



国际道路安全研讨会

International Symposium on Safety of Vulnerable Road Users

25-26 March 2019
Changsha, China

Proceedings



About ICoRSI:

The Independent Council for Road Safety International (ICORSI) is a not-for profit organization that provides independent and authoritative advice on global road safety policies by road safety scientists that have no financial conflicts of interest. ICoRSI aims to: (1) provide rapid, independent and evidence-based information on road safety policy and practice to policy makers and the public; (2) strengthen the capacity of safety professionals and policy makers to understand existing evidence and undertake new research; and, (3) facilitate capacity building for safety professionals and policy makers in the field of transportation safety.

More information: <http://www.icorsi.org>

Contact: manager@icorsi.org

Acknowledgement

Independent Council for Road Safety International (ICoRSI) is supported by the Tata Education and Development Trust, Mawana Sugars, Tata Sons and individual donors.

The International Symposium on Safety of Vulnerable Road Users in Changsha, China, was supported by the University of Chicago, Beijing Center.

Declaration

The papers presented at the International Symposium on Safety of Vulnerable Road Users represent the views of the authors and the contents may be published separately after discussion at the symposium. All papers will also be available at www.icorsi.org after the symposium.

Suggested citation

ICoRSI (2019). Proceedings. International Symposium on Safety of Vulnerable Road Users, Changsha, China, 25-26 March. Independent Council for Road Safety International, <https://www.icorsi.org/icorsi-publications>.

© Independent Council for Road Safety International, 2019, www.icorsi.org.

Effective Police Enforcement: What Works

Dinesh Mohan^{1a} and Rahul Goel^b

Abstract

Enforcement of traffic rules and regulations forms an important component of strategies to reduce deaths and injuries due to road traffic crashes. As with many other issues concerning road safety policy, it is not always clear whether common sense approaches in police enforcement actually reduce injuries and fatalities on the road. It is therefore important to assess whether a given enforcement measure, though seemingly beneficial in its intent, actually results in any reduction of delinquent behaviour of drivers and number of crashes. In this article we assess the evidence base of effectiveness of on-road enforcement measures by conducting a review of systematic reviews on this topic. In this review we focussed only on the objective police programmes or strategies and excluded the reviews which assessed the effectiveness of a traffic enforcement law. We answer the following questions in this review: (a) What is the theoretical basis of different enforcement measures? (b) What are the different road safety enforcement measures for which evidence is available in systematic reviews and how current is this evidence? (c) What are the different limitations or drawbacks of different studies as reported by the systematic reviews and what are their implications on results? (d) What are the different factors which limit the generalisations of available evidence across different settings or across different types of modes? Our review suggests that: (i) Legislation and enforcement is effective when violations are visible and easy to detect. (ii) Strict punishment not as effective as subjective perception of being caught violating a law. (iii) There is an absence of studies that could provide guidelines on police enforcement for low and middle-income countries on the following issues: a. Influence of road and infrastructure design on traffic violations and the difficulties of enforcement when designs are not adequate for the kind and volume of road users present; b. critical/minimum levels of enforcement necessary for different traffic violations; c. enforcement methods that would be cost effective in situations with high proportion of motorcycles and other vulnerable road users.

Keywords: Penalties, traffic safety, enforcement, police

1. INTRODUCTION

Road traffic injury (RTI) reduction depends on interventions in institutional arrangements, road and environment design, vehicle safety features, post-crash care and ensuring safer road user behaviour by better policing systems. Regulation of traffic by police enforcement can be an effective strategy to reduce the public health burden resulting from traffic injuries (1-3). As with many traffic safety interventions, the outcomes are not always as expected, and a weak theoretical foundation in traffic safety research makes it difficult to predict the effectiveness of different enforcement measures. For example, an increase in fixed penalties for speeding or jail terms for drinking and driving offences have not been found to be very effective deterrent measures in some studies (4-9). Given the large variation in road designs and types of traffic mix, a given intervention is likely to have varying effects across different settings. Traffic enforcement measures can be costly, lead to additional workload for enforcement agencies and may involve additional costs in publicising these measures through various platforms. It is therefore important to assess whether a given enforcement measure, though seemingly beneficial in its intent, actually results in any reduction of delinquent behaviour of drivers and number of crashes.

1.1. Theoretical framework for enforcement measures

Elvik (10) discusses a simple theoretical model that was developed by Evans (11) which can be used to understand the finding of a road safety evaluation study (Figure 1). The basic understanding according to this model is that there are two causal chains which connect a road safety measure to its final outcome—engineering and behavioural. In the context of traffic enforcement, we are concerned with the causal chain through the behavioural effect. There are, therefore, two main theoretical strands based on which we can explain the effectiveness of traffic enforcement. First is the theory which explains why drivers correct their behaviour when

¹ Corresponding author, dineshmohan@outlook.com

a. Indian Institute of Technology Delhi, India

b. MRC Epidemiology Unit, University of Cambridge, UK

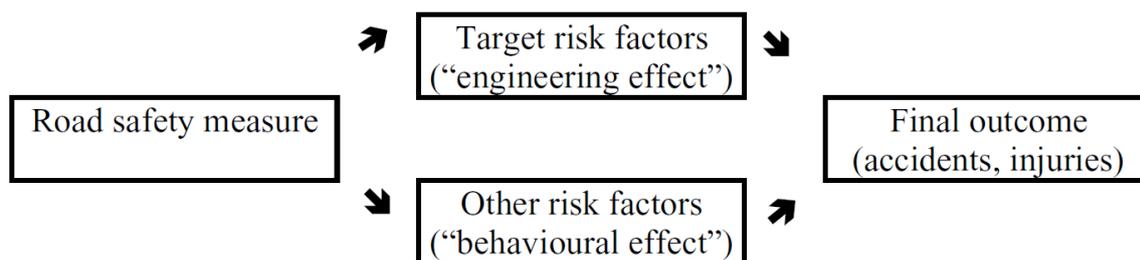


Figure 1. Theoretical model of road safety (Adapted from Reference 2).

an enforcement measure is implemented. Second is the theoretical basis which explains why that particular change in behaviour would lead to higher safety. For example, an enforcement measure targeting over-speeding would likely result in reducing the proportion of drivers driving above a certain speed limit. This is the behavioural effect of the enforcement. The final outcome i.e. number of crashes and accidents would then be dependent on the relationship between speed distribution and crashes.

The underlying theory which explains the effectiveness of different enforcement measures is called the ‘deterrence theory’, where deterrence is ‘the omissions or curtailment of a crime from the fear of legal punishment’ (12). According to this theory the fear of punishment encourages potential offenders to comply with the law. The enforcement measure works not only by apprehending the offenders, which is often a very small proportion of all road users and in fact a small proportion of all offenders, but also by discouraging ‘potential’ offenders because of the perceived certainty getting caught (5, 6, 13-15).

“The principal opportunity for criminal law to be effective in reducing drunk driving is paradoxically, not by affecting the apprehended law violators, who stand within its power. Rather, it lies in affecting unapprehended individuals who are sensitive to the threat that, should they behave illegally, they will be punished (15)”

There are two types of deterrence, specific and general. Specific deterrence primarily focusses on punishing apprehended offenders and assumes that they will be deterred from repeating their offence in the future to avoid punishment. On the other hand, general deterrence focuses on the population in general and assumes that the threat of punishment will deter people from violating the law in the first place. The greater the perception of risk of punishment, the greater the likelihood that general deterrence will be effective. For an enforcement policy to be effective, it needs to ensure both types of deterrence are at work, so that a sanction not only impacts the individual who is being punished but also others who do not directly experience the sanction. The understanding of theoretical aspects that explain the effectiveness of enforcement measures is important to develop hypotheses for future application of these measures in different settings.

2. OBJECTIVES

In this paper we assess the evidence base of effectiveness of on-road enforcement measures by conducting a review of systematic reviews on this topic. In this review we focussed only on the objective police programmes or strategies and excluded the reviews which assessed the effectiveness of a traffic enforcement law. This is because in different settings across the world a law may translate to actual implementation on the road by varying degrees in terms of how soon it is implemented as well as its spatial coverage. In some countries, while a law may exist, but its implementation may be limited because police may think of it as less of a priority or because there is lack of capacity to implement it (3, 16). We will use this review to answer the following questions:

- 1) What are the different road safety enforcement measures for which evidence is available in systematic reviews and how current is this evidence?
- 2) What are the different limitations or drawbacks of different studies as reported by the systematic reviews and what are their implications on results?
- 3) What are the different factors which limit the generalisations of available evidence across different settings or across different types of modes?
- 4) What is the theoretical basis of different enforcement measures?

3. SUMMARY OF SYSTEMATIC REVIEWS

To find relevant studies, we used three main sources with a database of systematic reviews of road traffic injuries. These are The Handbook of Road Safety Measures (17), Cochrane Injuries Review Group (<https://injuries.cochrane.org/our-evidence>) and Community Preventive Services Task Force (<https://www.thecommunityguide.org/content/task-force-findings-motor-vehicle-injury>). We also searched for the systematic reviews using the ancestry approach. We have not included any reviews published before 1990. Among the traffic enforcement measures, we found reviews covering four offences: speeding, red-light running, alcohol-impaired driving, and seat belt use. In some cases, we found multiple reviews for the same enforcement measure. For example, the review of red-light cameras by Aeron-Thomas and Hess (18) has been updated by Perkins, Steinbach (19). The speed camera review by Wilson, Willis (20) published in 2006 (Cochrane Collaboration) was updated by Wilson, Willis (21) in 2010, and a study to update and expand the Cochrane systematic review, to provide a comprehensive account of the range of automatic speed enforcement strategies employed worldwide has been initiated by Steinbach, Perkins (22). For effectiveness of speed cameras, we have also included a later contemporary review by Høye (23) as it added value in terms of discussing some other facets that are missing from Steinbach's review.

3.1. Speed control

One of the earliest reviews of the effectiveness of speed cameras was done by Pilkington and Kinra (24) in 2005. The authors did not conduct a meta-analysis given the differing nature of the studies included. The review found that all the studies reported reduction in various crash outcomes (collisions, injuries and deaths). However, the authors noted that the level of evidence was relatively poor, and most studies lacked adequate comparison groups. The other two meta-analysis of speed enforcement were conducted more recently and includes all types of speed camera measures.

The most common speed enforcement methods are point-based where vehicle speeds are detected at fixed locations on the road. With point-based speed enforcement methods, the drivers get familiar with locations of cameras and modify their behaviour only in the immediate vicinity of speed enforcement. Hence, innovative approaches were needed to make speed enforcement more effective. Average speed enforcement method was developed as an alternative to point-based method. This is also referred to as 'average speed section control', 'point to point', 'time over distance' cameras or section control or trajectory control (21, 24). This type of enforcement involves the installation of a series of cameras at multiple locations along a road section. The average speed of a vehicle over a section of a road is calculated by capturing its license plate number at more than one camera locations. In case this speed exceeds the posted speed limit, the vehicle information is communicated to a central unit. Almost all current installations throughout the world involve some degree of human verification to assess the validity of detected infringements. In such a system there are stopping sites for manual enforcement.

A meta-analysis of speed cameras and average enforcement method was conducted by Høye (23). The study reported following:

- Speed cameras resulted in reduction of all crashes (20%) and larger reduction of fatal crashes (51%), though the latter may be affected by regression-to-the-mean.
- Section control resulted in larger reduction in all crashes (30%) compared to speed cameras, and reduction in KSI crashes (56%) was even greater than reduction of all crashes by section control and reduction of fatal crashes by speed cameras
- The effect of speed cameras reduce as the distance from the camera increases.
- The authors also compared the reduction in the number of crashes as estimated by the two of the reviewed studies to the estimate from the power model of speed as reported by (17). Both the studies found crash reduction to be greater than what would be expected from the reduction in speed alone as predicted by the power model.
- The implementation of speed cameras may be accompanied by crash migration when drivers tend to slow down close to the cameras and then driver faster than they would have otherwise away from the cameras. The review found no evidence that this phenomenon, known as kangaroo driving, resulted in adverse safety effects.

Another review of speed cameras was done by the Cochrane group (22). This review includes mobile and fixed cameras, including the average enforcement methods. Unlike fixed cameras, mobile cameras are operated from parked motor vehicles, and therefore can be moved from one place to another. The study concluded the following:

- There was no difference of effect between the covert and overt cameras or between the urban and rural areas.
- There is a strong evidence suggesting that the implementation of speed cameras is associated with reduction in speed and crash outcomes.
- There was a reduction in percentage of vehicles exceeding the speed limit (50% to 64%)
- The effects do not account for the differences in the posted speed limit though percentage reduction is likely to be a function of the speed limit
- There is evidence of some halo effect i.e. the greater reduction in speed and crash outcomes in the vicinity of the cameras.
- No study provided empirical information on the effects of camera programmes on speeding and crash outcomes in the wider areas within which speed cameras are implemented, in order to assess whether general deterrence theory might be supported.
- No studies reported on the sizes of fines or penalties issued to offenders. By linking the size of fine with the specific road and camera where the driver had offended, it would be possible to assess whether larger fines and penalties are more effective. It is possible that ‘persuasive’ letters to offenders once caught speeding are equally effective a deterrent as being caught and brought to justice.

A review of the effectiveness of average speed enforcement methods was reported by Soole, Watson (25) in 2003. The review concluded the following:

- In general, drivers show higher level of acceptance of average speed enforcement. The traditional camera-based measures using instantaneous speed are criticised on the grounds that drivers need to speed at certain points due to unforeseen reasons.
- The limited evidence suggests that average speed enforcement method may be more effective than instantaneous speed enforcement methods.
- Studies have found the implementation of this method is associated with the reduction in average and 85th percentile speeds, the proportion of speeding vehicles and speed variability. The approach has been specifically effective in reducing excessive speeding behaviour.
- In addition to reduction in speed, studies have also found considerable reduction in fatal and serious injury crash rates.
- There is lack of distance ‘halo’ effect resulting from average speed enforcement implementation. This means that reduction in speed and crash rates have not been found outside the area of enforcement. Therefore, this enforcement method should be used as complementary to the existing fixed and mobile speed enforcement methods.
- Studies suffered from multiple drawbacks because of which the evidence needs to be carefully interpreted. None of the studies used the control/comparison site. Other drawbacks include lack of driving exposure data and studies not accounting for regression-to-the-mean effect.

There is a strong theoretical understanding based on which effectiveness of average speed enforcement method can be explained. Reduction in excessive speeding behaviour has considerable implications for road safety given the exponential relationship between vehicle speed and crash risk (26-28).

3.2. Red-light cameras

Red-light running results mostly in side-collision crashes which are more severe than other type of intersection crashes. In case there is a dedicated signal for the left-turning vehicles (in right-hand traffic), red-light running also results in head-on collisions. The implementation of red-light cameras (RLCs) is also associated with an increase in rear-end crashes resulting from drivers’ tendency to apply break abruptly in order to avoid the fine. Since both the head-on and right angle crashes have higher severity than rear-end crashes, even if the number of crashes are cancelled out, the severity level of crashes is still likely to reduce with the implementation of RLCs. A review by Høyе (29) summarises the empirical evidence of the effects of RLCs on intersection crashes.

- The present study found a non-significant decrease of all injury crashes by 13% and a non-significant increase of all crashes by 6%.
- Right-angle collisions were found to decrease by 13% (not statistically significant) and rear-end collisions were found to increase by 39% (statistically significant).
- For right-angle injury collisions a far larger decrease was found (–33%, statistically significant) and for rear-end injury collisions a smaller increase was found (+19%, statistically significant).

- The results seem to be affected to some degree by publication bias and the effects may therefore be less favourable than indicated. The direction of the effects does however not change when controlled for publication bias.
- The effects for crashes with unspecified severity are likely to be still more favourable when RLC-warning signs are not set up at each RLC-intersection, possibly because of drivers getting a habit of respecting red lights and expecting other drivers braking. If this assumption is correct, one may also expect RLC to become more favourable over time.

A systematic review of the effectiveness of red-light cameras by Perkins, Steinbach (19) concluded the following:

- RLCs can be effective in reducing red-light violations and some types of traffic crashes, particularly right-angle crashes, right-angle injury crashes, and total injury crashes.
- RLCs also appear to be linked to an increase in rear-end crashes which is likely a result of drivers abruptly braking to prevent the offense.
- The presence or absence of warning signs did not appear to have an impact on RLC effectiveness.
- While a number of studies reported that spillover (or diffusion of benefits) occurred, the magnitude of this effect is not established.
- Studies are limited to four countries: USA, Canada, Singapore and Australia. The authors caution the use of this evidence in the UK since the intersections in the USA and Australia are much larger in size than the UK hence drivers may have greater feeling of openness and more likely to jump the light. Further, the speed limits across the settings are different which may also influence the likelihood of red light running.
- This review did not include studies which evaluated the effectiveness of red light cameras used both for red-light running as well as enforcing speed limit during the green.
- Due to the rarity of death or severe injury events, most studies use a combined measure of crashes and do not differentiate between the severity levels of crashes.

In some cases, additional time is given to yellow times and successful RLC programmes may include many on-site modifications such as red-light visibility, addition of warning signs, and amelioration of intersections geometry. This is clearly a case where engineering and enforcement measures are highly interrelated or at least the relationship between the two can be established (30).

3.3. Police patrol for alcohol-impaired driving

Control of drivers under the influence of alcohol has a strong empirical justification. A meta-analysis demonstrates that there is no evidence of a threshold effect for alcohol. Alcohol gradually affects driving skills. There is no sudden transition from unimpaired to impaired occurring at a particular BAC level. A review from the US (31) indicates that crash risk grows exponentially with increasing blood alcohol concentration (BrAC). The study shows that at low levels of alcohol (e.g., 0.03 BrAC) the risk of crashing is increased by 20 percent, at moderate alcohol levels (0.05 BrAC) risk increases to double that of sober drivers, and at a higher level (0.10 BrAC) the risk increases to five and a half times. At a BrAC of 0.15, the risk is 12 times, and by BrACs of 0.20+ the risk is over 23 times higher. Another meta-analysis concludes that “most skills which are relevant for the safe operation of a vehicle are clearly impaired by BACs of 0.05%, with motor functions being more affected than cognitive functions and complex tasks more than simple tasks. Generally, the results provided no evidence of a threshold effect for alcohol. There was no driving-related performance category for which a sudden transition from unimpaired to impaired occurred at a particular BAC level” (32)

A systematic review by Goss, Van Bramer (33) of effectiveness of increased police patrols for preventing alcohol-impaired driving (including studies evaluating increased police patrols, either alone or combined with other interventions) targeting alcohol-impaired motor vehicle drivers concludes that:

- The 32 eligible studies included one randomized controlled trial, eight controlled before-after studies, 14 controlled interrupted time series (ITS) studies, six ITS studies, and three studies with both ITS and controlled before-after analyses. Most interventions targeted only alcohol-impaired driving (69%) and included additional interventions such as media campaigns or special training for police officers (91%).
- Only two studies reported sufficient information to assess study quality completely. Two-thirds of studies were scored ‘not adequate’ on at least one feature. Five of six studies evaluating traffic fatalities reported reductions with the intervention, but differences were statistically significant in only one

study. Effects of intervention on traffic injuries were inconsistent in the six studies evaluating this outcome, and no results were statistically significant.

- All four controlled studies evaluating fatal crashes reported reductions with the intervention, which were statistically significant in one study. All 12 controlled studies assessing injury crashes reported greater reductions with the intervention, though effects were minimal or not significant in several studies. ITS studies showed less consistent effects on fatal crashes (three studies) and injury crashes (four studies), and effect estimates were typically imprecise. Thirteen of 20 studies showed reductions in total crashes and about two-thirds of these were statistically significant.
- Therefore, the available evidence does not firmly establish that increased police patrols reduce the adverse consequences of alcohol-impaired driving. Good quality controlled studies with adequate sample size are needed to evaluate increased patrols. Also needed are studies assessing the cost-effectiveness of this intervention.

Evidence shows that an increase in the perceived risk of arrest appears to deter alcohol-impaired driving more effectively than increasing the severity of penalty after arrest and police patrol intervention increase the presence of police and the perception of being caught (33).

3.4. DUI (Driving under the Influence) checkpoints

These checkpoints refer to police operations where one or more police cars are standing beside the road and where police officers pull out drivers in order to check whether or not he or she has an illegal blood alcohol level (BAC). At these checkpoints, also known as sobriety checkpoints, drivers can be stopped even if they do not give any indication of driving under the influence of alcohol, and therefore, by correcting their driving behaviour close to these checkpoints does not necessarily prevent the drivers from being stopped. Erke, Goldenbeld (34) conducted a meta-analysis of the effectiveness of DUI-checkpoints. The review concludes:

- Crashes involving alcohol (or proxy measures of such crashes) are reduced at least by 17% and all types of crashes are reduced by 10-15%. Proxy measures of alcohol-related crashes include night-time or weekend night crashes.
- The largest reductions were found during the first 6 months of the DUI-checkpoint implementation, which may be confounded because the intensity of implementation may be much higher for short-term programmes.
- DUI-checkpoints in Australia result in the highest reduction in crashes indicating the Australian methods of booze buses and intensive publicity are highly effective. A similar approach when implemented in New Zealand also found large reductions, thus strengthening the evidence of their effectiveness.

A practical implication from this meta-analysis is that highly visible checkpoints where many drivers are pulled out and tested, following the Australian example, are likely to be most effective.

3.5. Seat belts

Dinh-Zarr, Sleet (35) conducted a systematic review of the effectiveness of primary seat belt laws in the United States which included five evaluations of the effect of primary laws on observed seat belt use. These studies examined belt use in 12 states and the District of Columbia that enacted primary laws during the 14-year period from 1984 to 1997 and a couple of years later Shults, Elder (36) re-examined the studies included in the systematic review to explore whether the benefits of a primary law differ based on: (1) the baseline seat belt use rate; or (2) whether or not the primary law replaces a secondary law. This review includes studies from 1980 to 2000 and is restricted to the studies from US. This review also estimates the effect of seat belt enforcement where the law is graduated from secondary to primary. A primary seat-belt law implies that a driver can be stopped by enforcement officers solely for not wearing a belt. On the other hand, within a secondary seat-belt law the driver can be fined for seat belt only after the driver has been stopped for another offence. The authors hypothesised that a primary law has a greater effect on drivers' perceived risk of detection and punishment, and public in general may also perceive seat belt law as important. These factors may result in making a primary law more effective than a secondary law. The study concluded the following:

- All the studies evaluating primary vs secondary law found primary seat belt law to be more effective than secondary law. The studies which reported fatalities as outcome, found median decrease of 8% higher among primary law states than secondary law states, though statistical significance of this estimate was not reported.

- Enforcement enhancement programs are associated with an increase in seat belt use (median 16 percentage points) and decrease in injuries.
- Based on the studies which carried out a follow-up of the enforcement enhancement programmes after they had concluded, there is evidence that the seat-belt use somewhat declined after the programs are ended.

Elvik, Vaa (17) have reported meta-analysis of seat belt enforcement with no restriction to country and conclude the following:

- The results show the enforcement increases seat belt use by 21% during the enforcement period and by 15% afterwards.
- The covertness of the enforcement improves the effectiveness of seat-belt use. Greater effects have been found when checkpoints are not announced compared to when they are. This may be possible if the drivers think that they will fasten the seatbelts close to a checkpoint, and therefore, general compliance may be lower.
- The change in seat-belt usage rate is higher when the baseline rate is lower. A scatterplot of increase in usage rate versus the baseline usage rate shows a negative relationship between the two.

4. EFFECT OF INTENSITY OF ENFORCEMENT AND PENALTIES ON DETERRENCE

Though a great amount of research has been done on the mechanisms and processes of deterrence over the past four decades, the exact situations under which sanctions (or the threat of sanctions) are likely to influence or change a person's behaviour are still not known in certainty. The difficulty associated with determining causal relationships arises partly from the problem of eliminating competing explanations. Some of these include effect environmental design changes on road user behaviour, changes in modal shares on the road and secular changes in people's behaviour over time. Another problem is that police enforcement levels and intensities can change over short periods of time due to economic and political changes and so it is difficult to do long term studies in many locations. Because there are no systematic reviews of the effect of penalties on deterrence in this section we discuss the results of studies that are available.

4.1. Intensity of enforcement

In 2002 Koornstra et al (37) published a report where they attempt to find a relationship between intensity of police enforcement and level of traffic law violation as an approach to get more insight about which enforcement level is needed in order to change road user behaviour and fatality risks. The results are shown in Figure 2 illustrated by belt wearing and drunk driving data on enforcement and violation levels in Sweden, the United Kingdom, and the Netherlands at that time. The authors cautioned that this curve needs to be validated with research results because of the complexity of that research when it comes to differentiating police

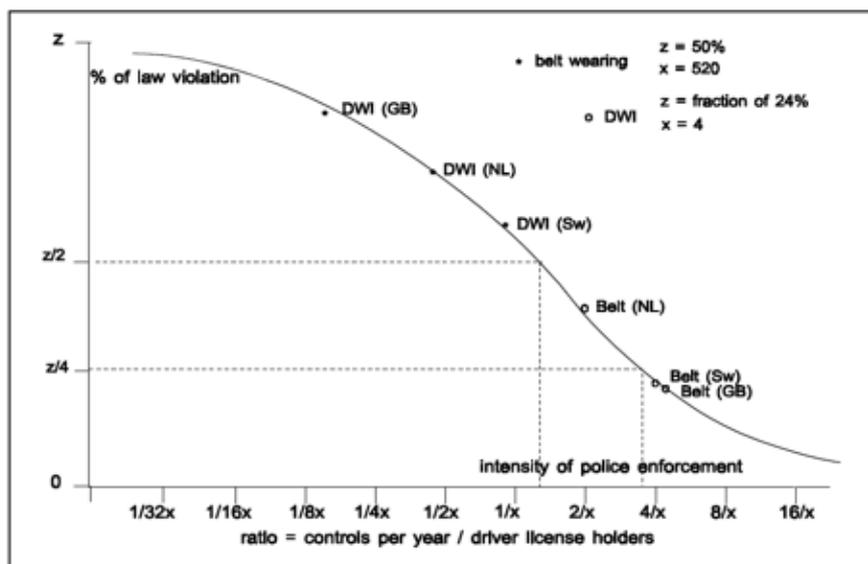


Figure 2. Relationship between enforcement intensity and law violation levels (Source: Reference 20).

GB-United Kingdom, Sw-Sweden, NL-Netherlands, DWI-driving while intoxicated

Table 1. Overview of all information regarding the alcohol related BAC limits, road toll and enforcement measures in selected European countries, data 2007-2010. Adapted from Reference 37.

Country	Legal blood alcohol limit g/L	Police tests per 1,000 inhabitants	Share of alcohol related road fatalities, percent		Share alcohol offenders (above legal limit) %	Share respondents who had atleast once a week 5 or more drinks %
			Expert estimates	Official statistics		
Poland	0.2	47	13	7	9.5	19
Portugal	0.5	63	35	6	5.9	28
Austria	0.5	87	18	6	5.8	36
Spain	0.5	112	NA	31	1.8	34
Hungary	0	130	8	31	3.1	24
France	0.5	190	29	31	3.3	20
Sweden	0.2	287	25	16	0.8	13
Finland	0.5	385	24	29	1.3	22

enforcement efforts (combined with publicity) and the complexity of data-collection. To the best of our knowledge no serious efforts have been made to determine such curves for speed control, seat belt use, helmet use, DUI control and other violations for different modal shares in different countries of the world. What the curve does show is that percent law violation decreases as enforcement intensity increases and that enforcement levels have to be different for different types of violations. For example, the curve shows that in Sweden the enforcement levels needed for control of DWI and for enforcing seat belt use so that violations were limited to about 12 per cent, there had to be 250 checks per 1,000 driver license holders for DWI and 8 for seat belt use.

Table 1 shows information regarding the alcohol related BAC limits, road fatalities and enforcement measures in selected European countries (38). This report commissioned by the DG for Mobility and Transport, European Commission, concluded that 20 to 28% of all road fatalities in the EU in 2012 could be attributed to drink-driving. This is a significant decrease from the 1980s when many countries reported share of alcohol related fatalities to be in the range 30 to 45% (39). The data also show that in some countries expert estimates of the share of alcohol related alcohol fatalities can be higher than the official statistics. Moreover, the definition of ‘impaired’ is different for each country. It ranges from 0.2g/l in Sweden to 0.5g/l in many countries and so a comparison of countries based on numbers of deaths from drink driving crashes is not really possible. There is general agreement that there was a significant reduction in the period 1980-2010 which can be attributed to stronger laws, vigorous enforcement, and changes in social norms which all contributed to the progress that has been made though not much change has been observed over the last decade.

However, what is not clear is the level of enforcement that ensures a significant reduction in fatalities attributed to drinking and driving. Table 1 shows the that the enforcement levels range from 100 to over 300 tests per 1,000 inhabitants per year. This means that in megacities like Delhi, Shanghai, Beijing or Mexico (populations in excess of 15 million persons), about 5,000 to 15,000 drivers would have to checked every day for effective control of drinking and driving in these cities. At present, we do not have reliable studies available to inform us about the minimum level of enforcement that needs to be put in place in a cost-effective manner in low and middle-income countries.

4.2. Effect of penalties

In a review of deterrence based measures on road user behaviour Davey and Freeman (40) state:

- In order for the ‘fear of punishment’ to be effective, individuals must believe that the likelihood of apprehension for breaking the law is relatively high.
- A considerable body of early research demonstrated a weak negative relationship between perceived severity of sanctions and a range of illegal behaviours. That is, as perceptual severity increases, the likelihood of an individual committing that offence decreases; *however, an opposing body of research demonstrates that perceptions regarding the severity of penalties do not have the salient deterrent impact that was once assumed* (emphasis added). In fact, some researchers have reported a counter-intuitive relationship, with crime rates actually increasing with increases in the severity of the penalty. Nevertheless, it may be suggested that the greatest deterrent impact in regards to severity of sanctions will be found among those who have never committed an offence, rather than habitual offenders.
- It is recognised that for road safety, the swiftness of impending penalties is an important aspect for achieving deterrence. However, despite the link between the speed of the response and learned

behaviour, the effects of the celerity of legal sanctions is by far the least studied of the three major deterrent mechanisms.

- In regards to general deterrence, a considerable body of evidence suggests that the threat of apprehension and subsequent legal sanctions, especially when supported by well-publicised media campaigns, can produce a deterrent effect, even if short, on offending behaviour.
- In order to create and maintain a deterrent effect, policing operations should be highly visible, sustained and widespread. This ensures that all motorists, whether newly licensed or experienced, perceive a constant high risk of apprehension. If drivers do not regularly observe policing operations, they may become undeterred which may be then reinforced by successfully engaging in offending behaviours that remain undetected, e.g., punishment avoidance.
- Any deterrence-based method employed in isolation does not offer a panacea for the problem of road accidents and fatalities.
- Our current understanding of the mechanisms of deterrence is based heavily on studies that have focused on younger populations. In fact, the bulk of published deterrence-based studies are from a small number of highly industrialised countries (e.g., United States, Canada, Australia, etc), and thus deterrent forces are likely to fluctuate with the surrounding environment.

The above summary highlights the fact that we do not have enough systematic reviews that assess the effectiveness of general deterrence policies on road safety that may have universal applicability. For the present, we have to rely on the studies that seem to point in a similar direction. A brief summary from different countries is given below.

4.2.1. Fixed penalties – fines

Norway

“For speeding in general, no effect of increasing fixed penalties can be found. For speeding close to speed camera sites, there is a weak tendency for the violation rate to go down. This tendency is not statistically significant at conventional levels. For seat belt wearing, wearing rates are found to increase as fixed penalties have increased. In recent years, however, enforcement of the seat belt law has stepped up, making it impossible to separate the effect of enforcement from that of fixed penalties” (4).

The Netherlands

“Many studies have demonstrated that the combination of enforcement and penalties prevent the violation of traffic regulations and increase road safety. However, the most common type of penalty at the present time, a fine, has been found to have little effect... When road users consider the subjective probability of detection to be sufficiently likely, they will avoid violating a regulation... The combination of enforcement and penalty is generally preventative when road users avoid traffic violations on the basis of the expected negative consequences. In other words, road users adapt their behaviour without having already been punished. In particular, frequently conducted and very visible traffic checks, which are unpredictable in terms of time and place and are combined with public information campaigns, bring about the general prevention of traffic violations. Many studies have demonstrated that combining enforcement and penalties prevents violations and increases road safety. Of course, the penalty must match the seriousness of the violation and must be substantial enough to influence behaviour, but particularly the frequency, visibility, and unpredictability of inspections are responsible for the general prevention of traffic violations. Making penalties heavier, as an isolated measure, has been found to have little extra effect. Research into the specific preventative effect of penalties shows that the effect of the currently most common type of penalty, a fine, is negligible when expressed in time. The effects are also negligible in terms of recidivism.” (5)

Australia

“What we do know from the available evidence, however, is that the certainty of detection, apprehension and conviction does matter and in fact may matter more than punishment severity in deterring potential offenders. Informal sanctions from family, peers and colleagues who learn about the offence, and the resulting feelings of shame and embarrassment, are also anticipated costs associated with apprehension and conviction for an offence. Policies that can successfully increase the perceived certainty of detection and prosecution for drink-driving offences are therefore likely to have a greater impact on offending and, subsequently, road accident rates than those advocating harsher penalties.” (6)

“It is suggested that substantial increases in fines and licence disqualifications would have limited potential in deterring recidivist offenders. The present analysis, failed to find any evidence for a significant relationship between fine amount and the likelihood that an offender will return to court for a new driving offence. Nor was

there any evidence from our analyses to suggest that longer licence disqualification periods reduced the likelihood of an offender reappearing before the courts.” (41)

USA

“Speeding citations and their legal consequences are the most common enforcement tools to identify and control speeders, yet little is known about the effectiveness of a speeding citation. There was no significant effect of receiving legal consequences on the risk of receiving a subsequent speeding citation (adjusted RR 0.98, 95% CI 0.83-1.16)... Increasing drivers' perception that they are at risk of being caught speeding and awareness of the consequences from receiving points may improve the effectiveness of speeding law enforcement.” (8)

“We examined effects of state statutory changes in DUI fine or jail penalties for first time offenders from 1976 to 2002. Results: Twenty-six states implemented mandatory minimum fine policies and 18 states implemented mandatory minimum jail penalties. Estimated effects varied widely from state to state. Using variance weighted meta-analysis methods to aggregate results across states, mandatory fine policies are associated with an average reduction in fatal crash involvement by drivers with $BAC \geq 0.08$ g/dl of 8% (averaging 13 per state per year). Mandatory minimum jail policies are associated with a decline in single-vehicle nighttime fatal crash involvement of 6% (averaging 5 per state per year), and a decline in low-BAC cases of 9% (averaging 3 per state per year). No significant effects were observed for the other outcome measures. Conclusions: The overall pattern of results suggests a possible effect of mandatory fine policies in some states, but little effect of mandatory jail policies.” (9)

“Driving under the influence (DUI) is a significant public health problem... The results showed support for the swiftness and certainty of punishment, there was no support for the severity of punishment. That is, the relationship between the amount of the fine and DUI relapse was not significant. However, deterrence theory would expect certainty and severity of punishment to show a multiplicative relationship, meaning that severity would have its strongest effects when certainty of punishment was high. This interaction was not tested in either study; therefore, firm conclusions regarding the influence of fines cannot be drawn at this time.” (42)

New Zealand

“The question arises whether it is fair and appropriate to have flat-rate penalties (irrespective of prior records) for more and more offences, particularly in the cases of first offenders who can receive no concession and those who continue to re-offend and incur no additional penalty... There must be principled means for adjusting the amount of a fine to take account of both the offender's culpability and his or her resources and there must be efficient and reliable systems of collection and enforcement to ensure that most fines that are imposed will be paid in full and on time... Large fines are often difficult to collect and prove costly to enforce... as with infringements (although to a lesser extent) they may get to be perceived as a method of raising additional public revenue rather than as appropriate penalties for offences.” (7)

4.3. Summary of the evidence on deterrence

- Legislation and enforcement is effective when violations are visible and easy to detect.
- Stricter punishment not as effective as subjective perception of being caught.
- Severe punishment and laws sometimes reduce enforcement by police officials and conviction rates in courts
- There is little evidence that severe penalties reduce violations in traffic, including jail sentences given in isolation.
- Announcement of severe punishments can have a deterrent effect over a short period and the beneficial effect disappears over time.
- All violations that are not considered serious in terms of threat to life or wilful negligent acts endangering the community (serious injury or death), and those that do not require court judgement should have fixed penalties. Penalties for such offences should be in proportion to the ability of the defaulter to pay.
- There is an absence of studies that could provide guidelines on police enforcement for low and middle-income countries on the following issues:
 - Influence of road and infrastructure design on traffic violations and the need of enforcement or effectiveness of enforcement.
 - Critical/minimum levels of enforcement necessary for different traffic violations.

5. CONCLUSIONS

There is a need to translate the results from car-based studies to settings where motorcycles and cyclists share the road space with cars. In such a context, what car-based studies refer to as property-damage only crashes may translate to higher severity crashes if the parties involved are cars/buses/trucks and vulnerable road users. This is the same for intersection crashes resulting from red-light running. The side crashes are often lead to high-severity crashes in case of cars. These will result in even higher severity injury crashes if between a four-wheeled vehicle hitting a motorcycle. It is possible that some of the enforcement measures which proved to be successful in car-based societies may lead to higher reduction in severity of crashes if not the number of crashes in contexts where vehicular mix consists of cars and a high proportion of vulnerable road users.

The reviews included focussed on answering multiple questions. The outcomes include both the compliance rate for the law that is being enforced as well as the crash rates. The first outcome indicates how effective enforcement measure has been to reduce the delinquent behaviour of the drivers that was being targets. The second outcome which includes various metrics of crashes indicates whether enforcement measure translates to reducing the crashes which is not always a given. For instance, red-light camera enforcement results in overall increase in the number of crashes because increase in rear-end crashes may offset the decrease in side and head-on crashes resulting from red-light running.

The reviews have not discussed the injuries classified by the road user types. This means that there is a potential for a revised review of the same studies to understand the effect of the enforcement measures on road users outside the cars such as pedestrians, cyclists and motorcycle riders.

In summary:

- Legislation and enforcement is effective when violations are visible and easy to detect.
- Stricter punishment not as effective as subjective perception of being caught.
- Severe punishment and laws sometimes reduce enforcement by police officials and conviction rates in courts
- There is little evidence that severe penalties reduce violations in traffic, including jail sentences given in isolation.
- Announcement of severe punishments can have a deterrent effect over a short period and the beneficial effect disappears over time.
- All violations that are not considered serious in terms of threat to life or wilful negligent acts endangering the community (serious injury or death), and those that do not require court judgement should have fixed penalties. Penalties for such offences should be in proportion to the ability of the defaulter to pay.
- There is an absence of studies that could provide guidelines on police enforcement for low and middle-income countries on the following issues:
 - Influence of road and infrastructure design on traffic violations and the difficulties of enforcement when designs are not adequate for the kind and volume of road users present.
 - Critical/minimum levels of enforcement necessary for different traffic violations.
 - Enforcement methods that would be cost effective in situations with high proportion of motorcycles and other vulnerable road users.

REFERENCES

1. Peden M, Scurfield R, Sleet D, Mohan D, Hyder AA, Jarawan E, et al. World report on road traffic injury prevention. Geneva World Health Organization; 2004. 217 p.
2. Elvik R, Vaa T. The handbook of road safety measures. Amsterdam: Elsevier; 2004. 1-1078 p.
3. Blais E, Dupont B. Assessing the capability of intensive police programmes to prevent severe road accidents: A systematic review. *British Journal of Criminology*. 2005;45(6):914-37.
4. Elvik R, Christensen P. The deterrent effect of increasing fixed penalties for traffic offences: The Norwegian experience. *Journal of Safety Research*. 2007;38(6):689-95.
5. SWOV. Penalties in traffic. Leidschendam, NL: SWOV; 2013.

6. Briscoe S. Raising the bar: can increased statutory penalties deter drink-drivers? *Accident Analysis & Prevention*. 2004;36(5):919-29.
7. Criminal Justice Policy G. Review of Monetary Penalties in New Zealand. Auckland: Ministry of Justice; 2000.
8. Li J, Lawpoolsri S, Braver ER. Speeding Tickets: Effective Deterrents for Future Violations or Not? TRB 85th Annual Meeting Compendium of Papers CD-ROM 29. Washington DC: Transportation Research Board; 2006. p. 1-29.
9. 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. *Accident Analysis & Prevention*. 2007;39(5):982-94.
10. Elvik R. To what extent can theory account for the findings of road safety evaluation studies? *Accident Analysis & Prevention*. 2004;36(5):841-9.
11. Evans L. *Traffic Safety and the Driver*. New York: Van Nostrand Reinhold; 1991.
12. Gibbs JP. *Crime, punishment, and deterrence*. New York: Elsevier; 1975.
13. Bjornskau T, Elvik R. Can road traffic law enforcement permanently reduce the number of accidents? *Accident Analysis & Prevention*. 1992;24(5):507-20.
14. Ross HL. *Deterring the drinking driver*. Lanham, MD: Lexington Books; 1982. 129 p.
15. Ross HL. Are DWI sanctions effective? *Alcohol, Drugs and Driving*. 1992;8(HS-041 390).
16. Shults RA, Nichols JL, Dinh-Zarr TB, Sleet DA, Elder RW. Effectiveness of primary enforcement safety belt laws and enhanced enforcement of safety belt laws: a summary of the Guide to Community Preventive Services systematic reviews. *J Safety Res*. 2004;35(2):189-96.
17. Elvik R, Vaa T, Høye A, Sørensen M. *The handbook of road safety measures: second edition*. Bingley, UK: Emerald Publishing Limited; 2009. 1140 p.
18. Aeron-Thomas A, Hess S. Red-light cameras for the prevention of road traffic crashes. *Cochrane Db Syst Rev*. 2005(2).
19. Perkins C, Steinbach R, Edwards P, Beecher D, Hess S, Aeron-Thomas A, et al. Red light enforcement cameras to reduce traffic violations and road traffic injuries. London; 2017.
20. Wilson C, Willis C, Hendrikz JK, Bellamy N. Speed enforcement detection devices for preventing road traffic injuries. *Cochrane Db Syst Rev*. 2006(2).
21. Wilson C, Willis C, Hendrikz JK, Le Brocq R, Bellamy N. Speed cameras for the prevention of road traffic injuries and deaths. *Cochrane Db Syst Rev*. 2010(10).
22. Steinbach R, Perkins C, Edwards P, Beecher D, Roberts I. Speed cameras to reduce speeding and road traffic injuries: protocol for a systematic review. London; 2016.
23. Høye A. Speed cameras, section control, and kangaroo jumps—a meta-analysis. *Accident Analysis & Prevention*. 2014;73:200-8.
24. Pilkington P, Kinra S. Effectiveness of speed cameras in preventing road traffic collisions and related casualties: systematic review. *BMJ*. 2005;330(7487):331-4.
25. Soole DW, Watson BC, Fleiter JJ. Effects of average speed enforcement on speed compliance and crashes: A review of the literature. *Accident Analysis & Prevention*. 2013;54:46-56.
26. Doecke SD, Kloeden CN, Dutschke JK, Baldock MRJ. Safe speed limits for a safe system: The relationship between speed limit and fatal crash rate for different crash types. *Traffic Injury Prevention*. 2018;19(4):404-8.
27. Elvik R. *Speed and road safety - new models*. Oslo: Institute of Transport Economics; 2014. Contract No.: 1296/2014.
28. Koornstra M. Prediction of traffic fatalities and prospects for mobility becoming sustainable-safe. *Sadhna - Academy Proceedings in Engineering Sciences*. 2007;32(4):365-96.
29. Høye A. Still red light for red light cameras? An update. *Accident Analysis & Prevention*. 2013;55:77-89.

30. McGee HW, Eccles KA. Impact of red light camera enforcement on crash experience. Washington D. C.: Transportation Research Board; 2003.
31. Compton RP, Berning A. Drug and alcohol crash risk. *Journal of Drug Addiction, Education, and Eradication*. 2015;11(1):29.
32. Schnabel E. Alcohol and driving-related performance - A comprehensive meta-analysis focusing the significance of the non-significant (Alkohol und fahrrelevante Leistungen - Eine umfassende Metaanalyse). Würzburg: Universität Würzburg; 2011.
33. Goss CW, Van Bramer LD, Gliner JA, Porter TR, Roberts IG, DiGuseppi C. Increased police patrols for preventing alcohol-impaired driving. *Cochrane Db Syst Rev*. 2008(4).
34. Erke A, Goldenbeld C, Vaa T. The effects of drink-driving checkpoints on crashes—A meta-analysis. *Accident Analysis & Prevention*. 2009;41(5):914-23.
35. Dinh-Zarr TB, Sleet DA, Shults RA, Zaza S, Elder RW, Nichols JL, et al. Reviews of evidence regarding interventions to increase the use of safety belts. *American Journal of Preventive Medicine*. 2001;21(4):48-65.
36. Shults RA, Elder RW, Sleet DA, Thompson RS, Nichols JL. Primary enforcement seat belt laws are effective even in the face of rising belt use rates. *AccidAnalPrev*. 2004;36(3):491-3.
37. Koornstra M, Lynam D, Nilsson G, Noordzij P, Pettersson H-E, Wegman F, et al. SUNflower: A comparative study of the development of road safety in Sweden, the United Kingdom, and the Netherlands. Leidschendam: SWOV; 2002.
38. ECORYS. Study on the prevention of drink driving by the use of alcohol interlock devices. Rotterdam: European Commission: DG for Mobility and Transport; 2014.
39. Sweedler B, Biecheler M, Laurell H, Kroj G, Lerner M, Mathijssen M, et al. Worldwide trends in alcohol and drug impaired driving. *Traffic Injury Prevention*. 2004;5(3):175-84.
40. Davey JD, Freeman JE. Improving Road Safety through Deterrence-Based Initiatives: A review of research. *Sultan Qaboos University medical journal*. 2011;11(1):29-37.
41. Moffatt S, Poynton S. The deterrent effect of higher fines on recidivism: Driving offences. Sydney: Attorney General's Department, NSW Bureau of Crime Statistics and Research; 2007.
42. Nochajski TH, Stasiewicz PR. Relapse to driving under the influence (DUI): A review. *Clinical Psychology Review*. 2006;26(2):179-95.

Symposium Supported by



TATA TRUSTS



www.icorsi.org