of Barcelona were indeed effective in reducing road traffic injuries, those installed on the arterial roads were ineffective. These finding show how the effectiveness of speed cameras can be affected by the characteristics of the context and

location where they are installed, in this case by the presence of traffic lights and the lower speed limits of the arterial roads.

The evaluation of road safety interventions also allows to identify differences in their effectiveness by gender, age and other variables of interest. Of special interest is the different effect the interventions being assessed in the present thesis had among men and among women. Specifically, road safety prioritisation brought about larger risk reductions among women, which could be explained by their higher willingness for behaviour change (Jonah, 1997) (Laapotti, 1998). However, the impact of both the penalty points system and the reform of the Penal Code was greater among male road users, probably because they are generally less compliant with the traffic law (Fergusson, 2003) (Turner, 2003). Regarding other variables of interest, in paper 3 (penalty points system), the penalty points system also showed larger reductions in the risk of being injured in a traffic collision among moped riders, on urban roads and for daytime collisions. Likewise, in paper 4 (reform of the Penal Code), criminalizing certain road behaviours was also associated with larger risk reductions among male motorcycle or moped riders. Therefore, intervention evaluation studies not only allow to confirm the effectiveness of road safety interventions, but they can also identify differences in risk reductions among road users. This can help to improve road safety since the identified ineffective interventions can be removed or re-designed and larger efforts can be directed to those road users and locations that are less receptive to the implemented interventions.

2.3. The need for removing ineffective measures

One of the main conclusions of paper 1 (literature review) is that those interventions based on road users' education are the least effective of all. In fact, those exclusively based on education are generally ineffective. Some may even be counterproductive. For instance, certain educational programmes have been observed to induce earlier acquisition of a driving license among younger adults, which would therefore increase the proportion of adolescents involved in traffic collisions and the crash rates in younger drivers (Roberts, 2001) (Vernick, 1999).

Notwithstanding these facts, education-based measures are still among the main interventions implemented in Spain. Specifically, the first and second strategic areas of the Road Safety Strategic Programme 2005-2008 refer to education-based measures (i.e., road safety education and road safety awareness) (DGT, 2006a). Similar approaches can be observed in regional Road Safety Strategic Programmes (Xunta de Galicia, 2005) (SCT, 2004), some of which invest up to 20% of the budget assigned for road safety (Dirección de Tráfico, 2006). Moreover, road safety education is a common topic in conferences and in road safety workshops addressed to adults or to children under the belief that it is the main mechanism for preventing road traffic injuries. In addition, the use of educational advertisements in audiovisual media to improve road behaviour is widely spread. However, a qualitative study revealed that young people are aware of the individual, structural and social determinants of road traffic injuries (Ramos, 2008), suggesting that it is not necessary to increase road safety knowledge. Moreover, scientific literature points out that an increase in road safety

knowledge is not necessarily followed by an improved road traffic behaviour (Zeedyk, 2001) (Mohan, 2003). The risk compensation hypothesis could explain this fact: risky behaviours are not due to ignorance or incompetence, they are rather adopted after balancing risks and benefits of such behaviours (Richens, 2000). The social cognitive theory also indicates that, although skill and knowledge are important, many other factors influence the person's final decision of carrying out a certain behaviour (Bandura, 1986) (Simons-Morton, 2006).

Mohan suggests two explanations for the fact that educational-based measures are widely implemented although international literature suggests that they are ineffective in reducing road traffic injuries: 1) the persistent conception of human error as the main cause for road traffic collisions, which leads to the belief that education must be the solution; 2) the large turnover of professionals - due to road safety not being recognized as a scientific occupation -, who are still not experts in road safety issues when they start working in this area, and who generally start by implementing education-based interventions (Mohan, 2003).

There are, however, some situations in which education-based measures can have a beneficial impact on road safety. Specifically, they can enhance the effectiveness of certain interventions, such as by increasing their visibility through high-quality media campaigns (e.g. television advertisements can increase the visibility of alcohol sobriety checkpoints) (Fell, 2006).

2.4. The need for implementing additional effective measures

Although several effective interventions have contributed to reduce the burden of road traffic injuries in Spain, there are other interventions with proven international effectiveness – reviewed in paper 1 (literature review) - that have not been implemented as yet and that could help to further reduce the number of road injuries that take place on the Spanish roads. For instance, Graduated Licensing Systems have been observed to reduce road traffic crashes, injuries, and fatalities, both in novice young drivers and in novice drivers of all ages (31% reduction in crashes, 7-19% reduction in fatalities) (Hartling, 2004) (Shope, 2007) (Simpson, 2003). Also, the use of daytime running lights has been proven effective in reducing the number of multiparty collisions during daytime (10-15%). However, if this measure were to be implemented in Spain, it would be especially important to assess its effectiveness, since its use has been associated with increases in the overall number of rear-end collisions and its effect has been observed to decrease on those countries closer to the equator, with shorter periods of dusk and dawn (Elvik, 1996).

With regard to vehicle quality standards, vehicle technology is advancing very rapidly. For example, electronic stability control (ESC), an evolution of the antilock brakes (ABS) designed to prevent loss-of-control crashes caused by excessive speeds, sudden maneuvers and slippery road surfaces, has been observed to reduce single-vehicle crashes (31- 53%), injuries (2-41%) and fatalities (41-56%), and multi-vehicle crashes (3-30%), injuries (5%) and fatalities (17%) (Ferguson, 2007) (Erke, 2008). In accordance with the availability of safer vehicles – both for occupants and for other road users –, the

government should attempt to implement policies that foster replacing older vehicles with newer and safer ones. They should also make special emphasis in ensuring that the more economically deprived sectors of the population also have access to these vehicles.

In addition, area-wide traffic calming, which aims to reduce both traffic volume and traffic speed on local roads by means of physical measures, is also effective in preventing road traffic injuries (0-20% reduction) (Bunn, 2003) (Elvik, 2001). Although this type of measure is increasingly being implemented in many Spanish cities, there are still many areas where the vulnerable road users, mostly pedestrians and cyclists, could greatly benefit from the implementation of further traffic calming measures.

Investing in improving roads - so as to make them safer - is also expected to have a great impact on reducing the burden of traffic injuries. For instance, although median barriers can increase the overall number of crashes, they have been observed to considerably reduce their severity (14-46% mortality reduction). In addition, guardrails and crash cushions reduce both the crash rate (18-35% and 74-90%, respectively) and the crash severity (40-48% and 46-83% mortality reduction, respectively) (Elvik, 1999). Given the large number of secondary roads in Spain, and the large risk they involve for road users, implementing this type of measures could substantially improve road safety.

2.5. The need for exposure-reduction based approaches

Compared with the extensive literature assessing the effectiveness of interventions aimed to reduce the probability of a collision, of injury, or of permanent disability or death, few studies have focused on assessing measures aimed to reduce exposure to traffic collisions. As observed in paper 1 (literature review), none of the pre-collision phase interventions included in the review aimed to reduce exposure to traffic, with the exception of area-wide calming measures, which could induce road users to increase their trips walking or cycling.

Furthermore, this type of interventions is seldom taken into consideration by road safety professionals when planning future interventions. In fact, none of the actions included in the Road Safety Strategic Programme 2005-2008 (DGT, 2006a) include exposure-reduction approaches. However, several studies have observed a beneficial impact of investing in appropriate land-use and transport planning (e.g. creation of extensive bicycle paths and automobile-free streets, inclusion of essential establishments in the neighbourhoods, promotion of public transport and restriction of private motor vehicle use) (Priyantha, 2006) (Pucher, 2003) (Ewing, 2003) (Nicholl, 1987). In addition to reducing road traffic injuries, these interventions have other beneficial effects, such as the reduction of obesity, noise, and air pollution. In fact, the WHO recommends incorporating this type of approaches in every country's road safety strategy (Peden, 2004). Specifically, it recommends:

1) To reduce exposure through land-use and transport planning. For instance, placing the facilities people need close to each other

induce people to walk, cycle or use the public transport instead of their private cars. Also, it is important to ensure that the safer routes for vulnerable road users are also the shorter ones. In addition, motorised traffic should be channelled to those roads less frequently used by vulnerable road users, and low speeds should be ensured in residential areas.

2) To encourage the use of safer modes of transport. Given the higher risk that travel by car and motorised two-wheeled vehicles poses to road users as compared to travel by bus and rail, providing convenient and affordable public transport can reduce the distance travelled by riskier modes of transport. In addition, the use of a private vehicle can be discouraged by means of policies such as increasing fuel taxes.

It must be taken into account, however, that implementing this type of interventions requires the collaboration of all the stakeholders involved in road injury prevention (i.e., urban planners, architects, environmentalists, traffic engineers, and police, among others).

In Spain, the reduction of road traffic injuries by means of reducing exposure to crash has, as yet, been given little consideration. Although the use of public transport is increasingly being fostered, especially compared to other countries like the United States of America, its use is mainly limited to large cities, being the citizens of villages and smaller cities still largely dependent on a private vehicle for their daily mobility. As such, there is still much left to be done as regards land-use and transport planning in Spain. Politicians should bear in mind the

importance of this type of interventions, which should be encouraged, since they are at the beginning of the injury sequence (i.e., primary prevention) (see Figure 2 in the Introduction).

3. DISCUSSION OF METHODOLOGICAL ISSUES

3.1. Sources of information

The main sources of information used in the present thesis consist in police databases: the local police accident database (data from the city of Barcelona) and the traffic crashes database of the Dirección General de Tráfico (nationwide data). Originally, these databases were conceived for administrative purposes. As such, the data collected by the police officers might not always include every piece of information needed to analyse road traffic injuries and assess the effectiveness of the implemented interventions. However, they are widely used by public health officers and other professionals since they are the most exhaustive databases available. Nevertheless, it must be pointed out that the institutions in charge of these databases are increasingly aware of their importance for research activities. Accordingly, important efforts are being made to improve their quality and include relevant information.

Similarly, the hospital discharge registry, which was also used in paper 2 (road safety prioritisation), was also originally conceived for administrative purposes, therefore also involving a set of limitations. However, this database is also being improved, especially as regards

the external cause code and the number of hospitals which report their cases to the database.

Despite the limitation of the police and hospital databases, discussed in the "Limitations and strengths" section, they are very useful for research purposes. Furthermore, their linkage can be very enriching, since the combined database would have both information about the characteristics of the collision and the vehicle involved (included in the police database) and about the type of injuries sustained by the victim (included in the hospital registry).

3.2. Adjustment for exposure to road traffic injuries

The number of road traffic injuries can vary due to changes in the exposure to road traffic collisions originated from variations in the number of people travelling or in their time spent travelling. Therefore, appropriate exposure denominators should be included in road safety intervention evaluation studies. However, these denominators are not always available. In Spain, the number of kilometres driven by vehicle, one of the most recommended denominators, is only available for non-urban roads. On urban roads, where approximately half of road traffic collisions occur, this information is not systematically collected.

Exposure variables used in the thesis

In the present thesis, in an attempt to control for exposure, the vehicle fleet and the new vehicle registrations were used as *proxies* for exposure. However, the use of these variables has several drawbacks, since they might not adequately collect exposure variation. First,

vehicle ownership does not always imply vehicle use, nor is it informative of the time and distance travelled with these vehicles. In addition, it does not inform of the non-motorised mobility. Similarly, the acquisition of a new vehicle does not necessarily entail an increase in the time spent travelling nor a change in the means of transport. Moreover, other factors could involve variations in exposure to traffic without these changes being reflected in these two variables. For instance, an increase in fuel prices could give rise to a greater use of cheaper means of transport (public transport, walking and cycling) accompanied with a decrease in the use of cars, motorcycles and mopeds, without necessarily involving changes in the vehicle fleet or new registrations.

The national fuel consumption was also considered as a *proxy* for exposure. This variable reflects the motorised mobility of the population, although it gives no information of the non-motorised mobility. Also, since it does not contain information about the distribution of consumption by age, sex, and type of road user, it was necessary to assume that mobility changes during the study period were similar across the different subgroups.

Given the abovementioned drawbacks of the available exposure variables, the statistical models adjusted the absolute number of crashes and people injured, assuming that exposure remained stable throughout the study period. In addition, they were also adjusted including vehicle fleet, vehicle registrations or fuel consumption as covariables or exposure denominators, depending on the study. Finally, the results obtained in the exposure-adjusted and unadjusted models

were compared. In many cases, both results are informative and complementary. For instance, in paper 2 (road safety prioritisation), when exposure was not taken into account, an important increase was observed in the risk of sustaining a road traffic injury among motorcycle and moped users. On the contrary, an important reduction in risk was observed among these road users when the number of new registrations was included as a denominator in the model. A potential explanation could be that a regulation was passed on October 2004, which allowed car drivers with more than three years of experience to ride motorcycles up to 150 cc without needing to pass a motorcycle riding examination. This led to an important increase in the number of motorcycle registrations. However, its impact on mobility by means of a motorcycle remains unknown. Therefore, the exposure-adjusted results should be interpreted with caution, vehicle fleet and vehicle registration only reflect the change in the number of available vehicles, and not in road users' mobility. As regards fuel consumption, its inclusion as a covariable in the models did not modify the results in papers 2 (road safety prioritisation) and 3 (penalty points system), whose study period ended in 2006 and 2007, respectively. However, it noticeably changed the results in paper 4 (reform of the Penal Code) -which included injury information up to the year 2008 -. In this paper, the important decrease in fuel consumption observed during the year 2008, probably attributable to the economic crisis, led to an important decrease in the exposure to road traffic injuries. On the contrary, the number of vehicle registrations showed an ever-increasing time trend during the year 2008, thus not appropriately capturing the mobility changes.

Exposure variables used in the literature

Other authors have used rates per population and rates per licensed drivers to adjust for exposure (Margolis, 2007) (Males, 2007). However, these denominators do not adequately reflect the variations in the exposure to road traffic injuries, since they do not inform of the variations in the type of vehicle used or in the time spent travelling. Moreover, their impact in exposure is expected to be small.

The potential number of motor vehicles on the roadway (i.e., the vehicle fleet) and the number of motor vehicle registrations have also been used by other authors, who have included them as covariables in the models (Zambon, 2007) (Miller, 2004) (Trolldal, 2005). These variables were also tested in the present thesis. However, their inclusion as covariables did not always adjust exposure variations as efficiently as when they were included as denominators. For example, in paper 2 (road safety prioritisation), their use as covariables did not noticeably modify the results, whereas important variations were observed when they were included as exposure denominators.

Finally, other authors have been able to include the number of kilometres driven in their models (Vernon, 2004) (Nagata, 2008). However, it must be noted that, to fully adjust for exposure variations, the number of kilometres driven should be available by vehicle type, since exposure might vary in one type of vehicle while remaining stable in other vehicles. For example, in Europe, the number of road traffic injuries in motorcycle users has experienced an important increase during the last few years while a reduction has been observed among other road users (ERSO, 2008).

The need for high-quality mobility surveys

To best adjust for exposure changes, high-quality mobility surveys are needed, which should, moreover, be periodically performed. These surveys collect information about the time and the distance travelled, taking into account the means of transport used, by sex and age. Some mobility surveys have been carried out in Spain, such as the *Enquesta de Mobilitat Quotidiana de Cataluña* (Daily Mobility Survey of Catalonia) of the year 2006 or the *Encuesta de Movilidad de las Personas Residentes en España (MOVILIA)* (Mobility Survey of Spanish Residents) of the year 2006. These surveys were led by professionals from sectors other than the public health sector, mainly from the transport sector. As such, the original purpose of these surveys was not to generate exposure denominators. Therefore, researchers might be faced with certain data limitations, such as being unable to estimate with precision the mobility of some road users (e.g., cyclists). Most importantly, the periodicity with which these surveys are performed do not allow to have the monthly, or even yearly, exposure denominators needed for the study of traffic injuries through time.

3.3. Limitations and strengths

Limitations

The following methodological limitations were detected during the elaboration of the present thesis:

1) Lack of appropriate exposure denominators. Appropriate exposure denominators, such as the number of kilometres driven, were only available for non-urban roads. In addition, information from mobility surveys was only available for the year 2006. Consequently, analyses were performed comparing the absolute number of crashes and people injured throughout the time series, assuming that exposure has remained stable throughout the study period. In an attempt to control for exposure, analyses were also performed using vehicle fleet, new vehicle registrations, and fuel consumption as *proxies* for exposure. The comparison of the unadjusted and exposure-adjusted results was particularly helpful to adequately interpret the findings of the intervention evaluation studies.

2) Lack of an adequate comparison group. With the exception of the study assessing the effectiveness of fixed speed cameras in Barcelona, the inclusion of a comparison group was not possible, since the interventions were implemented nationwide. However, although it may add evidence to the results, it is not essential when using time series analysis, as percent change is only compared among time points in the same series. However, in paper 2 (road safety prioritisation), data on people admitted to hospital due to road traffic injuries was also analysed. The similar results obtained using hospital and police data add consistency to the results.

3) Data-related limitations.
   a. Data quality. The validity of the results is subject to data quality. For instance, misclassification among mopeds and

motorcycles has been previously observed in a police database (Pérez, 2009).

Also, police-collected data on injury severity may involve inadequate classification in some cases: one third of seriously injured people are classified as being slightly injured (Pérez, 2006). In paper 2 (road safety prioritisation), to improve the validity of the results for the seriously injured people, a healthcare database was also analysed, as suggested in Lyons et al (Lyons, 2008). In addition, the injury severity included in the local police database of Barcelona was not properly collected prior to the year 2005, which did not allow to stratify the analyses by injury severity.

b. Lack of information. Information which can be of interest for intervention evaluation studies is sometimes lacking in road traffic databases. This is because it is either not properly collected (e.g., high number of missing values) or because it is not collected at all. For example, the police database does not have information about the cylinder capacity of the motorcycles involved in road traffic collisions, therefore not allowing to separately analyse the effectiveness of road safety interventions in high- and low-capacity motorcycles. Also, there is no information about the home address of the person injured, which would allow to study social inequalities in terms of road traffic injuries. For example, some authors have used the ZIP code to assign the income and educational level of people injured in traffic, studying their association with the

ownership of safer vehicles (Girasek, 2010). As regards the hospital database, the type of vehicle involved in the collision is missing in 96% of the cases.

c. Under-reporting of road traffic collisions. The number of road traffic collisions included in the police database is known to be incomplete, especially regarding collisions involving slightly injured people. Moreover, under-reporting is not homogeneously distributed, since it predominantly affects those collisions which occur on urban roads and varies depending on the region and on the city.

d. Variations in time in the notification of road traffic collisions. The assessment of road safety interventions is subject to variations during the study period in the notification of road traffic collisions. A clear example of this is the effect that the new protocol for police data collection, implemented on July 2005, had on the number of collisions reported in Spain, as observed in paper 2 (road safety prioritisation). The protocol, which aimed to improve the reporting of road traffic crashes in Spain, led to a considerable increase in the number of collisions reported, mostly those involving slightly injured people, which are the type of collisions more frequently underreported. Specifically, this protocol was mainly addressed at the national police, who are in charge of collecting traffic collisions occurred on non-urban roads. Therefore, it was on this type of roads where the increase in the number of crashes reported was more obvious. Although an attempt to control for

the variation in the notification of crashes was made in paper 2 (road safety prioritisation), the models adjusted and unadjusted by the new protocol showed limited differences. This could be explained by a lag-time effect with respect to the consequences of the protocol, or because the variable also includes the effect of other events close in time such as the introduction of the penalty points system.

On urban roads, where it is the local police that are in charge of collecting traffic collisions, the notification of road traffic crashes has also experienced an improvement, although the change has been more gradual and heterogeneous than on non-urban roads.

Also, it must be noted that the number of road traffic crashes can also experience reductions attributable to other type of notification variations, such as those observed on urban areas during the summer vacation, owing to a lack of human resources.

Comparison between police and healthcare databases can help to distinguish between real changes in the number of people injured in road traffic collisions and changes attributable to notification variations, although only among people sustaining serious injuries.

The availability of information obtained from insurance companies' databases would help to solve these issues, as well as those of under-reporting.

4) Lack of detailed road safety information in Spain. An exhaustive database including all of the road safety measures implemented in Spain is not available. Several circumstances hinder centralizing all road safety information. For instance, being the national government in charge of establishing road safety normative, it is the local governments who decide the specific road safety actions carried out, which can show important variations depending on the region. Moreover, whereas the national police are in charge of road safety on non-urban roads, on urban areas it depends on the local police.

   Therefore, given that a database containing this information is not available, it was not possible to clearly define the interventions implemented before and after road safety prioritisation in Spain. Consequently, in paper 2 (road safety prioritisation) the two periods had to be considered as two black boxes that mainly differed in that the intensity of road safety enforcement was much higher after road safety prioritisation.

5) Uncontrolled factors. Certain factors which have an influence on the number of road traffic injuries might have not been included in the models, either because the information was not available, because the quality of the information was poor, or because they were difficult to control for methodologically. For example, the

dummy variable included in the model to account for the effect of the new protocol for police data collection implemented on July 2005 did not seem to properly control for the effect of the protocol on crash notification. The effect of other uncontrolled factors – such as weather conditions - can be accounted for by using a comparison group. However, this was only possible in the study assessing the effectiveness of speed cameras installed on the arterial roads of Barcelona.

6) Stability of the series. In time-series analyses, the statistical significance of the results does not only depend on the sample size and on the real effect of the intervention being assessed. It is also subject to the stability of the series. To illustrate this concept, whereas the series for injured car users is rather stable, the series for injured pedestrians does not follow a clear pattern, as observed in Figure 4 of paper 2 (road safety prioritisation). However, to our knowledge, a statistical tool aimed to analyse the stability of the time series does not exist as yet.

Strengths

The studies included in the thesis show the following strengths:

1) Appropriate design and statistical analysis. The design and the statistical analysis performed allowed to control for the main potential confounding factors that usually affect road safety evaluation studies, such as regression to the mean and general trends and seasonality in the number of crashes (Hauer, 2005).

Some authors suggest that the Empirical Bayes approach with a comparison group and flow correction is the best approach (Hauer, 2005). However, the estimates obtained with this method depend on the quality of the prediction models used, as well as on the fact that the models may become outdated if, for example, trends in crash risk decline (Mountain, 2005). In addition, other authors suggest using ARIMA models (Dupont, 2007). However, Poisson regression has been observed to yield similar estimates with a similar goodness of fit of the models. Moreover, their coefficients can be interpreted in terms of relative risks, which provide a straightforward interpretation of the effectiveness of an intervention (Tobías, 2001) (Kuhn, 1994).

2) Assessment of the short- and long-term effectiveness. Most studies assessing road safety interventions compare the overall mean number of crashes in the pre- and post-intervention periods, without taking into consideration differences in the effectiveness in the the short- and in the long-term. In the present thesis, two different RRs were considered (one for the change in the mean number of events the month after the intervention was implemented – short-term effect- and another for the change in the time trend between the pre- and post-intervention periods – long-term effect-). Whenever the RR for time trend was non-significant, only one RR was considered in the model, reflecting the mean change in the number of events throughout the whole post-intervention period. This strategy allowed to obtain a more detailed picture of the effect of the intervention, compared to the use of

only one RR, which does not allow to distinguish between short- and long-term effectiveness.

3) Gender- and age-stratified results. Whenever possible, the analyses carried out in the present thesis were stratified by sex and age. Generally, the observed differences by age in the effectiveness of the interventions mainly reflected the fact that the type of road user varied with age: children and the elderly were mostly injured as pedestrians or car passengers, whereas adolescents were injured mainly as moped or motorcycle riders, and middle-aged adults were generally injured as car occupants. The differences observed between men and women could also be explained by their different pattern as road users: women were more frequently injured as passengers than as drivers, and men sustained traffic injuries while riding two-wheel motor vehicles in a higher proportion than women (Tavris, 2001). However, they could also be due the fact that women show a safer driving behaviour and a higher compliance with traffic norms than men (Jonah, 1997) (Laapoti, 2003) (Oltedal, 2006). These different attitudes might derive from their socialization of the gender roles dictated by the society they live in, which establishes that being a skilful and fearless driver is considered a masculine feature, while being a safe driver is a feminine characteristic (Özkan, 2005) (Sibley, 2009).

4) Long pre- and post-intervention periods. Most of the papers included in the thesis have long pre- and post-intervention periods, which provide stability to the analysis. In fact, the shortest

available period was of 13 months, corresponding to the post-intervention period of paper 4 (reform of the Penal Code).

5) A large sample size, allowing for subgroup analyses. With the sole exception of the intervention group in paper 5 (speed cameras) – the enforced stretches of arterial roads - a large sample size was available in all of the studies, which allowed to take into consideration a set of relevant variables such as age, injury severity, type of road user, road type, and the moment at which the collision occurred.

F. CONCLUSSIONS

The following conclusions can be made as a result of the findings of the studies included in the thesis:

1) The prioritisation of road safety in the year 2004 – and the subsequent implementation of a pack of road safety measures - reduced the burden of road traffic injuries in Spain.

   Specifically, between the years 2004 and 2008, 4,058 people were prevented from being killed as a consequence of a road traffic collision. This important reduction brings Spain closer to the goal of reducing traffic fatalities by 50% by the year 2010, as set by the European Commission on its White Paper on European transport policy. These findings highlight the importance of a strong and sustained political will in order to effectively reduce the number of road traffic injuries in a country. It will ensure that road safety is given enough priority and that enough human and economic resources are assigned to improve it. In Spain, after the Spanish government established road safety as a political priority, the Road Safety Special Measures 2004-2005 and the Road Safety Strategic Programme 2005-2008 were created. These documents reflect a change in the conception of the type of road interventions that should be implemented, moving from measures based exclusively on passing traffic laws to enforcement-based measures.

2) The penalty points system, the criminalisation of a series of traffic behaviours, and speed cameras are some of the measures

implemented following road safety prioritisation which have been proven effective in reducing the number of people injured on traffic collisions.

The penalty points system was shown to reduce both the number of drivers involved in injury collisions and the number of people injured in road traffic collisions, especially among the seriously injured or killed and among those drivers and locations where little interventions had been implemented previously or where the implemented interventions had not been effective. Also, the criminalisation of a set of road traffic behaviours improved road safety, reducing both the number of drivers involved in injury collisions and the number of people injured in traffic collisions, especially among young male drivers and among male motorcycle and moped riders. Finally, with respect to the speed cameras installed in Barcelona, the long-term effectiveness of the speed cameras installed on the beltway was confirmed, whereas those cameras installed on the arterial roads did not show any effect, suggesting that speed enforcement through fixed speed cameras is effective for medium-high-speed roads, although effectiveness cannot be generalized to roads with lower speed limits and traffic lights. This finding highlights the need to assess any road safety intervention implemented, even if it has previously proven effective, since contextual characteristics might alter its effectiveness.

3) Many interventions with proven international effectiveness have not been implemented in Spain as yet.

G. RECOMMENDATIONS

Based on the findings and the conclusions of the present dissertation, the following recommendations can be made:

1. DATA COLLECTION AND VALIDITY

1) To collect adequate exposure information. In order to properly assess road safety interventions, appropriate exposure denominators are needed. Ideally, mobility surveys, such as the Mobility surveys in Spain (Movilia) (Movilia, 2006) and in Catalonia (EMQ) (EMQ, 2006), should periodically gather information about the amount of time people spend travelling taking into consideration a set of relevant variables, including the type of road and the means of transport used, whether motorised or non-motorised. This type of surveys should at least be done annually in order to have information that is updated and that allows to observe the population's mobility variations through time.

   Whenever it is not feasible to perform high-quality periodical mobility surveys, given their extremely high economic cost, the number of kilometres travelled could be used instead. However, this variable has some limitations, the most important of which being that it does not inform about the non-motorised mobility, and that information is generally exclusively given for overall vehicles. The number of kilometres travelled should be available by sex,

age, type of vehicle, road type, geographical area, and hour and day of the week. Although collecting such detailed information is a difficult task, some countries have attempted to do it. For instance, in Japan, the number of kilometres travelled is collected by vehicle by incorporating an odometer to a sample of the registered vehicles in the country, which measures the distance travelled by the vehicle (Nagata, 2008).

2) To improve the reporting of road traffic collisions. A complete and accurate road traffic collision database is needed, since it is the main instrument used for road safety surveillance and research. Although efforts are being made to improve crash reporting, under-reporting still exists, which is, moreover, heterogeneously distributed. Information obtained from insurance companies would be of a great value in order to complete police collisions databases. However, to date, this information is not available. In addition, as regards traffic deaths, mortality registers could also be very useful sources of information. Nevertheless, these databases only collect the date the death occurred, whereas the date of the collision is not registered. As such, it is not possible to know if the death took place within the first 30 days following the traffic crash (which is the definition of a road traffic death).

3) To improve data quality. Not only is it important to report road traffic collisions exhaustively, but also to ensure the accuracy of the collected information. Recently, pocket computers for police officers are being incorporated for the collection of crash information, which are expected to improve data quality and

reduce the errors associated with data-entering procedures. Moreover, special attention should be given to missing information, such as the E-code variable in the hospital registry (missing in a 47% of the cases and unspecific in 92% of the remaining cases), which allows to identify those injuries due to road traffic collisions.

4) To incorporate additional relevant information in the crashes databases. Although a large amount of variables are included in the crashes databases, other variables relevant for research on injury prevention are not available. For instance, information on the home zip code of the person injured would allow to study socio-economic inequalities in road traffic injuries. Reaching a consensus on which information should be prioritised and included in the road traffic crashes databases is of paramount importance.

5) To include the necessary information in the databases to allow the linkage of police and healthcare datasets. As previously mentioned, road traffic crashes are under-reported. Also, whereas the police database includes exhaustive information about the characteristics of the collisions, information about the derived injuries is more accurate and exhaustive in the hospital database. Accordingly, research on road traffic injuries would greatly benefit from combining both databases through a linkage process. However, to date, a combined database at the national level has not been possible to obtain since there are not enough variables to perform the linkage (Cirera, 2007) (Novoa, 2010).

6) To gather information about the implemented road safety interventions. In order to properly assess the effectiveness of road safety measures, an exhaustive database of the interventions implemented in Spain, including detailed information about their location and the date they were introduced, is required. This database would allow to accurately identify the date the intervention being assessed was implemented, and to adjust for other interventions implemented during the period of study. To date, no such database exists, as discussed in paper 2 (road safety prioritisation). The fact that road safety depends on different police departments - the national police for non-urban roads, the local police for urban roads, and for Catalonia and the Basque Country the road safety competences are transferred – hinders gathering together all road safety information at a national level.

2. METHODOLOGY

7) To create a specific methodology to assess the stability of a time series. One of the methodological difficulties researchers using time-series analyses come up against is that it is not possible to distinguish which non-statistically significant results are due to a lack of effectiveness and which to unstable time series. It would be necessary to create a specific methodology that would allow to assess the stability of a time series.

3. INTERVENTIONS

8) To implement effective road safety interventions. Although much has been done in Spain during the last years to reduce the number of road traffic injuries, there is still much more left to be done. The year 2008, still 134,047 people were injured and 3,100 were killed in road traffic crashes on the Spanish roads. This demands further efforts to reduce the burden of traffic injuries in Spain. Now that a new Road Safety Strategic Programme is needed, the interventions set out should be revised, always bearing in mind that every road traffic measure should have proven effectiveness:

- Additional effective measures should be taken into consideration, since some interventions with proven international effectiveness (such as Graduated Licensing Systems or the use of daytime running lights) have not been implemented in Spain as yet.

- The interventions more likely to reduce traffic injuries, as concluded in paper 1 (literature review), are those which focus on factors related to the vehicle and the infrastructures, since they do not depend on road users' behaviour change and reduce the possibility of human error. As such, the government should attempt to implement policies that foster replacing older vehicles with newer and safer ones, as well as invest in improving the roads in Spain, attempting to reduce the risk of injury for road users.

- The interventions based on traffic laws and regulations can also be effective in reducing traffic injuries, although to a lesser extent given their dependence on road users' compliance.

- Ineffective measures should not be implemented, such as those based exclusively on road users' education. This task will be more easily put into practice once human fault is no longer regarded as the main cause for road traffic collisions.

- In addition, it would be necessary to enhance exposure-reduction based interventions, since they are at the beginning of the injury sequence. Although investing on land-use and transport planning can be very costly and with little effect at the short-term, politicians should bear into mind the important reduction on road traffic injuries that this type of measures could have at the long-term, in addition to the important benefits at other health levels (e.g., air-quality improvement).

- Special attention should be given to vulnerable road users throughout this process of rethinking the type of road safety measures to be implemented in the near future in Spain. In the first place, given the increasing number of motorcycle riders and their higher vulnerability to road injuries, special efforts should be made to reduce the risk of injury for this type of road users. Also, historically, non-motorised vulnerable road users have been given little attention, since most interventions have been focused on reducing traffic injuries in drivers and passengers, especially on non-urban roads.

- Finally, gender and social differences with respect to injury risk and to the effectiveness of road safety measures should also be born in mind when planning the new strategy to further reduce the burden of traffic injuries in Spain.

9) To assess every road safety intervention implemented. Even if only effective road safety measures are introduced, once implemented they should be assessed again for effectiveness to ensure that the contextual characteristics at the local level have not modified their effect. As observed in paper 2 (road safety prioritisation), although available scientific literature suggested that speed cameras were effective in reducing traffic collisions and injuries, those installed on the arterial roads of Barcelona were observed ineffective, probably due to the specific characteristics of these roads (lower speed limits and presence of traffic lights).

10) To increase the enforcement of road traffic legislation. Although the regulation of road traffic behaviour is an essential component of road safety policy, its effectiveness is directly dependent on the intensity with which the laws are enforced. In Spain, several traffic laws had been passed prior to the year 2004. However, as observed in paper 2 (road safety prioritisation), it was not until the enforcement of these laws had been given enough importance that the number of road traffic injuries began to decrease. Furthermore, paper 4 (reform of the Penal Code) shows that, in addition to a strict enforcement, punishing traffic offences with strict penalties – such as the possibility of imprisonment - can increase the deterrent effect of the law, especially among the least compliant road users.

However, policy makers have to find a balance between public safety interests and individual liberties (Helbach, 1991). Politicians come up with similar ethical problems in other public health issues, such as tobacco control (Harvey, 2002) (Häyry, 1989). Some authors suggest that only when alternative measures have proven ineffective should policy makers regulate behaviour, always bearing people's liberty in mind (Callahan, 1989).

11) To enhance exposure-reduction based interventions. The introduction of exposure-reduction based interventions should be enhanced, since they are at the beginning of the injury sequence. Primary prevention strategies should be prioritised over those based on secondary or tertiary prevention.

12) To improve communication between road safety institutions. Several stakeholders are involved in road safety policy. However, discrepancies observed between scientific evidence and a number of road safety interventions implemented in Spain (e.g., education-based measures are still being implemented despite the fact that international literature has repeatedly proven them ineffective) suggests that the communication between these institutions needs to be improved. In other words, special efforts should be made to ensure that evidence-based knowledge on road safety issues is easily accessible to all stakeholders involved in road safety decision-making.

13) To improve advocacy of road safety issues. Adequate public health advocacy should help to implement effective policies and

measures. Appropriate advocacy involves increasing awareness of the problem of road traffic injuries to all stakeholders which influence injury prevention policy, including the general public. It also involves effectively conveying which are the road safety measures proven to reduce traffic injuries, as well as achieving public acceptability of the measure (Breen, 2004). Therefore, there is a need to widen the dissemination of the results from scientific research to include the general public, in addition to the scientific community.

14) To promote the collaboration between road safety institutions, enhancing the role of the health sector. Historically, road safety has been regarded as competence of the transport and the police sectors. However, given the large impact it has on mortality and morbidity, the health sector should take part in the decision-making process to a greater extent. Road safety should be a shared responsibility between all the institutions and stakeholders involved.

4. NEW TARGETS

15) To adhere to the international recommendations with regard to road safety. At the international level, having the 3rd Road Safety Action Programme come to an end, the ETSC urges the European Community to develop the 4th Road Safety Action Programme (ETSC, 2008), suggesting that it includes a new set of targets for 2020 in order to further reduce the still unacceptably high level of

traffic injuries in Europe. Specifically, the ETSC suggests setting the target of reducing road traffic fatalities by 40% between 2010 and 2020, as well as including another target for serious injuries, particularly to reduce injuries with lasting effects by 20% by the year 2020. To achieve these targets, the ETSC emphasises the importance of political courage and leadership, since politicians will need to support initiatives that can sometimes be disapproved of by the public.

The 20th of November 2009, the First Global Ministerial Conference on Road Safety was held in Moscow. The conference brought together ministers and representatives dealing with transport, health, education, and safety to discuss progress in implementing the recommendations of the World Report on Road Traffic Injury Prevention (Peden, 2004) and to provide an opportunity for Member States to exchange information and best practices. At the end of the conference, those attending signed The Moscow Declaration, which recognises road traffic injuries as a major public health problem, includes a series of resolutions aimed to further reduce the impact of road traffic injuries, and invites the United Nations Assembly to declare the decade 2011-2020 as the "Decade of Action for Road Safety" in order to reduce the number of traffic injuries forecasted by 2020.

In Spain, the number of serious traffic injuries and deaths has been considerably reduced since 2000, mostly owing to a series of effective measures implemented following road safety prioritisation in 2004. Important efforts and enough resources will

be needed to maintain the level of road safety achieved. Furthermore, additional effective road safety measures should be implemented to reduce the still unacceptably high number of people injured or killed on the Spanish roads every day.

G. REFERENCES

(Ajzen, 1980)
Ajzen I, Fishbein M. Understanding attitudes and predicting social behavior. Englewood Cliffs: Prentice-Hall, Inc.:1980.

(Awadzi, 2008)
Awadzi KD, Classen S, Hall A, Duncan RP, Garvan CW. Predictors of injury among younger and older adults in fatal motor vehicle crashes. Accid Anal Prev. 2008 Nov;40(6):1804-10.

(Baker, 1974)
Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974 Mar;14(3):187-96.

(Baker, 1984)
Baker SP, O'Neill B, Karpf RS. The injury fact book. Lexington, MA: Lexington Books; 1984.

(Bandura, 1986)
Bandura A. Social foundations of thought and action: A social cognitive theory. Upper Saddle River:Prentice HAll;1986.

(Barell, 2002)
Barell V, Aharonson-Daniel L, Fingerhut LA, Mackenzie EJ, Ziv A, Boyko V, Abargel A, Avitzour M, Heruti R. An introduction to the Barell body region by nature of injury diagnosis matrix. Inj Prev. 2002 Jun;8(2):91-6.

(Barton, 2007)
Barton BK, Schwebel DC. The roles of age, gender, inhibitory control, and parental supervision in children's pedestrian safety. J Pediatr Psychol. 2007 Jun;32(5):517-26.

(Bastida, 2004)
Bastida JL, Aguilar PS, Gonzalez BD. The economic costs of traffic accidents in Spain. J Trauma. 2004;56(4):883-8.

(Becker, 1974)
Becker MH. The health belief model and personal health behavior. Health Educ Monographs. 1974;2:324–473.

(Begg, 2002)
Begg S, Tomijima N, Vos T, Mathers C. Global burden of injury in the year 2000: an overview of the methods. Geneva: World Health Organization; 2002.

(Brabyn, 2005)
Brabyn JA, Schneck ME, Lott LA, Haegerström-Portnoy G. Night driving self-restriction: vision function and gender differences. Optom Vis Sci. 2005 Aug;82(8):755-64.

(Breen, 2004)
Breen J. Road safety advocacy. BMJ. 2004 Apr 10;328(7444):888-90.

(Bunn, 2003)
Bunn F, Collier T, Frost C, Ker K, Roberts I, Wentz R. Traffic calming for the prevention of road traffic injuries: systematic review and meta-analysis. Inj Prev. 2003;9(3):200-4.

(Calafat, 2008)
Calafat A, Adrover D, Juan M, Blay NT. Relación del consumo de alcohol y drogas de los jóvenes españoles con la siniestralidad vial durante la vida recreativa nocturna en tres comunidades autónomas. Rev Esp Salud Pública. 2008;82(3):323-31.

(Callahan, 1989)
Callahan D. Legislating safety--how far should we go? N Engl J Med. 1989 May 25;320(21):1412-3.

(CARE, 2010)
European Commission. Directorate-General for Energy and Transport. Energy and transport in figures. 2010. Brussels: European Commission; 2010.

(Cirera, 2007)
Cirera E, Pérez K, Borrell C, Cabeza E, González JC, Cózar R, Lardelli P, Lizarbe V, Ferrer A et al. Viabilidad de la conexión de datos policiales y hospitalarios para estimar muertes a 30 días por accidente de tráfico. Gac Sanit. 2007;21(Espec Congr):11-149 Presented at the twenty-fifth Scientific Meeting of the Sociedad Española de Epidemiología, Córdoba, Spain, October 17-19, 2007.

(Courtenay, 2000)
Courtenay WH. Constructions of masculinity and their influence on men's well-being: a theory of gender and health. Soc Sci Med. 2000 May;50(10):1385-401.

(Cubí, 2008)
Cubí P, Herrero C. Evaluación de riesgos y del impacto de los accidentes de tráfico sobre la salud de la población española, 1964-2004 [dissertation]. Bilbao: Fundación BBVA; 2008.

(DGT, 2005)
Dirección General de Tráfico. Ministerio de Interior. Plan Estratégico de Seguridad Vial 2005-2008. Medidas Especiales de Seguridad Vial 2004-2005. Madrid: Dirección General de Tráfico; 2005.

(DGT, 2006a)
Dirección General de Tráfico. Ministerio de Interior. Plan Estratégico de Seguridad Vial 2005-2008. Plan de Acciones Estratégicas Claves 2005-2008. Madrid: Dirección General de Tráfico; 2006.

(DGT, 2006b)
Dirección General de Tráfico. Ministerio de Interior. Memoria de actuaciones de seguridad vial 2005. Madrid: Dirección General de Tráfico; 2006.

(DGT, 2007)
Dirección General de Tráfico. Ministerio de Interior. Memoria de actuaciones de seguridad vial 2006. Madrid: Dirección General de Tráfico; 2007.

(Dirección de Tráfico, 2006)
Dirección de Tráfico. Viceconsejería de Seguridad. Departamento de Interior. Plan estratégico de seguridad vial de Euskadi. Memoria de actuaciones e informe de evaluación 2005. Dirección de Tráfico; 2006.

(Dupont, 2007)
Dupont E, Martensen H, editors. Multilevel modeling and time series analysis in traffic research – Methodology. Deliverable D7.4 of the EU FP6 project. SafetyNet; 2007.

(ECORYS, 2005)
ECORYS Transport and SWOV. Impact assessment road safety action programme. Assessment for mid term review. Rotterdam: ECORYS Transport; 2005.

(Elvik, 2001)
Elvik R. Area-wide urban traffic calming schemes: a meta-analysis of safety effects. Accid Anal Prev. 2001;33(3):327-36.

(Elvik, 1999)
Elvik R. The safety value of guardrails and crash cushions: a meta-analysis of evidence from evaluation studies. Accid Anal Prev. 1995;27(4):523-49.

(Elvik, 1996)
Elvik R. A meta-analysis of studies concerning the safety effects of daytime running lights on cars. Accid Anal Prev. 1996;28(6):685-94.

(EMQ, 2006)
Autoritat del Transport Metropolità. Departament de Política Territorial i Obres Públiques. Generalitat de Catalunya. Enquesta de mobilitat quotidiana de Catalunya 2006. Barcelona: Autoritat del Transport Metropolita; 2007.

(Erke, 2008)
Erke A. Effects of electronic stability control (ESC) on accidents: a review of empirical evidence. Accid Anal Prev. 2008 Jan;40(1):167-73.

(ERSO, 2007)
European Road Safety Observatory. [Homepage] Leidschendam: SWOV; 2007 [accessed the 30th of March 2009]. Available at: www.erso.eu

(ERSO, 2008)
European Road Safety Observatory. Annual Statistical Reports 2008. SafetyNet; 2008.

(ETSC, 2006)
European Transport Safety Council. A methodological approach to national road safety policies. Brussels: European Transport Safety Council; 2006.

(ETSC, 2008)
European Transport Safety Council. A blueprint for the EU's 4th Road Safety Action Programme 2010-2020. Brussels: European Transport Safety Council; 2008.

(Evans, 2001)
Evans L. Female compared with male fatality risk from similar physical impacts. J Trauma. 2001 Feb;50(2):281-8.

(Ewing, 2003)
Ewing R, Schieber RA, Zegeer CV. Urban sprawl as a risk factor in motor vehicle occupant and pedestrian fatalities. Am J Public Health. 2003 Sep;93(9):1541-5.

(Fell, 2006)
Fell JC, Voas RB. The effectiveness of reducing illegal blood alcohol concentration (BAC) limits for driving: evidence for lowering the limit to .05 BAC. J Safety Res. 2006;37:233-43.

(Ferguson, 2007)
Ferguson SA. The effectiveness of electronic stability control in reducing real-world crashes: a literature review. Traffic Inj Prev. 2007 Dec;8(4):329-38.

(Fergusson, 2003)
Fergusson D, Swain-Campbell N, Horwood J. Risky driving behaviour in young people: prevalence, personal characteristics and traffic accidents. Aust N Z J Public Health. 2003;27(3):337-42.

(Girasek, 2010)
Girasek DC, Taylor B. An exploratory study of the relationship between socioeconomic status and motor vehicle safety features. Traffic Inj Prev. 2010 Apr;11(2):151-5.

(Granié, 2009)
Granié MA. Effects of gender, sex-stereotype conformity, age and internalization on risk-taking among adolescent pedestrians. Safety Science. 2009;47:1277-83.

(Haddon, 1968)
Haddon W Jr. The changing approach to the epidemiology, prevention, and amelioration of trauma: the transition to approaches etiologically rather than descriptively based. Am J Public Health Nations Health. 1968;58(8):1431-8.

(Haddon, 1995)
Haddon W Jr. Energy damage and the 10 countermeasure strategies. 1973. Inj Prev. 1995;1(1):40-4.

(Hardin, 2007)
Hardin JW, Hilbe JM. Generalized linear models and extensions. 2nd edition. College Station: StataCorp LP; 2007.

(Hartling, 2004)
Hartling L, Wiebe N, Russell K, Petruk J, Spinola C, Klassen TP. Graduated driver licensing for reducing motor vehicle crashes among young drivers. Cochrane Database of Systematic Reviews 2004, Issue 2. Art. No.: CD003300. DOI: 10.1002/14651858.CD003300.pub2.

(Harvey, 2002)
Harvey HD, Fleming P, Patterson M. Ethical dilemmas and human rights considerations arising from the evaluation of a smoking policy in a health promoting setting. Int J Environ Health Res. 2002 Sep;12(3):269-75.

(Hauer, 2005)
Hauer E. Observational Before-after studies in road safety. Estimating the effect of highway ant traffic engineering measures on road safety. Oxford: Pergamon Press; 2005 digital printing.

(Häyry, 1989)
Häyry H, Häyry M, Karjalainen S. Paternalism and Finnish anti-smoking policy. Soc Sci Med. 1989;28(3):293-7.

(Helbach, 1991)
Helbach D. A legislative view of driving and legal restriction. Wis Med J. 1991 Mar;90(3):119-20.

(Hernández-Tejedor, 2008)
Hernández-Tejedor A, García-Fuentes C, Toral-Vázquez D, Chico-Fernández M, Alted-López E. Diferencias en el mecanismo y patrón lesional, gravedad y evolución de los pacientes politraumatizados en función del género. Med Intensiva. 2008 Oct;32(7):337-41.

(HiAP, 2006)
Health in all policies. Prospects and potentials. Stahl T, Wismar M, Ollila E, Lahtinen E, Leppo K, editors. Helsinki: Ministry of Social Affairs and Health; 2006.

(Holland, 2007)
Holland C, Hill R. The effect of age, gender and driver status on pedestrians' intentions to cross the road in risky situations. Accid Anal Prev. 2007 Mar;39(2):224-37.

(ICDMAP-90, 1996)
ICDMAP-90 Database Manager Version 1.0. The Johns Hopkins University and Tri-Analytics, Inc. 1996.

(Iversen, 2004)
Iversen H, Rundmo T. Attitudes towards traffic safety, driving behaviour and accident involvement among the Norwegian public. Ergonomics. 2004 Apr 15;47(5):555-72.

(Jelalian, 2000)
Jelalian E, Alday S, Spirito A, Rasile D, Nobile C. Adolescent motor vehicle crashes: the relationship between behavioral factors and self-reported injury. J Adolesc Health. 2000 Aug;27(2):84-93.

(Jonah, 1997)
Jonah BA. Sensation seeking and risky driving: a review and synthesis of the literature. Accid Anal Prev. 1997 Sep;29(5):651-65.

(Keskinen, 2003)
Keskinen E, Rajalin S. Comparison of young male and female drivers' attitude and self-reported traffic behaviour in Finland in 1978 and 2001. J. Saf. Res. 2003;34(5):579–87.

(Kuhn, 1994)
Kuhn L, Davidson LL, Durkin MS. Use of Poisson regression and time series analysis for detecting changes over time in rates of child injury following a prevention program. Am J Epidemiol. 1994;140(10):943-55.

(Laapotti, 2004)
Laapotti S, Keskinen E. Has the difference in accident patterns between male and female drivers changed between 1984 and 2000? Accid Anal Prev. 2004 Jul;36(4):577-84.

(Laapotti, 2003)
Laapotti S, Keskinen E, Rajalin S. Comparison of young male and female drivers' attitude and self-reported traffic behaviour in Finland in 1978 and 2001. J Safety Res. 2003;34(5):579-87.

(Laapotti, 1998)
Laapotti S, Keskinen E. Differences in fatal loss-of-control accidents between young male and female drivers. Accid Anal Prev. 1998 Jul;30(4):435-42.

(Langbein, 2006)
Langbein LI, Felbinger CL. The quasi experiment. In: Langbein LI. Public program evaluation: a statistical guide. New York: ME Sharpe; 2006. p.106-33.

(Lerner, 2001)
Lerner EB, Jehle DV, Billittier AJ 4th, Moscati RM, Connery CM, Stiller G. The influence of demographic factors on seatbelt use by adults injured in motor vehicle crashes. Accid Anal Prev. 2001 Sep;33(5):659-62.

(Llàcer, 2001)
Llàcer A, Fernández-Cuenca R, Martínez de Aragon MV. Mortalidad en España en 1998. Evolución en la década. (I) Mortalidad General, principales causas de muerte y años potenciales de vida perdidos. Boletín Epidemiológico Semanal 2001:9:241-44.

(López, 2006)
Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJ. Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. Lancet. 2006 May 27;367(9524):1747-57.

(Lyons, 2008)
Lyons RA, Ward H, Brunt H et al. Using multiple datasets to understand trends in serious road traffic casualties. Accid Anal Prev. 2008; 40:1406-10.

(Males, 2007)
Males M. California's graduated driver license law: Effect on teenage drivers' deaths through 2005. J Safety Res. 2007;38(6):651-9.

(Margolis, 2007)
Margolis LH, Masten SV, Foss RD. The effects of graduated driver licensing on hospitalization rates and charges for 16-and 17-year-olds in North Carolina. Traffic Inj Prev. 2007 Mar;8(1):35-8.

(Martin, 2004)
Martin JL, Lafont S, Chiron M, Gadegbeku B, Laumon B. Differences between males and females in traffic accident risk in France. Rev Epidemiol Sante Publique. 2004 Sep;52(4):357-67.

(Mathers, 2006)
Mathers CD, Loncar D. Projections of global mortality and burden of disease from 2002 to 2030. PLoS Med. 2006 Nov;3(11):e442.

(Miller, 2004)
Miller T, Blewden M, Zhang JF. Cost savings from a sustained compulsory breath testing and media campaign in New Zealand. Accid Anal Prev. 2004 Sep;36(5):783-94.

(Mohan, 2003)
Mohan D. Road traffic injuries--a neglected pandemic. Bull World Health Organ. 2003;81(9):684-5.

(Morrongiello, 2004)
Morrongiello BA, Hogg K. Mother's reactions to children's misbehaving in ways that can lead to injury: Implications for gender differences in children's risk taking and injuries. Sex Roles. 2004;50:103–18.

(Morrongiello, 1998)
Morrongiello BA, Rennie H. Why do boys engage in more risk taking than girls? The role of attributions, beliefs, and risk appraisals. J Pediatr Psychol. 1998 Feb;23(1):33-43.

(Mountain, 2005)
Mountain LJ, Hirst WM, Maher MJ. Are speed enforcement cameras more effective than other speed management measures? The impact of speed management schemes on 30 mph roads. Accid Anal Prev. 2005;37(4):742-54.

(Movilia, 2006)
Instituto Nacional de Estadística. Encuesta de movilidad de las personas residentes en España, MOVILIA 2006. Madrid: Instituto Nacional de Estadística; 2006.

(Nagata, 2008)
Nagata T, Setoguchi S, Hemenway D, Perry MJ. Effectiveness of a law to reduce alcohol-impaired driving in Japan. Inj Prev. 2008 Feb;14(1):19-23.

(Nicholl, 1987)
Nicholl JP, Freeman MR, Williams BT. Effects of subsidising bus travel on the occurrence of road traffic casualties. J Epidemiol Community Health. 1987 Mar;41(1):50-4.

(Novoa, 2010)
Novoa AM, Pérez K, Santamariña-Rubio E. Estimación de lesionados graves y fallecidos a 30 días por accidente de tráfico. Madrid: DGT; 2010. Available at: www.dgt.es/portal/es/seguridad_vial/estudios_informes/estudios_informes128.htm

(OECD, 2006)
Joint OECD/ECMT Transport Research Centre. Road Safety. Achieving ambitious road safety targets. Paris: Organisation for Economic Co-operation and Development; 2006.

(Oltedal, 2006)
Oltedal S, Rundmo T. The effects of personality and gender on risky driving behaviour and accident involvement. Safety Science. 2006;44:621-8.

(Özkan, 2005)
Özkan T, Lajunen. Why are there sex differences in risky driving? The relationship between sex and gender-role on aggressive driving, traffic offences, and accident involvement among young Turkish drivers. Aggressive Behavior. 2005;31:547-58.

(Peden, 2002a)
Peden M, McGee K, Sharma G. The injury chart book: a graphical overview of the global burden of injuries. Geneva: World Health Organization; 2002.

(Peden, 2002b)
Peden M, McGee K, Krug E (Eds). Injury: A leading cause of the global burden of disease, 2000. Geneva: World Health Organization; 2002.

(Peden, 2004)
Peden M, Scurfield R, Sleet D, Mohan D, Hyder AA, Jarawan E et al., editors. World report on road traffic injury prevention. Geneva: World Health Organization; 2004.

(Peiró, 2006)
Peiró R, Seguí-Gómez M, Pérez K, Miralles M, López A, Benavides FG. Lesiones por tráfico, de ocio y domésticas y laborales. Descripción de la situación en España. Informe SESPAS 2006. Gaceta Sanitaria, 2006; 20(supl 1): 32-40.

(Pérez, 2009)
Pérez K, Marí-Dell'Olmo M, Borrell C, Nebot M, Villalbí JR, Santamariña E, Tobias A. Road injuries and relaxed licensing requirements for driving light motorcycles in Spain: a time-series analysis. Bull World Health Organ. 2009 Jul;87(7):497-504.

(Pérez, 2007)
Pérez K, Marí-Dell'Olmo M, Tobias A, Borrell C. Reducing road traffic injuries: effectiveness of speed cameras in an urban setting. Am J Public Health. 2007 Sep;97(9):1632-7.

(Pérez, 2006)
Pérez K, Cirera E, Borrell C, Plasencia A on behalf of the work group of the Spanish Society of Epidemiology on the Measuring of the Impact on health of road traffic accidents in Spain. Motor vehicle crash fatalities at 30 days in Spain. Gac Sanit. 2006; 20:108-15.

(Pilkington, 2005)
Pilkington P, Kinra S. Effectiveness of speed cameras in preventing road traffic collisions and related casualties: systematic review. BMJ. 2005;330:331-4.

(Priyantha, 2006)
Priyantha DM, Bird RN, Metcalfe AV. The influence of urban land-use on non-motorised transport casualties. Accid Anal Prev. 2006 Nov;38(6):1049-57.

(Pucher, 2003)
Pucher J, Dijkstra L. Promoting safe walking and cycling to improve public health: lessons from The Netherlands and Germany.Am J Public Health. 2003 Sep;93(9):1509-16.

(Ramos, 2008)
Ramos P, Díez E, Pérez K, Rodriguez-Martos A, Brugal MT, Villalbí JR. Young people's perceptions of traffic injury risks, prevention and enforcement measures: a qualitative study. Accid Anal Prev. 2008 Jul;40(4):1313-9.
(RC55/R9, 2005)
World Health Organisation, Regional Office for Europe resolution RC55/R9. Prevention of injuries in the WHO European Region. Fifty-fifth session of the WHO Regional Committee for Europe, (15 September 2005)

(UN58/289, 2004)
United Nations General Assembly resolution 58/289. Improving global road safety. Fifty-eighth session of the United Nations General Assembly,(14 April 2004)

(Richens, 2000)
Richens J, Imrie J, Copas A. Condoms and seat belts: the parallels and the lessons. Lancet. 2000 Jan 29;355(9201):400-3.

(Rivara, 1999)
Rivara FP, Thompson DC, Beahler C, MacKenzie EJ. Systematic reviews of strategies to prevent motor vehicle injuries. Am J Prev Med. 1999;16(1 Suppl):1-5.

(Roberts, 2001)
Ian Roberts, Irene Kwan and the Cochrane Injuries Group Driver Education Reviewers. School-based driver education for the prevention of traffic crashes. Cochrane Database of Systematic Reviews 2001, Issue 3. Art. No.: CD003201. DOI: 10.1002/14651858.CD003201.

(Rodríguez, 2009)
Rodríguez JI. Del viejo código al permiso por puntos. Tráfico y seguridad vial. 2009;197:42-3.

(Rosenbloom, 2009)
Rosenbloom T. Crossing at a red light: behaviour of individuals and groups. Transportation Research Part F. 2009;12:389-94.

(RSAP, 2003)
European Commission. Saving 20 000 lives on our roads. A shared responsibility. European Road Safety Action Programme. Halving the number of road accident victims in the European Union by 2010: A shared responsibility. Luxembourg: Office for Official Publications of the European Communities; 2003.

(Schwebel, 2005)
Schwebel DC, Barton BK. Contributions of multiple risk factors to child injury. Journal of Pediatric Psychology. 2005;30:553–61.

(SCT, 2004)
Servei Català de Trànsit. Departament d'Interior. Generalitat de Catalunya. Plan de seguridad vial 2005-2007. Barcelona: Servei Cátala de Trànsit; 2004.

(Seguí-Gómez, 2007)
Seguí-Gómez M, González-Luque JC, Robledo de Dios T. La problemática del accidente de tráfico. In: Arregui C, Luzón J, Seguí-Gómez , eds. Fundamentos de biomecánica en las lesiones por accidente de tráfico. Madrid: Dirección General de Tráfico; 2007.p.1-20.

(Shope, 2007)
Shope JT. Graduated driver licensing: Review of evaluation results since 2002. J Safety Res. 2007;38(2):165-75.

(Sibley, 2009)
Sibley CG, Harré N. A gender role socialization model of explicit and implicit biases in driving self-enhancement. Transportation Research Part F. 2009;12:452-61.

(Simons-Morton, 2006)
Simons-Morton B, Nansel T. The application of social cognitive theory to injury prevention. In: Gielen AC, Sleet DA, DiClemente RJ, eds. Injury and violence prevention. Behavioral science theories, methods, and applications. San Francisco: Jossey-Bass; 2006. p.41-64.

(Simpson, 2003)
Simpson HM. The evolution and effectiveness of graduated licensing. J Safety Res. 2003;34(1):25-34.

(StataCorp, 2005)
StataCorp. 2005 [computer program]. Stata Statistical Software: Release 10. College Station, TX: StataCorp LP.

(Stolwijk, 1999)
Stolwijk AM, Straatman H, Zielhuis GA. Studying seasonality by using sine and cosine functions in regression analysis. J Epidemiol Community Health. 1999;53:235-238.

(Tavris, 2001)
Tavris DR, Kuhn EM, Layde PM. Age and gender patterns in motor vehicle crash injuries: importance of type of crash and occupant role. Accid Anal Prev. 2001 Mar;33(2):167-72.

(Tobías, 2001)
Tobías A, Díaz J, Saez M, et al. Use of poisson regression and box-jenkins models to evaluate the short-term effects of environmental noise levels on daily emergency admissions in Madrid, Spain. Eur J Epidemiol. 2001;17(8):765-71.

(Trolldal, 2005)
Trolldal B. An investigation of the effect of privatization of retail sales of alcohol on consumption and traffic accidents in Alberta, Canada. Addiction. 2005 May;100(5):662-71.

(Turner, 2003)
Turner C, McClure R. Age and gender differences in risk-taking behaviour as an explanation for high incidence of motor vehicle crashes as a driver in young males. Inj Control Saf Promot. 2003 Sep;10(3):123-30.

(Ulfarsson, 2004)
Ulfarsson GF, Mannering FL. Differences in male and female injury severities in sport-utility vehicle, minivan, pickup and passenger car accidents. Accid Anal Prev. 2004 Mar;36(2):135-47.

(UN 58/289)
United Nations General Assembly resolution 58/289. Improving global road safety. Fifty-eighth session of the United Nations General Assembly, (14 April 2004)

(Vernick, 1999)
Vernick JS, Li G, Ogaitis S, MacKenzie EJ, Baker SP, Gielen AC. Effects of high school driver education on motor vehicle crashes, violations, and licensure. Am J Prev Med. 1999;16(1 Suppl):40-6.

(Vernon, 2004)
Vernon DD, Cook LJ, Peterson KJ, Michael Dean J. Effect of repeal of the national maximum speed limit law on occurrence of crashes, injury crashes, and fatal crashes on Utah highways. Accid Anal Prev. 2004 Mar;36(2):223-9.

(Villalbi, 2006)
Villalbí JR, Pérez C. Evaluation of regulatory policies: the prevention of traffic accidents in Spain. Gac Sanit. 2006 Mar;20 Suppl 1:79-87.

(Welsh, 2001)
Welsh R, Lenard J. Male and female car drivers--differences in collision and injury risks. Annu Proc Assoc Adv Automot Med. 2001;45:73-91.

(White Paper, 2001)
European Commission. White Paper. European transport policy for 2010: time to decide. Luxembourg: Office for Official Publications of the European Communities; 2001.

(WHO 57.10, 2004)
World Health Assembly resolution 57.10. Road safety and health. Fifty seventh World Health Assembly, (22 May 2004)

(WHO, 2002)
International statistical classification of diseases and related health problems, tenth revision. Volume 1: Tabular list. Geneva: World Health Organization; 2002.

(WHO, 2008)
The global burden of disease: 2004 update. Geneva: World Health Organization; 2008.

(WHO, 2009)
World Health Organization. Global status report on road safety: time for action. Geneva: World Health Organization; 2009.

(Widome, 1991)
Widome MD. Remembering as we look ahead: the three E's and firearm injuries. Pediatrics. 1991;88(2):379-83.

(Wilson, 2006)
Wilson C, Willis C, Hendrikz JK, Bellamy N. Speed enforcement detection devices for preventing road traffic injuries. Cochrane Database of Systematic Reviews 2006, Issue 2. Art. No.: CD004607. DOI: 10.1002/14651858.CD004607.pub2.

(Xunta de Galicia, 2005)
Consellería de política territorial, obras públicas y transportes. Xunta de Galicia. Plan de seguridad vial de Galicia 2006-2010. Santiago de Compostela: Xunta de Galicia; 2005.

(Yannis, 2007)
Yannis G, Antoniou C, Papadimitriou E. Road casualties and enforcement: distributional assumptions of serially correlated count data. Traffic Inj Prev. 2007;8(3):300-8.

(Zambon, 2007)
Zambon F, Fedeli U, Visentin C et al. Evidence-based policy on road safety: the effect of the demerit points system on seat belt use and health outcomes. J Epidemiol Community Health. 2007 Oct;61(10):877-81.

(Zeedyk, 2001)
Zeedyk MS, Wallace L, Carcary B, Jones K, Larter K. Children and road safety: increasing knowledge does not improve behaviour. Br J Educ Psychol. 2001 Dec;71(Pt 4):573-94.

H. APPENDIX

APPENDIX 1: THE IMPACT IN THE MEDIA OF THE STUDIES INCLUDED IN THE THESIS

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El permiso por puntos reduce más de un 11% el riesgo de lesiones graves en accidente

ABC. SEVILLA Publicado Martes, 03-03-09 a las 19:04

La implantación del permiso de conducir por puntos ha reducido en más de un 11 por ciento el riesgo de lesiones graves por colisión de tráfico entre los conductores de turismos en toda España, según se desprende de un estudio realizado por Catherine Pérez y Ana Novoa, de la Agencia de Salud Pública de Barcelona, así como por expertos de la Dirección General de Tráfico y del Centro Nacional de Salud Instituto Carlos III.

Este trabajo, que se ha presentado hoy en Sevilla en el marco del 'XIII Congreso de la Sociedad Española de Salud Pública y Administración Sanitaria' (Sespas), revela que **el número de heridos graves ha descendido tras la implantación** del carné por puntos en un 11 por ciento en hombres y un 12 por ciento en mujeres, evitando en los primeros 18 meses de implantación 3.773 casos de heridos graves.

El análisis revela que la implantación del carné por puntos se ha dejado notar tanto en carretera como en zona urbana, y tanto en usuarios de turismo como en usuarios de ciclomotor. Así, en carretera las diferencias se observan tanto en hombres (disminución del 10% de heridos graves) como en mujeres (disminución del 12%), mientras que en zona urbana la incidencia del permiso por puntos se deja notar principalmente en hombres (disminución del 13%).

Reducción de los lesionados graves

Asimismo, el estudio revela que en usuarios de turismos la reducción del número de lesionados graves es del 12 por ciento en hombres y del 9 por ciento en mujeres.

En cuanto a los usuarios de ciclomotor, las diferencias se observan fundamentalmente en zona urbana, donde la reducción de lesionados graves es del 18 por ciento en hombres y el 21 por ciento en mujeres.

Los autores de este trabajo constatan que la introducción del permiso por puntos ha supuesto una disminución del número de lesionados por colisión de tráfico, "especialmente en los casos de lesionados graves".

El equipo de investigación relaciona estos resultados con el tipo de medidas implantadas por la Dirección General de Tráfico (DGT) para vigilar el cumplimiento de la normativa de seguridad vial, "la mayoría de las cuales se aplican en carretera, como las orientadas a disminuir el exceso de velocidad o a impedir la conducción bajo los efectos del alcohol", agregan en sus conclusiones.

En este sentido, los autores subrayan que el permiso de conducir por puntos será "tanto más eficaz cuanto mayores sean las medidas de vigilancia y control de seguridad vial".

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El permiso de conducir por puntos reduce más de un 11% el riesgo de lesión grave por colisión de tráfico, según estudio

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Asimismo, el estudio revela que en usuarios de turismos la reducción del número de lesionados graves es del 12 por ciento en hombres y del 9 por ciento en mujeres.

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Los autores de este trabajo constatan que la introducción del permiso por puntos ha supuesto una disminución del número de lesionados por colisión de tráfico, "especialmente en los casos de lesionados graves".

El equipo de investigación relaciona estos resultados con el tipo de medidas implantadas por la Dirección General de Tráfico (DGT) para vigilar el cumplimiento de la normativa de seguridad vial, "la mayoría de las cuales se aplican en carretera, como las orientadas a disminuir el exceso de velocidad o a impedir la conducción bajo los efectos del alcohol", agregan en sus conclusiones.

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Esta iniciativa ha evitado en los primeros dieciocho meses de implantación casi 4.000 casos de lesionados graves.

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Así lo afirma un estudio de investigación realizado por Catherine Pérez y Ana Novoa en la Agencia de Salut Pública de Barcelona, y otros investigadores de la Dirección General de Tráfico y del Centro Nacional de Salud Instituto Carlos III que se difundirá en el XIII Congreso de la Sociedad Española de Salud Pública y Administración Sanitaria (SESPAS).

El estudio señala concretamente que el número de heridos graves ha descendido tras la implantación del carné por puntos un 11 por ciento en hombres y un 12 por ciento en mujeres, evitando en los primeros 18 meses de implantación 3.773 casos de lesionados graves.

El análisis revela que la implantación del carné por puntos se ha dejado notar tanto en carretera como en zona urbana, y tanto en usuarios de turismo como en usuarios de ciclomotor. En carretera, las diferencias se observan tanto en hombres (disminución del 10 por ciento de heridos graves) como en mujeres (disminución del 12 por ciento), mientras que en zona urbana la incidencia del permiso por puntos se deja notar principalmente en hombres (disminución del 13 por ciento).

En usuarios de turismos la reducción del número de lesionados graves es del 12 por ciento en hombres y del 9 por ciento en mujeres. En cuanto a los usuarios de ciclomotor, las diferencias se observan fundamentalmente en zona urbana, donde la reducción de lesionados graves es del 18 por ciento en hombres y el 21 por ciento en mujeres.

En las conclusiones del informe, financiado por la Agencia de Evaluación de Tecnologías Sanitarias del Ministerio de Sanidad y elaborado con datos de la Dirección General de Tráfico, los autores constatan que "la introducción del permiso por puntos ha supuesto una disminución del número de lesionados por colisión de tráfico, especialmente en los casos de lesionados graves".

El equipo de investigación relaciona estos resultados con el tipo de medidas implantadas por la Dirección General de Tráfico (DGT) para vigilar el cumplimiento de la normativa de seguridad vial, "la mayoría de las cuales se aplican en carretera, como las orientadas a disminuir el exceso de velocidad o a impedir la conducción bajo los efectos del alcohol". En este sentido, los autores subrayan que el permiso de conducir por puntos será tanto más eficaz cuanto mayores sean las medidas de vigilancia y control de seguridad vial.

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APPENDIX 2: PAPER 1 (LITERATURE REVIEW) IN ENGLISH (PREVIOUS VERSION)