Crash Reduction Factors for Education and Enforcement

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16. Abstract

ODOT has a goal of reducing total crashes by 10% by 2015. Driver education, licensing, testing, and enforcement strategies are all tools that can be used to help reduce the incidence of accidents, particularly among teenage drivers, who are involved in accidents well out of proportion to their numbers in the overall driver population. In order to determine which strategies are likely to provide the best results, ODOT needs to have some quantitative estimate of the effectiveness of each strategy in terms of the amount of reduction it provides, in other words a crash reduction factor (CRF).

A comprehensive literature and web search was conducted to determine driver education, licensing and enforcement practices, and CRF values used by other states and countries. An electronic survey of all states was conducted to get information about driver education, licensing programs, testing and enforcement measures, the state of the art in traffic safety practices, and CRFs. The relatively few CRFs obtained for driver education, licensing programs, and traffic enforcement measures were compared to those obtained for traffic engineering measures.

Based on the analysis of all the information obtained only a limited number of quantitative CRFs exist for any of the driver education, licensing and enforcement measures in any of the states in the US. Published studies where the effects on reducing crashes for new measures with sound statistical evaluations using proper control groups appear to be almost non-existent in the US. CRFs for driver education, licensing programs, and enforcement measures based on the estimates by traffic safety experts were found for Switzerland in the VESIPO report and the cost/benefit ratios for some selected Swiss measures were found. It has to be noted that even the Swiss CRFs are based on partial estimates and have not been truly validated with before and after studies using actual data except for one blood alcohol content measure ("Reduction of BAC limit from 0.08% to 0.05%" with extensive advertising and strict enforcement). Since some of the CRFs found were from countries outside the US, such as Switzerland and Canada, and since the road transportation system of the US is fairly similar to Western Europe the strategies used for crash reduction will usually be applicable to Ohio. The range for the CRFs reported in the literature for driver education, driver licensing, testing and enforcement are summarized in the conclusion section of the report. The ranges for CRFs for driver education, licensing programs, and enforcement measures are less than 1% to 32%, 0%-17% and 2%-51% respectively. A prioritized implementation plan based on the highest CRFs reported has been proposed for driver education, licensing and enforcement.

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SI* (MODERN METRIC) CONVERSION FACTORS

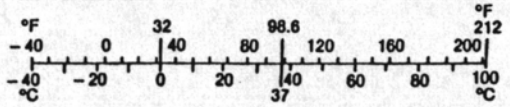
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

NOTE: Volumes greater than 1000 L shall be shown in m^3.

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

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Final Report
May 2007

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1 Statement of the problem

ODOT has a goal of reducing total crashes by 10% by 2015. According to Ohio Department of Public Safety about 80% of the 358,127 crashes in Ohio during 2005 were caused by driver error, it is logical to put the emphasis in the crash reduction on the driver. Based on nationwide statistics teenagers are involved in fatal crashes at three times the rate of all drivers [1], owing to their inexperience, risk taking behavior, immaturity, and greater exposure to risk. Drivers older than 60 years have the highest rate of car crash death rates in the country based on nationwide statistics [2] per mile driven; for them, conditions such as decreasing vision and increasing reaction time are the main causes of their higher involvement in crashes [2]. Road rage and aggressive driving are other important causes of crashes, and these include a combination of moving traffic offenses that endanger other persons or property. With such a diversity of driving problems in the population, driver education and training programs need to be tailored towards the needs of drivers according to their age group. This means applying new techniques in driver education, at both the initial and continuing levels. Better enforcement of traffic laws is another area that could reduce crash rates. In order to determine which strategies are likely to provide the best results, ODOT needs a crash reduction factor (CRF) to quantitatively estimate the effectiveness of each strategy, which will thus enable ODOT to prioritize those measures according to anticipated effectiveness.

In essence, a CRF for a given safety measure can be defined as the percentage reduction in crashes that can be attributed to that safety measure. For an engineering feature, such as a curve realignment, a comparison of accident rates before and after at the given location yields a straightforward basis for comparison and makes computing a CRF relatively easy. Education and enforcement measures are not always permanent changes (they typically begin and end at certain times), may target some populations but not others (e.g. older drivers), may not reach all drivers (not everyone will see a new advertisement on TV), and can get easily confounded with other issues (the effects of changes in education relative to winter driving may be masked if the next winter is particularly mild; also, an accident involving a teenage driver might not be the fault of that driver). Thus, making rigorous before and after comparisons is a difficult proposition at best, and the resulting CRFs are not as certain as those computed for engineering changes. However, the need for education and enforcement are eternal, and so is the need to find a way to measure the beneficial results of these efforts in order to justify the programs and ensure they are as effective as they can be made.

2 Objectives of the study

- Perform a comprehensive literature search using the information obtained from the web, government agencies, and libraries.
- Research education and enforcement strategies used by authorities in other states and countries through the literature search and surveys.
- Determine the effect each of these measures has on reducing crashes and from the data determine a CRF for each education, licensing, testing and enforcement strategy.

- Conduct interviews and meetings with traffic safety experts to get the latest information on the driver education, driver licensing, testing, and law enforcement measures.
- Conduct an electronic e-mail survey of all the states to get information on the state of the art practices used in traffic safety in each state.
- Analyze all the information obtained to determine a CRF for each driver education, driver licensing, or enforcement activity.
- Determine CRF's for different crash reduction measures to enable comparison of their effectiveness.

3 Research approach and methodology

A detailed literature search was performed for different known types of education and enforcement strategies that are being currently used by the different states, American territories, and the Canadian provinces. These practices were reviewed and analyzed based on their effectiveness in reducing crashes. Electronic surveys were performed to obtain more information from different people/agencies including all state DOTs, nationwide law enforcement agencies, and driver educators in order to elicit their ideas on the current as well as potential future education and enforcement strategies. Very few responses were obtained from the electronic surveys and very little statistically valid CRF information was found for education and enforcement strategies. The report also discusses the CRFs obtained for different traffic engineering measures as examples that show how valid CRFs can be obtained using sound statistical techniques.

4 Introduction

The most common types of crashes are run off the road, intersection movement, object in road, large animal in road (typically deer), head-on or sideswipe, rear end, pedestrian in road, rollover, and bicycle collision. The common driver causes which lead to crashes are as follows: speeding, alcohol, other drugs, fatigue, inattention/distractions, inaccurate judgment of surrounding traffic, inaccurate judgment of one's path, carelessness/impulsiveness, disregard for rules (changing lanes or turning without giving signals, etc.), bad weather conditions (fog, snow, rain), eating or drinking (nonalcoholic beverages) while driving, failure to keep sufficient distance between oneself and the vehicle ahead, and disability/illness. Causes of crashes and the categories of drivers most commonly involved in them are shown in Table 1, summarizing information from a number of studies of the type of crash and the corresponding class of drivers most commonly involved.

Table 1: Causes of crashes and associated driver types [2] [3].

Cause of crash	Driver category
Speeding	Young and middle age drivers, people late for an appointment, etc.
Alcohol and drugs	Teenagers
Fatigue	Long distance travelers, people returning from work, etc
Inattention	Families driving with small kids, cell phone users, etc
Inaccurate judgment	Novice drivers, Older drivers

Table 1: Causes of crashes and associated driver types [2] [3] continued.

Cause of crash	Driver category
Carelessness & disregard for rules (Aggressive Driving and Road Rage)	Younger drivers
Bad weather conditions & Deer/Vehicle Crashes	Anyone (faster drivers, generally)
Eating and drinking	Long distance travelers
Incorrect headway distance	Younger drivers, people in a hurry, etc
Disability or illness	People using a car that is not properly equipped to deal with their disability, people who are ill, people who have not had a physical or eye exam in a while, etc.

All the abovementioned situations increase the chances of a crash occurring to the driver and hence should be avoided.

4.1 Methods to reduce crashes

There are different methods that can be implemented to help reduce crashes. These methods can be divided into two major categories: Driver Education and Traffic Law Enforcement. These are shown in detail in Figure 1. Other methods of reducing crashes include improved freeway and road design, and improved vehicle design, but those methods lie outside the scope of this report, which focuses only on the human component of the Traffic – Vehicle – Human system. Graduated driver licensing is not considered an educational measure as it is not a classroom learning experience.

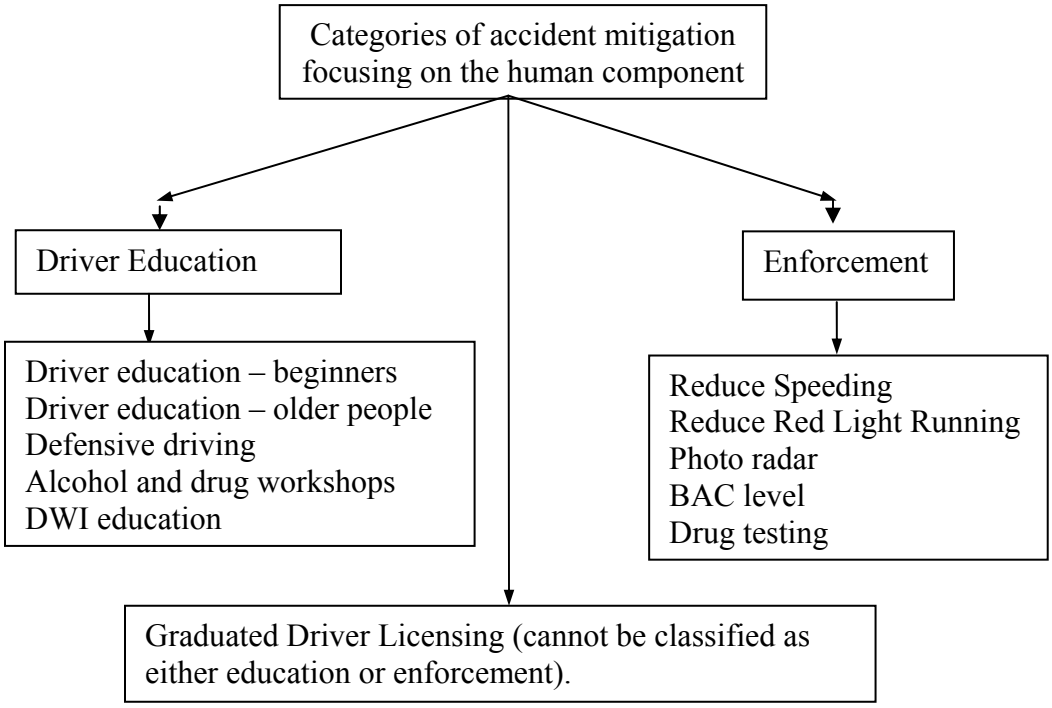


Figure 1: **Categories and subcategories for crash prevention focusing on driver behavior.**

Researchers nationwide are looking at how to simulate the occurrence of crashes in order to predict their occurrence and the conditions under which they occur. This research may then help prevent these conditions from occurring.

4.2 Economic losses due to crashes in the US

According to the report prepared for National Highway Traffic Safety Administration (NHTSA) [4], 41,821 persons lost their lives in 16.4 million motor vehicle crashes in the year 2000. These crashes resulted in 5.3 million personal injuries, and 27.6 million vehicles were damaged. The total economic costs were estimated at $230.6 billion which is approximately 50 percent higher than the previous estimate of $150.5 billion for the year 1994 [4]. According to the report; these motor-vehicle crash costs represent 2.3% of the $9,872 billion U.S. Gross Domestic Product for 2000 and is equivalent of $820 per person living in United States [4]. These economic costs include losses due to reduced productivity, medical and insurance costs, legal and court costs, emergency service costs, travel delay, property damage, and workplace losses. They are summarized in Table 2 [4].

Table 2: Summary of Total Costs associated with traffic accidents in the year 2000 [4]. Cost amounts are given in millions of dollars in the year 2000.

	PDO	MAIS 0	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	**Total**	**% Total**
Medical	$0	$3	$11,088	$6,813	$5,854	$4,794	$3,146	$924	**$32,622**	**14.15%**
Emergency Services	$733	$56	$452	$92	$46	$30	$8	$35	**$1,453**	**0.63%**
Reduced Market Productivity	$0	$0	$8,151	$10,908	$8,996	$3,886	$4,151	$24,898	**$60,991**	**26.45%**
Reduced Household Productivity	$1,111	$84	$2,664	$3,193	$2,653	$1,023	$1,413	$8,010	**$20,151**	**8.74%**
Insurance Administration	$2,741	$204	$3,453	$3,012	$2,379	$1,181	$645	$1,552	**$15,167**	**6.58%**
Workplace Cost	$1,208	$87	$1,175	$852	$537	$172	$78	$364	**$4,472**	**1.94%**
Legal Costs	$0	$0	$699	$2,172	$1,990	$1,230	$756	$4,272	**$11,118**	**4.82%**
Subtotal	**$5,793**	**$433**	**$27,682**	**$27,041**	**$22,456**	**$12,315**	**$10,197**	**$40,056**	**$145,973**	**63.31%**
Travel Delay	$18,976	$1,970	$3,620	$369	$118	$36	$87	$383	**$25,560**	**11.09%**
Property Damage	$35,069	$2,597	$17,911	$1,724	$856	$359	$89	$430	**$59,036**	**25.60%**
Subtotal	**$54,046**	**$4,567**	**$21,532**	**$2,093**	**$974**	**$395**	**$176**	**$812**	**$84,595**	**36.69%**
Total	**$59,838**	**$5,000**	**$49,214**	**$29,134**	**$23,430**	**$12,710**	**$10,373**	**$40,868**	**$230,568**	**100.00%**
% Total	**25.95%**	**2.17%**	**21.34%**	**12.64%**	**10.16%**	**5.51%**	**4.50%**	**17.72%**	**100.00%**	

Note: MAIS is the maximum injury severity level experienced by the victim. PDO is property damage only.

Totals may not add due to rounding.

This table can be summarized as shown in, which includes all crashes, Figure 3, which includes only fatal crashes, and Figure 4, which excludes fatal crashes.

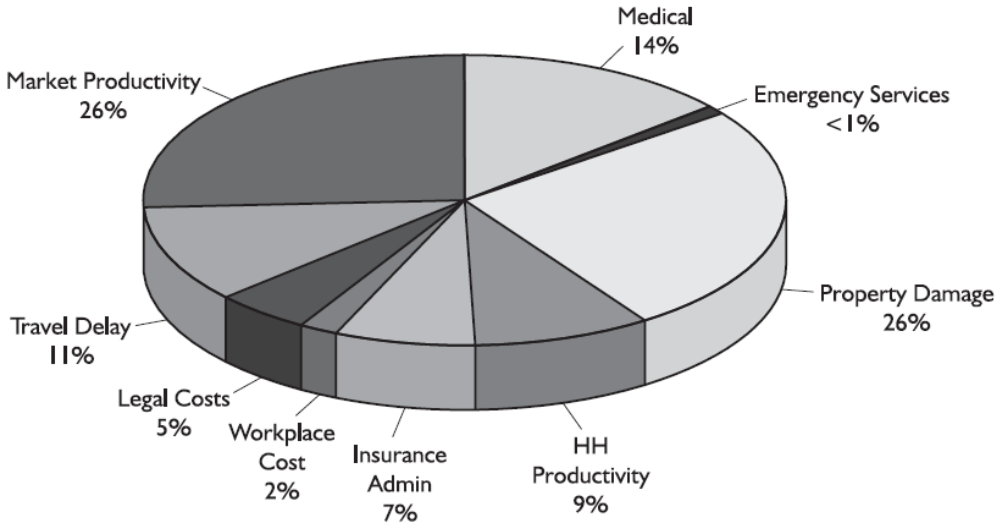


Figure 2: Components of Total Costs for all accidents [4].

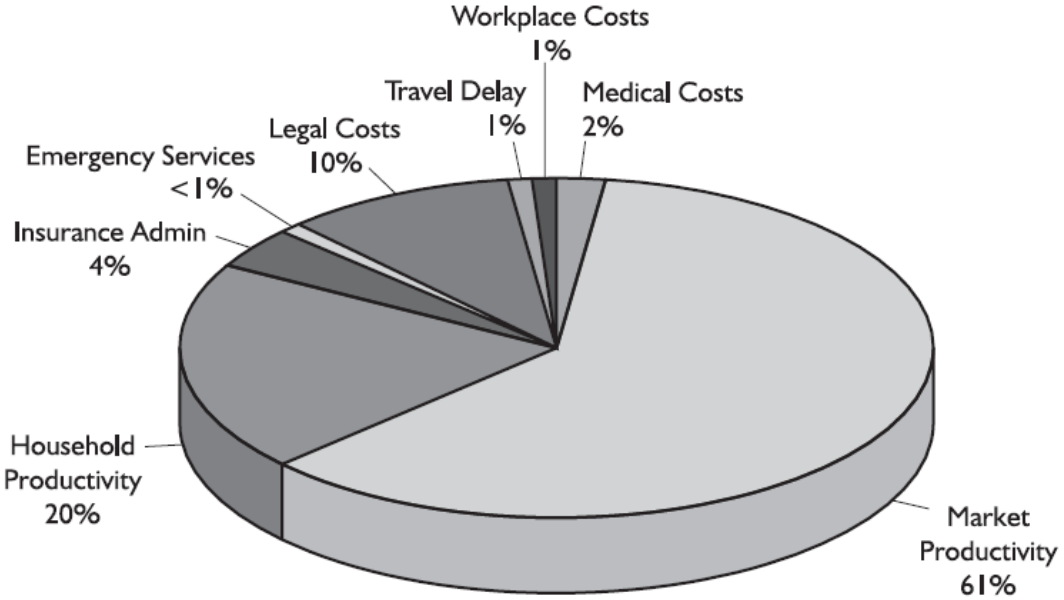


Figure 3: Components of Total Costs for Crashes with Fatalities [4].

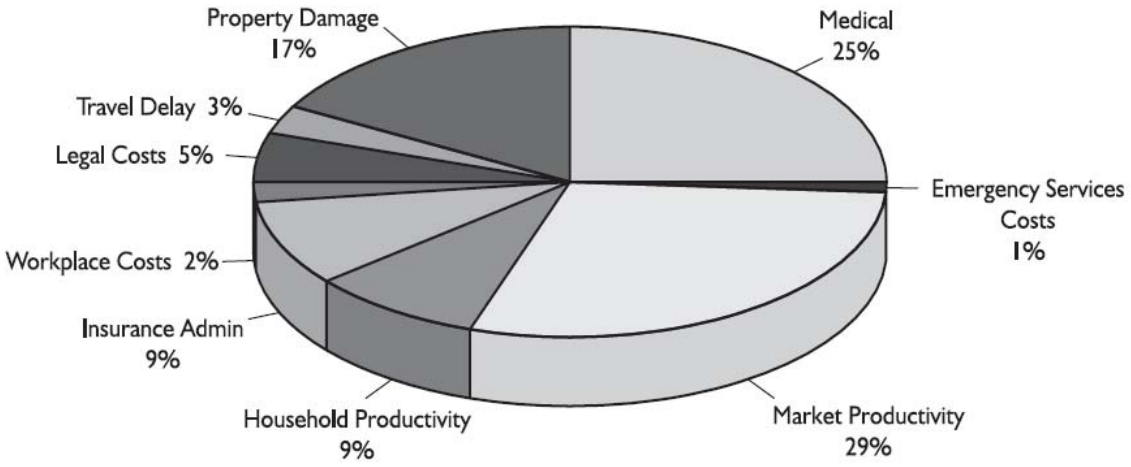


Figure 4: Components of Total Costs for Crashes with Non-Fatal Injuries [4].

The main motive behind crash reduction efforts is to avoid loss of life and limb to accident victims. However, crashes can also affect the entire community economically as Table 2 and

Figure 2 through Figure 4 illustrate. Thus reducing crashes will also benefit the economy as well as save lives.

For the State of Ohio, according to the Governor's Highway Safety Office's (GHSO) *Traffic Safety Action Plan* [5], 1,285 people were killed and 140,177 were injured in traffic automotive crashes during the year 2004. Table 3 shows the Ohio traffic crash data and measure of exposure between years 2001-2004.

Table 3: Ohio Traffic crash data and Measure of Exposure 2001-2004 [5]

	2001	2002	2003	2004	% Change 2001-04
Total Crashes	387,075	386,076	392,683	381,639	- 1.40%
Fatal Crashes	1,258	1,284	1,168	1,162	- 7.63%
Injury Crashes	94,971	95,374	94,970	94,058	- 0.96%
Fatal/Injury Crash Rate per 1,000 crashes	248.60	250.36	244.82	249.50	0.36%
People Killed	1,379	1,417	1,278	1,285	- 6.82%
People Seriously/Visibly Injured	66,854	67,864	66,466	66,842	-.0002%
Death Rate per 100,000 licensed drivers	17.47	18.02	16.20	16.24	- 7.04%
Fatal Crash Rate per 100,000 licensed drivers	15.93	16.33	14.81	14.69	-7.78%
Ohio Licensed Drivers	7,892,886	7,860,831	7,884,809	7,910,971	0.23%
Vehicle Miles of Travel	107,055,230,000	107,887,513,950	109,906,245,000	112,388,055,200	4.98%
Death rate per 100 MVMT	1.288	1.313	1.162	1.143	8.87%

Source: Ohio Traffic Crash Facts

5 Literature Review

5.1 Driver education

5.1.1 Education for beginning drivers

The purpose of driver education is to teach people how to drive SAFELY without injury to oneself and others on the road. There are many ways to instruct a person on driving as can be seen from the various driver education books that are available [e.g. 6, 7, and 8]. Learning to drive can be understood using "human learning" principles. There are three stages in human learning: cognitive (reading and assimilating the steps involved in performing a specific task), associative (the principles gleaned from the cognitive stage are put into practice through trial and error) and autonomous (the human performs the task with little or no external help). Driver education has to guide the student through all three stages to ensure that the driver will be able to perform effectively when he or she obtains his or her license.

There are specific teaching aids that enable a novice driver through these three stages of human learning.

- ✓ Classroom instruction aids help the novice driver understand the principles behind driving; these may include for example charts, pictures, videos, computer aids, magnetic traffic boards, and flannel boards.
- ✓ Field aids such as detonators which help in teaching the students the correct braking technique.
- ✓ Driving simulators help the students familiarize themselves with body movements used in driving, the feel of action with the immediate results, and continued practice without immediate danger.
- ✓ Once the student is comfortable with the simulator, it is time for in-car instruction. This will give the student the feel of the actual car and surrounding traffic, but hopefully if the student has put in enough practice hours on the simulator, it will not take long to get a good feel for driving.

Mayhew and Simpson [9] studied the effectiveness of the driver education and training programs. In the 1970s, the NHTSA developed two kinds of driver education curricula for high school students. The effectiveness of these two curricula, abbreviated SPC and PDL, was demonstrated in a study performed in DeKalb county Georgia. Over 3 years, students were assigned to either of these two curricula or to a no training group, randomly. There was a 6% reduction in crashes for the groups having education compared to the control group over the next 6 years based on driving records. There was no significant decrease in the number of crashes or the number of students who had a crash for the SPC group whereas there was a considerable decrease in the number of crashes for PDL students during the first two years after the program. Other researchers also studied the curricula and a summary of this work is given in Table 4.

Table 4: Review of work done on the Dekalb County driver education curricula experiment [9].

Authors	Subjects	Results
Stock et al. (1983)	All assigned students Completed course and licensed	No effect Positive effect for first six months - SPC, PDL
Smith and Blatt (1987)	Assigned students who had driving records	No effect-SPC* Positive effect-PDL**
DeWolf and Smith (1988)	Students who at least partially completed SPC or PDL; those who had never enrolled; controls	No effect
Lund et al. (1986)	All assigned students	Negative effect
Davis (1990)	All assigned students	Negative effect

(Extracted from DeKalb studies shown in [9])

**SPC – safe performance curriculum (72-hour course that included 32 hours of classroom, 16 hours of simulation, 16 hours of driving range instruction, three hours of instruction on evasive maneuvers, and five hours of on-street training)*

***PDL – pre driving license course (20-hour basic driver training course that also included classroom, range and simulation instruction as well as practice driving with parents)*

In *Transportation Research Circular* E-C101, August 2006, there are several papers related to the topic of driver education. In one of these papers David Preusser presented recent data that shows the extremely high rate of accident rate of novices, which drops by two thirds in the first month of driving. This focuses on the need of driver education on the initial "errors of inexperience" rather than trying to develop a "lifetime of responsible driving" within the context of a 30 and 6 program (30 hours of classroom with 6 hours of driving behind the wheel) [10].

In another paper from same circular, A. James McKnight explained the importance in driver education of focusing on the errors that are biggest contributors such as frequent lapses of attention, not looking where hazards lurk, not recognizing hazards when they appear, and not adjusting speed to road and traffic conditions [11].

John F. Brock emphasized computer-based training for driver education which is interactive and learner-centered due to its motion visual capabilities [12]. According to author Larry Lonero, student competency measures primarily depend on written and road tests [13]. Both said that the use of computer-based training allows the inclusion of situations that occur too rarely or are too dangerous on the road to make a part of student training or experiential assessment [12] [13]. The suitable alternative for accidents according to Raymond C. Peck is to measure the way novices drive – not how they can drive but the way they actually do drive when on their own – thus measuring the effectiveness of their education [14]. This can be achieved through random experiments in which control groups receive sufficient instruction and training to get licensed and face the same situations as the drivers that took the more comprehensive driver education program [14].

The Johns Hopkins School of Public Health conducted a literature search of different high school driver education courses conducted by different schools to see if they had an effect on the crash rate. The studies that assessed the effects of driver education courses or legislation for high school age persons, presented data on driver licensure rates and motor-vehicle related crashes were considered relevant for research. There were nine studies that matched these criteria, but there was no evidence from those studies to show that these education courses had a positive effect on drivers or that they reduced crash rates [15].

Details of the different education measures from a Swiss report and the crash reductions that could be obtained using these measures are provided in a separate section in the report.

5.1.2 Older Driver Education

Older drivers belong to the fastest growing group of drivers. Drivers older than 60 years have the highest rate of car crashes per mile when compared to all other age groups. Though there are programs that are ostensibly tailored towards older driver education, they do not seem to have a significant effect on crashes [16]. There are physical conditions that have to be considered for older drivers such as decreasing vision capability and increasing reaction time. The American Automobile Association (AAA) depicts the increasing prevalence of vision problems with age in Figure 5.

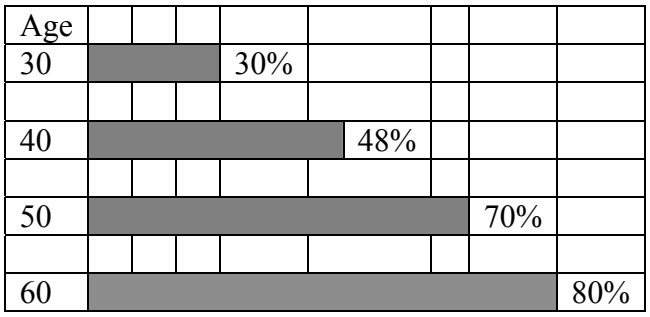


Figure 5: Percentage of Drivers Aged 30 - 60 years with vision problems [7].

There have been some suggestions that might reduce the crash rates among older drivers, but there were no quantitative studies or statistics available. These suggestions included [17]:

- Vehicle modifications to improve crash worthiness such as customized airbags, customized seat belt designs, larger in-vehicle displays, and visibility enhancements.
- Since most crashes by older drivers occur at intersections [18] better road designs with protected left turns at signals would reduce crashes not only for older drivers but drivers of all ages.
- Stricter requirements for license renewal for drivers beyond a certain age, but since age only is not a reliable indicator of a crash susceptible driver, a screening process should be developed to identify at-risk drivers. All the efforts which will restrict driving for older population should be done so that there is no decrease in

elderly mobility and more attention should be given on protecting older drivers while they drive [17].

5.1.3 Defensive driving courses

A defensive driving course is generally taken for personal reasons, such as to reduce insurance rates or reduce points against the license, or because the driver has been ordered to take the course by a law enforcement agency. West Virginia University has a comprehensive online defensive driving handbook [19]. In addition to this there are other websites that offer online defensive driving courses such as the National Safety Council [20], the Department of Motor Vehicles (DMV) [20], and the National Traffic Safety Institute (NTSI) [21]. There are no statistics available to establish that defensive driving courses reduce crashes.

From the literature presented above it is seen that driver education programs are primarily aimed at the novice teenaged driver or the older driver. There are a handful of programs that are conducted for high school students but these are not too many in number. Therefore, it may be good to convert the concept of safe and responsible driving into a formal traffic safety program as is done in European schools. From the elementary level to the time when the teenager actually learns to drive, children are taught the importance of traffic rules and safe driving [22]. These programs can thus ensure that even before the teen decides to enroll in a driving class, he/she will be absolutely familiar with traffic safety rules and will thus be a more responsible driver.

5.2 Enforcement

Traffic law enforcement is always associated with a reduced risk of fatal motor vehicle crashes because of its direct effect on drivers. Redelmeier et al. [23] identified licensed drivers in Ontario, Canada who were involved in fatal motor-vehicle crashes in the past 11 years, and used the case-crossover design to analyze the protective measures taken by drivers as a function of recent convictions. This study based on observation of drivers in Ontario, Canada which had 6.8 million drivers in 1993 for almost 11 years, and found that “each conviction leads to a 35% decrease in the relative risk of death over the next month for drivers and other road users; conversely, each conviction not issued would lead to a corresponding increase in risk” [23]. The data further suggests that, 80,000 convictions lead to the prevention of one death, 1300 convictions save one emergency department visit, assuming the benefits apply to crashes of all severity. Every 13 convictions also lead to the prevention of $1000 in societal costs, including property damage and time lost [23].

The meta-analysis done by these authors of past ecological data also implied a 2% risk reduction in death attributable to manual speed enforcement, a 19% reduction attributable to automated speed enforcement, an 11% reduction attributable to red light violation enforcement, and a 4% reduction attributable to enforcement of drunk driving laws [23].

Details of the traffic enforcement measures found from Swiss VESIPO report are provided in detail in a later section in the report. The Swiss measures had crash reduction

factors which were estimated by a group of experts from Swiss Council of Accident Prevention.

5.2.1 Speed Management

With regard to managing speed, various methods have been used but the ultimate goal is to ensure that the driver knows the effects of indiscriminate speeding and acts accordingly. Alicandri and Warren [1] address the issue of "Managing Speed" from different aspects. The authors show that driving speed is dependent on many factors such as driver behavior, vehicle performance, road characteristics, and enforcement policies. Each of these factors has to be considered by the driver while managing speed, and correspondingly the repercussions that a change in each factor will have on road users also have to be considered. The article also details the methods that were considered by a group formed by engineers, educators, and enforcement personnel. Setting speed limits according to the location and characteristics of the road, speed management workshops, and enforcement using photo radar were the techniques that were used to counter speeding and consequently speed related crashes.

The relation between speeding and crashes is shown very clearly in [24], which summarizes the research done in the area of speed management. This synthesis shows statistics that relate the occurrence of crashes to speed, as obtained by researchers in different studies. Researchers have studied the effects of setting appropriate speed limits by varying current speed limits and observing the ensuing changes in crash percentages, in other words by computing crash reduction factors.

5.2.2 Aggressive driving

The National Highway Traffic Safety Administration (NHTSA) defines aggressive driving as, "when individuals commit a combination of moving traffic offenses so as to endanger other persons or property" [25]. Some behaviors typically associated with aggressive driving include: exceeding the posted speed limit, following too closely, erratic or unsafe lane changes, improperly signaling lane changes, and failing to obey traffic control devices. More than 60 percent of the drivers interviewed believed that unsafe driving by others is a major personal threat to them and their families. Strategies to assist law enforcement agencies in coordinating aggressive driving enforcement were provided [25]. Examples of the different programs adopted by different police departments in USA were presented which may be adopted or modified to meet the needs of individual agencies. Aggressive driving programs adopted by nine police agencies across different states in USA were cited to give an idea of the programs that were used to enforce aggressive driving behavior [25].Though crash reductions obtained in all the nine cases were not provided, they were expected to certainly decrease aggressive driving. In a study conducted in Britain, 44% of drivers questioned claimed that they had suffered verbal or gesticulatory abuse in the past 12 months from other drivers and 9% of the drivers had been forced to pull off the road due to aggressive driving by others [26].

5.2.3 Speed enforcement efforts

The effects of enforcement techniques have been the subject of several investigations. For instance [27, 28,29] studied the effect of the presence of mobile patrol vehicles and found that the speeds decreased only in the vicinity of the patrol cars and increased in

unmanned areas. The effect of stationary patrol vehicles was also similarly restricted to the immediate neighborhood of the vehicle [30, 31]. When Stuster [32], conducted his experiment on communities that were selected based on the crash statistics or the complaints of the residents regarding speeding, special zones were selected and 8 hours of officer time per week were devoted to these zones. There was reduction in speed related crashes and when a time series analysis was conducted, there were 112 fewer crashes than what were expected based on prior rates.

Aerial speed enforcement has been found to have a better effect on reducing the average speed on the highways. A particular study of the effect of aerial enforcement conducted by Kearns and Webster [33], in New South Wales, Australia for 11 months showed that vehicle crashes were reduced by 22%. In the USA, Blackburn, Moran, and Glauz [34], also showed that aerial enforcement was more effective in identifying and apprehending vehicles that were above the speed limit, particularly those drivers employing radar detectors or CB radios.

Automated speed enforcement techniques have also been studied. Studies conducted by Maekinen and Oei [35], Rogerson, et al. [36], and Teed and Lund [37] indicated these techniques were effective in reducing the speeds some in the area covered directly by the camera, but once their vehicles were out of range of the camera, most drivers reverted to higher speeds. Elvik [38] conducted a before and after study of photo radar in Norway. There was a 26% reduction in injury crashes at high crash density areas. At the sites that did not conform to the warrants for installation of photo radar, there was a 5% reduction.

Enforcement in the area of drone radars and speed indicators showed that they were successful in reducing the speed but the vehicles returned to higher speeds beyond the range of the radar [24].

Traffic enforcement notification signs, when implemented, showed an improvement in crash percentages. These are signs that are placed near a roadway just before vehicles enter the enforcement zone. Inside the enforcement zone, all traffic laws are strictly enforced by police personnel. In Huntington Beach, California there was a 17% reduction in injury crashes and 100% reduction in fatal crashes between the time this program was introduced and the 1995 survey by Stuster [32].

Traffic safety programs that have highly visible public relations, advertising, and education components have been found to inculcate safer driving habits. Sali [39] introduced a program called the Selective Traffic Enforcement Program (STEP) in Boise, Idaho in 1983. This program consisted of aggressive traffic enforcement in selected unsafe areas in Boise coordinated with a publicity campaign broadcast over public radio that detailed the reasons why these areas were unsafe and the steps being undertaken to improve safety. The Boise Police Department was portrayed as being genuinely interested in the welfare of the residents. This program caused a 17% reduction in injury crashes as opposed to no improvement in the non-STEP control area.

The Washington DC metropolitan police department used photo radar to decrease the number of vehicles that were speeding. This technique was implemented in July 2001

resulting in a decrease in the percentage of speeding vehicles from 30% to a low of 4.7% in May 2004 [40]. Photo radar with speed displays is a tool used to decrease the number of travelers driving above the speed limit, as shown in [24], this helps reduce the average speed. The effectiveness of photo radar in other countries is shown in Table 5.

Table 5: Summary of Photo Radar Effectiveness in Other Countries [24].

Country/ Region	Implementation period	Reduction
London, UK	2 years	Fatal crashes reduced from 68 to 20 (70.5% reduction) Injury crashes reduced from 813 to 596 (26.7% reduction) (a selected corridor tested)
Norway	Not Available	Injury crashes reduced by 20%
Victoria, Australia	8 years	Fatal crashes reduced by 51% Injury crashes reduced by 34% Total collisions reduced by 22%
British Columbia, Canada		Fatal crashes reduced by 20% in the first year Total crashes reduced by 7% Speeding vehicles reduced 66% to 40% in 3 years (1996 to 1999)

5.2.4 Driving under the influence

Driving under the influence of alcohol or drugs (DUI) or driving while intoxicated (DWI) are common causes for crashes. This issue is primarily dealt with through enforcement. The most popular method of detecting drunk drivers is to stop them and give a sobriety test. The legally defined DUI threshold value of blood alcohol content (BAC) in Ohio and all other states is 0.08%.

The appropriate BAC levels and medico-legal interpretation of the corresponding level of intoxication are shown in Table 6.

Table 6: BAC levels, Medico legal interpretations as to whether the persons tested are under the influence of an intoxicant [modified from 7].

BAC	Medico legal interpretations
0 – 0.05%	No evidence of being under the influence of an intoxicant
0.05 – 0.1%	Inadequate evidence. Possibly under the influence. Requires further support.
0.1% or more	Presumed to be under the influence

With regard to drugged driving impairment there is no quantitative information available. The International Consultative Panel on Drugs and Driving Impairment was held in Seattle, Washington in August 2000. This panel consisted of delegates from different fields such as behavioral psychology, psychopharmacology, drug chemistry, forensic toxicology, and law enforcement. The meeting was sponsored by the State of Washington Traffic Safety Commission and NHTSA. Sixteen drugs were selected for review that included over the counter medication as well as commonly abused drugs. The panel then compiled a fact sheet for each of these drugs, which included effects of the

drugs, the duration of these effects, and the risks posed by individuals using these drugs, concentrating specifically on the driving risks. Scientists, law enforcement officials, and the public can use these facts to aid in issues related to drugs and driving [41].
The National Highway Traffic Safety Administration (NHTSA) developed a DWI detection guide which can be used by traffic safety personnel to identify a driver under the influence of alcohol. These techniques essentially consist of cues, which are used to detect problems in driving that may be caused by an inebriated driver. These cues include weaving, swerving, straddling a line, accelerating without a reason, driving in the wrong lane, stopping for no apparent reason, etc. Traffic law enforcement personnel use a point system based on probabilities that gives them a set of criteria to gauge when a driver is under the influence. The effectiveness of this system is about 35% at a minimum, i.e. the personnel are able to detect a driver that is under influence at least 35% of the time [42].

The city of College Station, Texas stated that 34% of all teen deaths are related to motor vehicle crashes and of these 43% are alcohol related. Therefore the College Station Fire Department (CSFD) conducts driving while intoxicated (DWI) training at the local high schools, which is comprised of a DWI Jeopardy game, a visit with the paramedic and also a set of double vision goggles that imitate two levels of intoxication. The CSFD also conducts an event called the DEAD – Drinking and Driving Ends All Dreams, every 4 years. This event consists of a reenactment of an auto crash involving many students, the reenactment of the death of 30 students, a retreat, and a student assembly. The quantitative effectiveness of this program is not available but it is said to be more effective than more conventional approaches because it involves students and their parents in the reenactments [43].

Fluid testing is a technique that could be used to test for the presence of a drug in the bloodstream but this may not be very effective because of the different chemical characteristics of the drugs. Some drugs break down into other components and may not be detectable despite the person being under the influence while other drugs take a very long time to break down and may be detectable in the bloodstream even weeks after being ingested while the impairment effects are long gone. Either situation may give law enforcement an incorrect indication of the driver's state of intoxication. Therefore a simpler way of testing for the driver being under the influence of a drug should be made available to better identify actually impaired drivers.

One other aspect that has to be considered is the combination of alcohol and drugs. If a driver is under the influence of both alcohol and drugs, he or she may still be a danger on the road while below the legal BAC limit. There has to be a way to prove that the driver was impaired by a combination of drugs.

5.3 Laws on Cell Phone usage while driving

Cell phone use while driving is a major distraction for drivers [44, 45]. There are about 300 deaths/year that can be attributed to cell phone use while driving [44]. The NHTSA reports [46] say that in 1995, cell phones may have been a major source of distraction to the driver in 40 fatal crashes. There are no federal laws that restrict the use of cell phones while driving though they have been advocated. In 1999, Brooklyn, Ohio was the first city in the United States to completely ban the use of cell phones while driving [47].

Table 7 shows the list of foreign countries that ban drivers from using cell phones while driving unless used with some kind of hands-free set. Table 8 shows similar bans for US states.

Table 7: List of countries that banned the use of cell phones while driving [48] as of January 2007.

Country	Banned	Notes
Australia	Yes	Banned in all states - fines vary though.
Austria	Yes	Fines vary - up to US$22 per incident
Belgium	Yes	Phones can be used without a hands-free unit when the car is stationary - but not while in traffic (such as at traffic lights)
Brazil	Yes	Ban imposed Jan. 2001
Botswana	Being debated	The attorney general is drafting the legislation
Canada	Variable	Banned in Newfoundland (Dec2002) fines up to US$180. Discussed again October 2006.
Chile	Yes	
Czech Republic	Yes	
Denmark	Yes	Ban imposed July 1998 - US$60 fine for infringements
Egypt	Yes	Fines of about US$100 per offence.
Finland	Yes	Ban imposed January 2003 - US$55 fine for infringements
France	Yes	Banned 2003, EUR40 fine per infraction
Germany	Yes	Ban imposed Feb. 2001 - usage allowed without a hands-free unit only when the engine is switched off. Fine of ?40 per infraction
Greece	Yes	
Hong Kong	Yes	
Hungary	Yes	Not often implemented by the police
India - New Delhi	Yes	New Delhi - Ban extended to ban all use of cell phones when driving, including use with a hands-free unit - July 2001
		Andhra Pradesh - Ban now enforced with prison sentences
Ireland	Yes	Banned, with a US$380 and/or up to 3 months imprisonment on a third offence. Hands free kits allowed, although that is subject to review.
Isle of Man	Yes	Banned since July 2000
Israel	Yes	
Italy	Yes	Fines of up to US$124 per infraction
Japan	Yes	Ban imposed Nov. 1999
Jersey	Yes	Ban imposed Feb. 1998
Jordan	Yes	Ban imposed Oct. 2001
Kenya	Yes	Ban imposed late 2001
Malaysia	Yes	
Mexico	Partial	Ban in Mexico City
Netherlands	Yes	
New Zealand	Being debated	Under debate - consultation being sought from interested parties

Table 7: List of countries that banned the use of cell phones while driving [48] as of January 2007 (continued).

Country	Banned	Notes
Norway	Yes	Fines of over $600 per infraction
Pakistan	Partial	Banned in Islamabad
Philippines	Yes	
Poland	Yes	Fines can be as high as US$1,000
Portugal	Yes	
Romania	Yes	
Russia	Yes	Ban imposed by Prime Minister - March 2001
Singapore	Yes	
Slovak Republic	Yes	
Slovenia	Yes	
South Africa	Yes	
South Korea	Yes	Ban imposed July 2001 - US$47 fine + 15 points on the license.
Spain	Yes	
Sweden	Yes	
Switzerland	Yes	
Taiwan	Yes	If the driver is using a reflective screen on the car, local privacy laws forbid stopping the car for violating the ban.
Thailand	Yes	Bill proposed in May 2000
Turkey	Yes	
Turkmenistan	Yes	Signed into law with effect from May 1st 2003, by President Saparmyrat Turkmenbasy
UK	Yes	Banned from December 2003
Zimbabwe	Yes	Ban imposed in Sept 2001, announced via official news agency only though, so not confirmed

Table 8: State regulations for cell phone use while driving [48] as of January 2007.

State	Banned	Notes
National	Being debated	Bills being debated in the Federal government that will override local legislation
Alabama	No	
Alaska	No	
Arkansas	Partial	School bus drivers are banned from using a cell phone.
Arizona	Partial	A bill to introduce a ban was lost by a 4-3 vote in the Senate Transportation Committee. Bus drivers are banned from using a cell phone
California	Yes	Bill to introduce ban failed Feb 1998. Beginning Jan. 1, 2008, violators face a US$20 fine for a first offense and a US$50 ticket for subsequent infractions.
Colorado	No	Teens with restricted licenses are banned - but can only be stopped for another violation first
Connecticut	Yes	Banned with effect from Oct. 2005 - teens are also forbidden from using hands free kits while moving
Delaware	No	A driver can already be prosecuted for "inattentive driving" - which can include using a cell phone. Studies into the issue have been requested
District of Columbia	Yes	Banned from July 2004
Florida	Partial	State Attorney General said that cities can set local regulations - July 2001. Overturned by Governor Jeb Bush.
Georgia	Partial	School bus drivers banned from using cell phones while driving. DeKalb County has fines when crashes can be attributed to driving while using a cellphone.
Hawaii	Being debated	A bill has been introduced in Hawaii's legislature by Sen. Joseph Souki.
Idaho	No	
Illinois	Partial	School bus drivers are banned from using cell phones. Chicago has passed a bill banning driving while using a phone, fines of US$50 per infraction.
Indiana	No	Ban proposed by State Sen. Rose Antich Carr - Jan 2004
Iowa	Being debated	
Kansas	No	Bill to introduce ban failed in 2000
Kentucky	No	
Louisiana	Being debated	Study into the effects of a ban underway
Maine	Partial	Minors and those on learner driving licenses may not use a cell phone while driving

Table 8: Statewide regulations for cell phone use while driving [48] as of January 2007 (continued).

State	Banned	Notes
Maryland	No	Bill to ban dropped Feb. 2001. New proposal in the House, proposed by Delegates Arnick and Mandel
Massachusetts	Partial	Bill for most users pending - but use by bus drivers already banned. Drivers required to keep at least one hand on the steering wheel while holding a phone.
Michigan	No	
Minnesota	Partial	Teenagers and provisional drivers are banned - $100 fine plus delays in license upgrades for offenders
Mississippi	No	Legislation prevents local councils enacting their own ban.
Missouri	No	
Montana	No	
Nebraska	No	Bill planned by State Sen. Jim Cudaback - Jan 2004.
Nevada	No	State bill to introduce ban failed April 1999. Local bill in Clark County also blocked Nov. 2001. Nevada state passed bill banning local regulations, March 2003.
New Hampshire	Partial	Not explicitly banned, but you can be prosecuted if using a cellphone when involved in a driving accident.
New Jersey	Yes	Banned as of July 2004 - the fine is up to US$250
New Mexico	Partial	Being debated - local ban in the city of Santa Fe
New York	Yes	Ban effective from Nov. 2001
North Carolina	Being debated	Study into the effects of cell phone usage while driving being carried out.
North Dakota	Being debated	Bill proposed by Sen. Harvey Tallackson, D-Grafton, Feb 2005
Ohio	Partial	The City of Cleveland is discussing a ban. Ban in place in Brooklyn.
Oklahoma	No	Bill to introduce ban failed in May 1999. Legislation prevents local councils enacting their own ban.
Oregon	No	A new bill enacted in Jan 2002 forbids the local governments from implementing their own cell phone ban.
Pennsylvania	Partial	Local cities have their own laws - state legislation pending
Rhode Island	No	Governor Almond rejected a ban - July 2001. School buses are banned from using a cell phone. Proposal for a ban being debated, April 2004.
South Carolina	No	

Table 8 Statewide regulations for cell phone use while driving [48] as of January 2007 (continued).

State	Banned	Notes
South Dakota	No	
Tennessee	Partial	School bus drivers are banned from using a cell phone
Texas	No	Senate Bill 154 proposed. If passed would come into effect from 2008. A previous attempt in 2005 failed
Utah	No	Bill to introduce ban failed March 1998. Highland city planning a ban - Feb 2005
Vermont	No	
Virginia	Partial	Bill failed in Dec. 1998 - but it only applied to school bus drivers. Passed a bill in Aug. 2001 to look for any impact on safety by the use of a cell phone while driving. Bill banning use of cell phones by minors while driving passed Jan 2005.
Washington	No	Bill to introduce ban failed Jan 2001. New laws proposed Q1 2005
West Virginia	No	Bill proposed in 1999, but never debated
Wisconsin	No	Bill to introduce ban failed in April 1998. Bill to ban younger drivers only being debated.
Wyoming	No	Bill proposed by Rep. Floyd Esquibel but not debated

5.4 Graduated Driver Licensing

An important and often-used technique for crash prevention is graduated driver licensing (GDL). GDL was introduced primarily to reduce teenage driving crashes. Teen drivers crash more often mainly because of their inexperience, risk taking behavior, immaturity, and greater risk exposure. GDL is a system designed to delay full driving privileges to inexperienced younger drivers while they obtain their initial experience under lower risk conditions [49]. It was introduced in the United States in 1996-98 as a means to reduce crashes by teenagers [50]. Teenagers are involved in fatal crashes at three times the rate of all drivers [51]. GDL for teenagers typically has three stages: a supervised learner's permit for a limited period, an intermediate license awarded upon passing the driving test that limits unsupervised driving in high risk situations, and a full privilege driver's license available after completion of first two stages [49]. Only 6 out of 42 states (Arizona, Arkansas, Kansas, Kentucky, Minnesota, and North Dakota) lack the intermediate licensing stage [49]. Currently all US states have a driver licensing system but each state has its own modifications of this process that have been implemented.

The Insurance Institute for Highway Safety (IIHS) has prepared a table listing driver education program and licensing requirements in the United States. The Institute has evaluated state licensing system using criteria designed to estimate their strength and effectiveness in reducing injuries [49]. It uses a point assignment system for key components of Graduated Licensing as follows [49]:

- Learner's entry age: 1 point for learner's entry age of 16

- Learner's holding period: 2 points for ≥6 months; 1 point for 3-5 months; none for <3 months
- Practice driving certification: 1 point for ≥30 hr.; none for less than 30 hr.
- Night driving restriction: 2 points for 9 or 10 p.m. 1 point for after 10 p.m.
- Passenger restriction: 2 points for ≤1 underage passenger; 1 for 2 passengers; 1 for 3; where supervising driver may be <21, point values were determined including the supervising driver as a passenger.
- Driver education: Where completion of driver education changed a requirement, point values were determined for the driver education track.
- Duration of restrictions: 1 point if difference between minimum unrestricted license age and minimum intermediate license age is 12 or more months; night driving and passenger restrictions were valued independently.

Based on the points generated using these components, each state Licensing system were given the rating of Good, Fair, Marginal, and poor[49].

- Good : ≥6 points
- Fair : 4-5 points
- Marginal: 2-3 points. If in any state, intermediate license holders could be younger than 16 or if the state allowed unrestricted driving before 16½ it was rated "marginal" regardless of total points.
- Poor : <2 points

Based on this point assignment system for the 50 states plus the District of Columbia: 43% of states (22 in number) were rated "Good", 31.4% (16 states) were rated "Fair", and 23.5% (12 states) were rated as having a "Marginal" driver licensing system. Only Arizona (2%) was rated "Poor". A pie chart showing these percentages is shown in the Figure 6 below. Figure 7 illustrates the evaluation of each state based on this point assessment. Most of the states on the east and west coasts have a good GDL system where as the north-central states have marginal GDL systems. Ohio's system was rated "Fair".

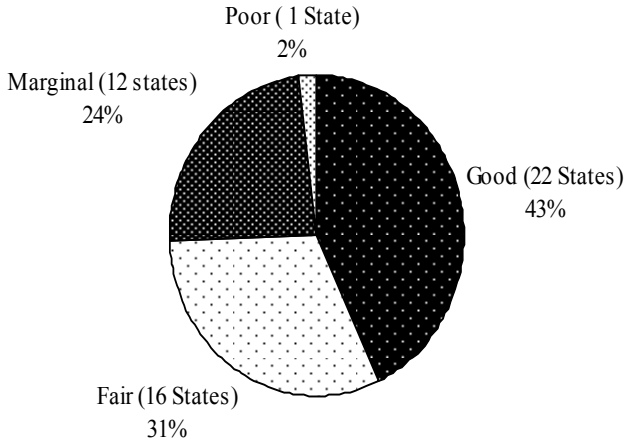


Figure 6: Pie chart for Evaluation of Graduated licensing system in the United States (Compiled from [49]).

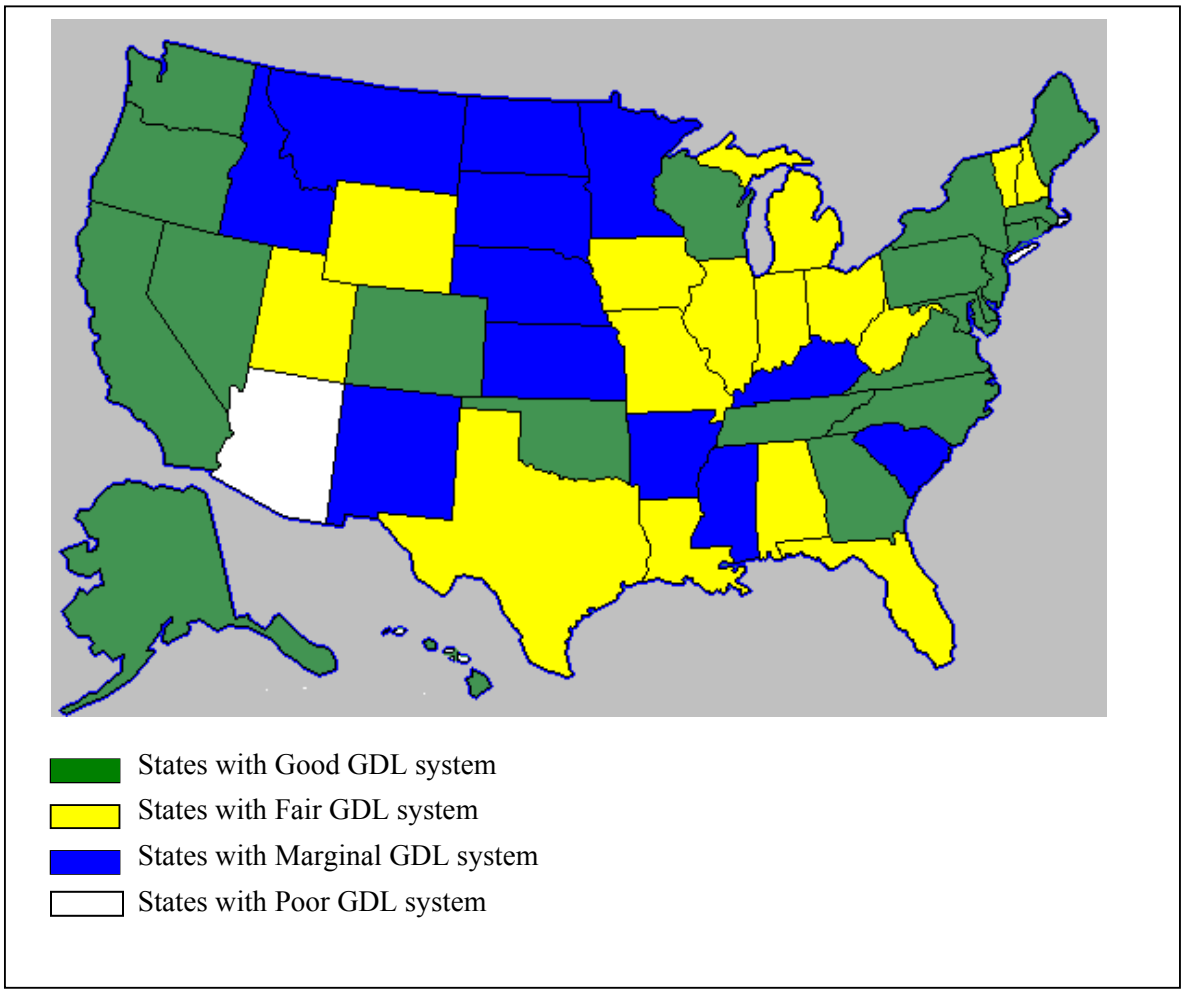


Figure 7: Map of USA showing the evaluation of the states' graduated licensing systems [49].

Patricia F. Waller proposed a graduated licensing system based on learning principles [52] which included a system based on initial experience under low risk conditions, extended supervised practice, gradual move to more complex conditions, and harsher penalties for deliberate risk-taking such as speeding, driving after drinking, and driving without safety belts. Figure 8 illustrates the proposed program in GDL system with the added requirement of parental certification of a specific amount of supervised practice along with the BAC requirement [52].

		Driver Age						
Time	Restriction	14	15	16	17	18	19-20	21-25
Day	Parent required	0.00 BAC	0.00 BAC					
	No parent required ≤ 1 passenger			0.00 BAC				
	No parent required ≥ 0 passengers				0.00 BAC	0.00 BAC	0.00 BAC	≤ 0.05 BAC
Night	Parent required		0.00 BAC	0.00 BAC				
	No parent required ≤ 1 passenger				0.00 BAC			
	No parent required ≥ 0 passengers					0.00 BAC	0.00 BAC	≤ 0.05 BAC

Figure 8: Proposed Graduated License System [52].

This system requires the parental supervision for the age of 14-17 under different conditions such as day/night time driving and number of passengers that can accompany the novice driver.
The major obstacles in acceptance of this plan include the fear of parental objection and unavailability of parent for some young people. Also the administrative costs may be seen as being too high. Other objections which are raised against GDL include such issues as the licensing age and difficulty in enforcement.

Daniel R. Mayhew [53], in his paper "The Learner's Permit" examines and evaluates the safety impact of the time discount in GDL learner stage and driver education. He considers the GDL system in Ontario and Nova Scotia in Canada where learner stages were reduced from 12 to 8 months and 6 to 3 months respectively if drivers successfully completed a driver education program.

In Ontario, The interim evaluation by Boase and Tasca (1998) reported that, the time discount of 4 months did not help in reduction of collisions for novice drivers [53]. The study also reported a 44% higher rate of pre-driver collision for novice drivers with certificates from approved driving schools [53].

The similar study in Nova Scotia by Mayhew et al (2002) [53] reported similar findings for a GDL program which includes time discount of 3 months for completion of a driver education program. It compared the two GDL groups, with and without driver education. Table 9 shows the collision rates for these two groups for their first 2 years of driving broken down into 6 month intervals.

Table 9 : Collision rates (crashes per 10,000 licensed drivers) for pre-GDL drivers and for GDL drivers ages 16–17 with and without driver education [53].

Months licensed	Pre-GDL	GDL with driver education	GDL without driver education	% Difference[a]	*p*
First 6 months	697	718	522	27	.000
7–12 months	454	472	429	9	.280
13–18 months	428	427	366	14	.098
19–24 months	391	324	345	−6	.565
First year	1,151	1,190	951	20	.000
Second year	819	751	711	5	.421

Difference[a] is between GDL group with and without driver education

It is seen from the table that GDL drivers who received the time discount for education have higher crash rates. The difference in crash rates for the two groups was 27% for the first 6 months [53]. The authors concluded from above that "time discount in GDL program provides no safety benefit and it appears to compromise the impact of the program" [53].

5.5 Ohio's Graduated Licensing Law

Table 10 shown below [49] compares Ohio's GDL System with an optimal graduated licensing system. It should be noted that according to the IIHS, no state has an optimal GDL system.

Table 10: Comparison of Licensing System for Young Drivers in Ohio with IIHS Optimal Graduated licensing system [49].

	Learner Stage			Intermediate Stage Restrictions on Driving while Unsupervised			Minimum Age at Which Restrictions May Be Lifted	
Jurisdiction/ Evaluation	Minimum Entry Age	Mandatory Holding Period	Minimum Amount of Supervised Driving	Minimum Age	Unsupervised Driving Prohibited	Restriction on Passengers (family members excepted unless otherwise noted)	Nighttime Restriction	Passenger Restriction
Optimal provisions	16	6 mo.	30–50 hr.	16, 6 mo.	9/10 p.m.–5 a.m.	No more than 1 teenage passenger*	Until age 18	17
Ohio / F	15, 6 mo.	6 mo.	50 hr., 10 of which must be at night	16[32]	1 a.m.–5 a.m. S	None	17[32]	—

Key: G=good, F=fair, M=marginal, P=poor; S=secondary enforcement.

[32] Driver education is required of license applicants younger than 18 in Ohio and Oregon.

Ohio is rated "Fair" under this Licensing System. This system has 50 hours of supervised driving 10 of which must be at night. Ohio's licensing system does not have any restriction on the number of passengers the teenage driver can have. Ohio's licensing system prohibits unsupervised driving from 1 am to 5 am in morning as a secondary enforcement [49]. The state of Ohio has signed a new law (House bill 343) which went into effect on April 6th, 2007 placing certain additional restrictions on probationary license holders and temporary instruction permit holders with age less than 18 years. The changes that were made to the teen driving law are shown on the next page which are given by Ohio Department of Public Safety webpage http://www.bmv.ohio.gov/driver_license/new_gdl_info.htm.

- “Probationary driver license holders under the age of 17 will not be permitted to operate a motor vehicle with more than one person who is not a family member in the vehicle, unless accompanied by the license holder's parent, guardian, or legal custodian. Studies conducted by the Insurance Institute for Highway Safety have shown that one passenger doubles the risk of a crash among teen drivers, two passengers triple the risk, and three or more passengers increase the risk by more than six”.
- “Probationary driver license holders between 17 and 18 years of age will be restricted from driving between the hours of 1 a.m. and 5 a.m. unless the holder is accompanied by a parent or guardian, with the following exceptions: an emergency situation, driving to or from a school activity, or driving to or from work. Travel to or from work is permitted provided the teen has written documentation from the employer”.
- “Probationary license holders under the age of 17 are prohibited from driving between midnight and 6 a.m. unless accompanied by a parent or guardian with the same exceptions as above. This is a change to the previous restriction of 1 a.m. to 5 a.m”.
- “Permit holders under the age of 18 will be prohibited from driving between the hours of midnight and 6 a.m., unless accompanied by a parent, guardian or legal custodian who holds a valid license. This is a change to the previous restriction of 1a.m. to 5 a.m”.
- “If a probationary driver license holder under the age of 17 is convicted of having committed one moving violation during the first six months of having a driver's license, the person must be accompanied by a parent or guardian whenever operating a motor vehicle during the six-month period commencing on the date on which the person is convicted of or pleads guilty to the moving violation or until the person turns 17”.

Now the law restricts the number of passengers to one for drivers younger than 17 years of age. Though the law changed the restricted night time driving hours for probationary and permit holders they still do not comply with the optimal provisions made by Insurance Institute of Highway safety. The optimal provisions given by the IIHS [49] restrict the unsupervised driving hours for probationary and permit instruction license holders from 9/10:00 pm – 5:00 am.

Three states that were early adopters of GDL, Maryland, California, and Oregon, studied the quantitative effect on crashes involving teenaged drivers [24]. These results are summarized in Table 11.

Table 11: Summary of GDL implementation from [24].

State	Year implemented	GDL	Parental Participation	Completion of Driver education	Restricted nighttime Driving	Alcohol emphasis	Crash free/ Conviction free time	Full license Age	Reduction in crashes
Maryland	1979	Modified	✕	✕	✕		6 mo	18 yrs	1983 report – 5% reduction in crashes and 10% reduction in convictions
California	1983	Modified	✕	✕				17 yrs	1987 Report – 5.3% reduction in crashes of drivers aged 15 – 17 yrs
Oregon	1989					✕	✕	18 yrs	1991 Report – 16% reduction in crashes for 16 – 17 yrs males. Not much difference for females.

Available statistics on GDL effectiveness for other states are given below from the study by [54]:

- Ohio – per capita, per license crash reductions for 16 year olds is 11%.
- North Carolina – 27% per capita drop in crashes among 16 year olds, but there is an unpublished study [54] that states that there was a 24% drop in the number of 16 year olds who obtained licenses.
- Michigan – 25% decrease in crashes among 16 year olds, and the number of unsupervised 16 year olds driving reduced from 59.7% to 37.5%.
- Florida – 9% per capita reduction in crashes
- Kentucky – 32% per driver, decrease in crashes among 16 year olds, in the first three years after GDL was introduced.
- Louisiana – did not introduce GDL but extended the period for when the learner's license had to be held before the full license was issued. The number of crashes among 15 year olds decreased by 20% in each of the first two years after the modified drivers licensing program was introduced, but the number of 15 year olds issued licenses also decreased by 35% and 29% respectively.
- Connecticut – also did not introduce GDL but lengthened the time that the learner's permit had to be held before the full license was issued. This decreased the number of crashes among 16 year olds by 22%.

Several foreign jurisdictions have also implemented and evaluated GDL.
New Zealand – implemented GDL in 1987 for drivers between the ages of 15 and 25 years. Emphasized training and testing. Restricted nighttime driving and no passengers allowed unless there is an adult present. Restricted licenses had to be held for 18 months before applying for the full license. This time is cut in half by passing an advanced training course. A report published in 1992 showed an 8% reduction in crashes involving drivers who were 15 – 19 years old [50].

Ontario, Canada – implemented GDL in 1994. Requires 12 month learner's license with restricted nighttime and freeway driving. A licensed driver who has been licensed for at least 4 years must be present in the car. Following the learner's license a provisionary license is also held for a minimum of 12 months with zero alcohol tolerance, which also applies to the learner's license. A report released in 1998 shows a 27% crash reduction in the drivers aged 16 – 19 years in 1995 when compared to 1993, the year before the GDL was implemented [50].

Quebec, Canada – 5% reduction among licensed drivers [51].

One aspect of GDL that has to be considered when looking at all these percentages is that the number of drivers in the eligible population has decreased. People who can drive either get the license before GDL is properly implemented or they wait till the law has been in effect for some time. This is called a transitional effect and this confounds the studies performed to assess the effectiveness of GDL on crash reduction. Therefore all percentages have to be considered with respect to the actual number of people who were issued licenses and not just on the basis of the number of crashes that occurred [54].

5.6 Crash prediction

There are some researchers working on crash prediction techniques. Khoury and Hobeika [55] developed a warning technique that is used in a no-passing zone. This warning system warns the violator about his illegal move and thus deters drivers. The authors also developed an extension to this warning system where the driver in the opposing lane is also warned of the move by the violator. These two techniques were simulated and results were obtained after 71,200 runs. The results show that warning the opposing driver of the illegal passing maneuver reduces crash percentages by an average of 26.3% in the eastbound direction and 33.3% in the westbound direction even if the driver completed the passing maneuver.

The National Institute of Standards and Technology (NIST) is conducting a series of tests that assess the effectiveness of using the lane departure warning systems that are presently installed on commercial trucks and which are now available for cars. These tests will evaluate how good these systems are in warning drivers against unintended lane departures before they occur. NIST will define the performance variables, decide on test-track requirements, specify measurement equipment and techniques, verify system performance, and determine how to present the solutions in a clear manner [56].

5.7 Countermeasures that work: A highway safety countermeasure guide for state highway safety offices

NHTSA report 809-980 "Countermeasures that work: A highway safety countermeasure guide for state highway safety offices" [57] was prepared to assist State Highway Safety Offices (SHSOs) for selecting effective, science-based traffic safety countermeasures to address major problems in highway safety. The guide describes and summarizes the major strategies and countermeasures that can be implemented by SHSOs, their effectiveness, cost, time to implement, and their use in the states. The guide also provides a comprehensive list of references for the research and studies completed on the countermeasures provided.

The guide discusses seven major areas related to highway safety which are:

1. Alcohol impaired driving
2. Safety belts
3. Aggressive driving and speeding
4. Distracted and fatigued driving
5. Motorcycle safety
6. Young drivers
7. Older drivers

All the topics identified are discussed in separate sections with the countermeasures that can be used by the SHSOs for increasing highway safety. Each countermeasure is described briefly in terms of its effectiveness, use, cost, and implementation time; each of these will be discussed shortly. All the countermeasures that were proven or judged likely to increase highway safety were further analyzed and summarized in the report for each major area. According to the guide, the definitions and levels or degrees for effectiveness, use, cost, and implementation time are as follows [57]:

Effectiveness: Effectiveness is measured by the reduction in crashes
Proven: Demonstrated by several high-quality evaluations with consistent results.
Likely: Balance of evidence from high-quality evaluations or other sources.
Uncertain: Limited and perhaps ambiguous evidence.
Unknown: No high-quality evaluation evidence.
Varies: Different methods of implementing this countermeasure produce different results.
It should be noted that the effectiveness is measured in terms of the number of studies that indicate an effect, and not on the actual magnitude of the effect in terms of reduced crashes. Thus a measure that ten studies agree produces a 5% reduction in crashes is more effective than a measure that has been studied once and shown a 50% reduction in crashes.
Use: Usage of the countermeasure in the states.
High: More than two-thirds of the States, or a substantial majority of communities.
Medium: Between one-third and two-thirds of States or communities.
Low: Less than one-third of the States or communities.
Unknown: Data not available
Cost: Cost to implement the countermeasure.

High: Requires extensive new facilities, staff, equipment, or publicity, or makes heavy demands on current resources.
Medium: Requires some additional staff time, equipment, facilities, and/or publicity.
Low: Can be implemented with current staff, perhaps with training; limited costs for equipment, facilities, and publicity.
Time: Time needed to implement a countermeasure.
Long: More than one year.
Medium: More than three months but less than one year.
Short: Three months or less.
It should be noted that these time estimates do not include the time to pass legislation or establish policies.

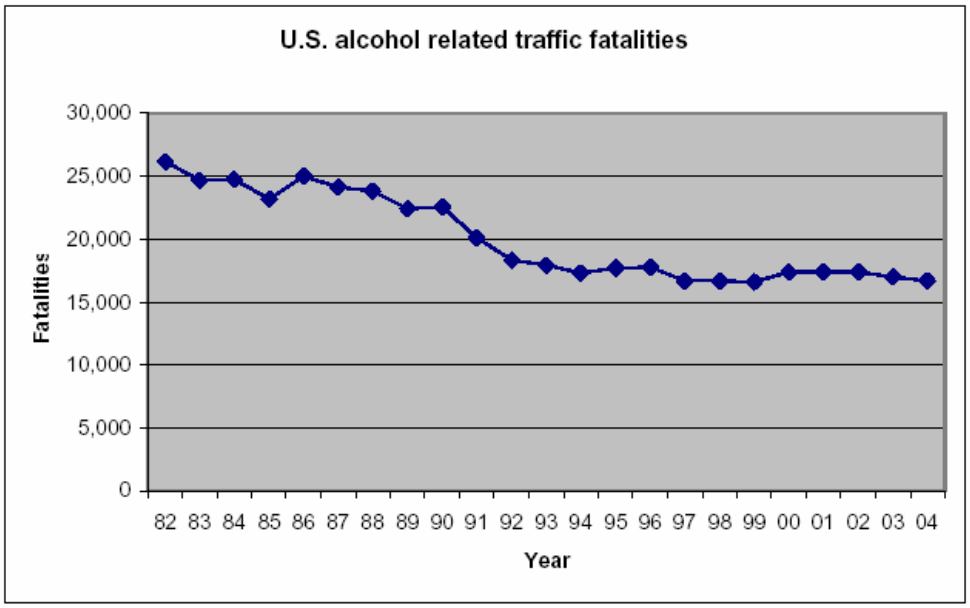
Table 12 gives a summary of the total number of countermeasures listed in the report for each topic and the number of countermeasures that were proven for their effectiveness in increasing highway safety. While using a safety belt is widely recognized as one of the most effective means of reducing the impact of crashes, it should be noted that safety belt usage by itself does not actually reduce crash frequency, which is why safety belt related measures are not discussed in as much detail as other topic areas in the report; safety belt usage was judged to be outside the scope of the project.

Table 12: Summary of the total number of countermeasures and the number of countermeasures that were proven for effectiveness listed in the report [57].

Topic	Number of Countermeasures						
	Total	**Proven**	**Likely**	**%Total[1]**	**Varies**	**Uncertain**	**Unknown**
Alcohol impaired driving	28	13	5	64.3	3	5	2
Aggressive driving and speeding	8	3	1	50.0	1	1	2
Distracted and fatigued driving	7	1	0	14.3	0	1	5
Motorcycle safety	9	1	0	11.1	0	2	6
Young drivers	11	3	2	45.5	1	2	3
Older drivers	8	2	2	50.0	0	2	2
Safety belts *	11	5	3	72.7	0	2	1
* Not considered for analysis as seat belts don't reduce crashes							
%Total[1]: % of total for proven and likely countermeasures							

5.7.1 Alcohol Impaired Driving:

Alcohol impaired drivers were involved in about 25% of all the fatalities in 2003 and 11,921 drivers with a BAC of 0.08% were involved in fatal crashes in 2005. Alcohol impaired driving levels have not changed a lot since 1992 which is shown in Figure 9.



Source: FARS

Figure 9: Graph showing the total number of alcohol related traffic fatalities in US from 1982-2004 [57].

Five strategies to reduce alcohol impaired driving crashes were discussed in the guide:

1. Deterrence.
2. Prevention and intervention.
3. Communications and outreach
4. Alcohol treatment.
5. Other traffic safety measures.

The countermeasures which fall under each strategy are listed below [57] with their effectiveness, use, cost, and time to implement.

1. Deterrent: Laws

Countermeasure	Effectiveness	Use	Cost	Time
1.1 ALR/ALS	Proven	High	High	Medium
1.2 BAC test refusal penalties	Proven-refusals	Unknown	Low	Short
1.3 High-BAC sanctions	Uncertain	Medium	Low	Short
1.4 Open containers	Uncertain	High	Low	Short
1.5 DWI code review	Likely	Low	Medium	Medium

2. Deterrent: Enforcement

Countermeasure	Effectiveness	Use	Cost	Time
2.1 Sobriety checkpoints	Proven	Medium	High	Short
2.2 Saturation patrols	Proven-arrests	High	Medium	Short
2.3 Integrated enforcement	Likely	Unknown	Low	Short
2.4 Preliminary Breath Test Devices	Proven- arrests	High	Medium	Short
2.5 Passive sensors	Proven-arrests	Unknown	Medium	Short

3. Deterrent: Prosecution and adjudication

Countermeasure	Effectiveness	Use	Cost	Time
3.1 Sanctions	Varies	Varies	Varies	Varies
3.2 Diversion, plea agreement restrictions	Proven-convictions	Medium	Low	Short
3.3 DWI courts	Likely	Low	High	Medium
3.4 Court monitoring	Proven-convictions	Unknown	Low	Short

4. Deterrent: DWI offender treatment, monitoring and control

Countermeasure	Effectiveness	Use	Cost	Time
4.1 Alcohol problem assessment, treatment	Proven	High	Varies	Varies
4.2 DWI offender monitoring	Proven-recidivism	Unknown	High	Medium
4.3 Alcohol interlocks	Proven	Medium	Medium	Medium
4.4 Vehicle and license plate sanctions	Varies	Medium	Varies	Medium
4.5 Lower BAC limit for repeat offenders	Uncertain	Low	Low	Short

5. Prevention, intervention, communications and outreach

Countermeasure	Effectiveness	Use	Cost	Time
5.1 Responsible beverage service	Likely	Medium	Medium	Medium
5.2 Alternative transportation	Unknown	Unknown	Medium	Short
5.3 Designated drivers	Unknown	Medium	Low	Short
5.4 Alcohol screening and brief interventions	Proven	Medium	Medium	Short
5.5 Mass-media campaigns	Proven *	High	High	Medium

* High-quality campaigns supporting other program activities, such as enforcement

6. Underage drinking and alcohol related driving measures

Countermeasure	Effectiveness	Use	Cost	Time
6.1 Age 21 enforcement	Varies	Varies	Varies	Varies
6.2 Zero-tolerance enforcement	Likely	Unknown	Medium	Short
6.3 School education programs	Uncertain	Unknown	Low	Long
6.4 Youth programs	Uncertain	High	Varies	Medium

Summary of the proven and likely countermeasures for alcohol impaired driving:

Administrative license revocation or suspension (ALR\ALS):
ALR/ALS allows law enforcement officials to revoke or suspend a driver's license if the driver refuses or fails a BAC test without a trial. ALR\ALS laws provide a swift method for penalties compared to lengthy criminal court proceedings. As of July 2005, 41 states and District of Columbia had some form of ALR\ALS [58] [59][60]. ALR/ALS laws have reduced alcohol-related crashes by an average of 13% as found in a summary of 12 evaluations thorough 1991 [61]. Voas and Tippets have also found that ALR laws in combination with other laws have reduced alcohol-related fatal crashes by about 30% from 1982-1997 [62]. ALR\ALS laws require funds to design, implement, and operate. In addition, a system of administrative hearing officers needs to be established for the laws to be more effective.

BAC test refusal penalties:
A driver's BAC is a positive piece of evidence to support a DWI charge. All states have BAC laws which make it illegal for the driver to drive with a BAC level higher than that specified. Many drivers stopped by law enforcement now refuse to submit to a BAC test.

Over all states, 18% of stopped drivers refused BAC tests, and in one quarter of the states more than 32 % of the drivers refused BAC tests [63]. All states have laws to penalize the driver for a BAC test refusal, but if the penalties for test refusal are less severe than those for failing a test, most drivers will refuse to submit to a test [64]. Zwicker et.al [63] found that the test refusal rates are lower in the states which have greater penalties for test refusal than for test failure. Though BAC test refusal penalties may not directly reduce crashes, they may help the effective implementation of other laws such as ALR/ALS or otherwise improve the DWI control system which will ultimately reduce crashes. Appropriate legislation is needed for implementing such measures where needed.

Alcohol impaired driving law review:
DWI laws have evolved in the past 30 years and the laws have become more complex because of ever-changing technology, societal changes, and evolving driving behavior. One result of state autonomy in drunk driving laws is an inconsistent DWI control system across the nation. Therefore a thorough law review is needed to identify irregularities in the current system and help establish a more uniform DWI control system. Many law enforcement officers, prosecutors, and judges have expressed opinions that the existing laws need to be simplified and streamlined to enhance their effectiveness [65].

Sobriety checkpoints:
A sobriety checkpoint is a predetermined location where law enforcement officers stop vehicles and check whether the driver is impaired. The purpose of these checkpoints is to stop driving after drinking by increasing the risk of arrest. In the US 37 states and The District of Columbia conducted checkpoints at least once in a year in 2000; only 11 states conducted them on weekly basis according to Fell et al. [66]. A systematic review of eleven studies revealed that sobriety checkpoints reduced alcohol-related fatal, injury, and property damage crashes each by 20% [67]. The cost of operating these checkpoints is usually high because they have to be publicized extensively and conducted regularly. They also require a commitment of several law enforcement officers to one site for several hours. Also some drivers worried about their level of impairment may choose alternate, and frequently riskier, routes to circumvent a widely publicized checkpoint.

Saturation patrols:
A saturation patrol consists of a large number of law enforcement officers patrolling a specific area in a specific time to detect and arrest alcohol impaired drivers. Such patrols are in use in 44 states [68]. Though the effects of saturation patrols on reducing crashes have not been evaluated they are quite effective in arresting impaired drivers [68].

Integrated enforcement:
Integrated enforcement involves integrating impaired driving enforcement into other enforcement activities which are directed primarily at speeding, seat belt use, or other violations [57]. A three site evaluation of integrated impaired driving, speed, and safety belt use was performed by Jones et al. [69] and they found that there was a reduction of alcohol related crashes by 10-35% combined with high publicity for the enforcement activities. Integrated enforcement methods used by Massachusetts, the “Saving Lives Comprehensive Program”, reduced alcohol-related fatal crashes by 42% [70].

Preliminary breath test devices (PBTs):
A preliminary breath tester is a small handheld alcohol sensor which can be used by a law enforcement officer to establish evidence for a DWI arrest. These instruments are quite accurate and reliable. The NHTSA has a conforming products list of alcohol testing and screening instruments that includes PBTs [71]. PBTs are used in 39 states as an evidence for a DWI arrest and the use of PBTs to establish evidence for DWI arrest is accepted in only half of the states [68]. PBTs are used in California to enforce zero-tolerance laws [72]. The effect of PBTs in reducing crashes is not known but 69% of the law enforcement officers surveyed by [73] supported PBT use.

Passive alcohol sensors (PAS):
A passive alcohol sensor is a device used to detect alcohol presence in the air which is generally integrated into a flashlight or clipboard [57]. PAS are proved to be more effective at checkpoints where the officers have to screen drivers very quickly. Several evaluations have shown that officers having PAS can detect twice as many drivers with high BAC than the officers not using a PAS [66][68]. PASs appear to be a tool in improving alcohol impaired driving enforcement, but no data is available on their use [57].

Diversion and plea agreement restrictions:
Diversion programs defer sentencing while a DWI offender participates in some form of alcohol education or treatment [57], while plea agreements are a part of efficient DWI prosecution and adjudication. A Century Council survey [74] reported that 16 states provide for diversion programs, and the NTSB [75] reported that 16 states restrict plea agreements in at least some DWI cases. There is no evidence that diversion programs reduce recidivism [76] but there is substantial evidence that removing the offense from the offender's record as a part of diversion program makes it difficult to identify repeating offenders [77] which is considered as a major loophole in the DWI control system. It was found in a study completed in 1991 that plea agreement restrictions reduced recidivism in all three study communities [57].

DWI courts:
A specialized DWI court provides a systematic and coordinated approach for prosecuting, sentencing, monitoring, and treating DWI offenders. A DWI court's underlying goal is to change offenders' behaviors by treating their alcohol problems and holding them accountable for their actions [57]. As of June 2005, there were 90 stand-alone DWI courts and 86 hybrid DWI/drug courts [77]. An evaluation of DWI courts on reducing recidivism was in progress as of summer 2005 [57]. DWI courts can be effective in reducing recidivism because judges, prosecutors, probation staff there are more familiar with DWI laws, issues, and sentencing options [57].

Court monitoring:
In this program, citizens observe, track, and report on DWI court or administrative hearing activities. These programs are generally funded and operated by citizen organizations such as Mothers Against Drunk Driving (MADD) [57]. The number of

court monitoring programs currently active is not available but there were over 300 programs in mid-1980s [78]. Monitored cases were found to produce higher conviction rates, stiffer sentences, and increased guilty pleas compared to unmonitored cases [78] [79].

Alcohol problem assessment and treatment:
Alcohol problem assessment varies from a brief paper and pencil questionnaire to a detailed interview with a treatment professional [57]. The treatment can vary from classroom education program to long term in-patient facilities. 41 states require alcohol assessment for some or all first offenders according to [57]. Most of the assessment instruments currently in use were not able to identify more than 70% of the offenders who were likely to repeat their offenses [80]. It was found that on average treatment reduced DWI recidivism and alcohol-related crashes by 7-9% [81].

Alcohol screening and brief interventions:
Brief interventions refer to short, one time encounters with people who are at risk of alcohol-related problems or injuries [57]. Alcohol screening is quick form of estimating alcohol-related problems in a person [57]. The combination of these methods is generally used with injured patients in emergency departments and trauma centers. It was found that alcohol screening and brief interventions in medical facilities reduced drinking, self-reported driving after drinking and alcohol-related crashes [85] [86][87].

DWI offender monitoring:
Monitoring offenders closely is one of the more successful methods for controlling DWI offenders and reduce recidivism [57]. Various methods like formal intensive supervision, home confinement with electronic monitoring, dedicated detention facilities, and individual oversight by judges are used for close offender monitoring. All the programs listed have proved to be effective in reducing DWI recidivism [57].

Alcohol interlocks:
An alcohol ignition interlock prevents a car from starting unless the driver provides a breath sample with a BAC level lower than the preset level. Interlocks are used as a condition for probation for DWI offenders [57]. 44 states allowed interlocks to be required for some DWI offenders [82]. Interlocks cut recidivism rates by half [83] or more but the effects largely were found to disappear after the interlocks were removed.

Responsible beverage service:
This covers a range of alcohol sales policies that prevent or discourage restaurant or bar patrons from drinking excess alcohol or driving while impaired [57]. As of 2005, 13 states had some kind of mandatory server training programs [84]. Evaluation of a state-wide server training program in Oregon showed a reduction of single vehicle nighttime injury crashes by 23% [69]. A state-wide server training program would require time for legislation, policy establishment, and proper administration.

Mass media campaigns:
A mass media campaign consists of intensive communications and outreach activities regarding alcohol-impaired driving using radio, television, print and other mass media [57]. Most states use or have used some sort of mass media campaign to reduce alcohol-related crashes. Most of these mass media campaigns have not been evaluated but mass media campaigns which were extensively funded, well designed, and executed in coordination with increased enforcement activities reduced crashes by 13% [88]. The disadvantage of using mass media campaigns is that they are extremely expensive and each takes at least six months of time to research, plan, produce, and distribute.

Zero tolerance laws:
Zero tolerance laws set a maximum BAC of 0.02% or lower for drivers under age 21 and violators have their license revoked or suspended. These laws have been in effect in all states since 1998 [57]. There was a drop of 21% in alcohol-related crashes in six months after zero tolerance law was introduced in six counties in Maryland and it further dropped by an additional 30% when the law was publicized more[69].

5.7.2 Aggressive driving and speeding

Aggressive driving can be understood as driving actions that are not considered norms of safe driving behavior which may pose some risk to other road users. Speeding is defined as exceeding the legal speed limit and is dangerous because half of the speed-related traffic fatalities occurred in 2003 due to the speeding on the roads with posted speed limit of 50 mph (80.4 kmph) or less and one quarter occurred on roads posted at 35 mph (56.3 kmph). The countermeasures to reduce crashes due to aggressive driving and speeding are listed below [57]:

1. Laws

Countermeasure	Effectiveness	Use	Cost	Time
1.1 Speed limits	Proven*	High	Low	Short
1.2 Aggressive driving laws	Unknown	Low	Low	Short

* When enforced and obeyed

2. Enforcement

Countermeasure	Effectiveness	Use	Cost	Time
2.1 High-visibility enforcement	Uncertain	Low	High	Medium
2.2 Automated enforcement	Proven	Medium	High*	Medium
2.3 Other enforcement methods	Varies	Unknown	Varies	Varies

*Can be covered by income from citations

3. Penalties and Adjudication

Countermeasure	Effectiveness	Use	Cost	Time
3.1 Penalty types and levels	Proven	High	Varies	Low
3.2 Diversion and plea agreements	Unknown	Unknown	Varies	Varies

4. Communications and Outreach

Countermeasure	Effectiveness	Use	Cost	Time
4.1 Supporting enforcement	Likely	Medium	Varies	Medium

Summary of the proven or likely countermeasures for aggressive driving and speeding:

Speed limits:
Without public acceptance and enforcement speed limits have minimal effect on highway safety. Speed limit policies are set by state, municipal, or federal law based on tradeoffs between safety, travel efficiency, and community concerns [57]. The effects of speed limits have been extensively studied over the past 30 years. The national maximum speed limit of 55 mph (88 km/h) enacted in 1974 to conserve fuel also saved more than 9100 lives from 1973 through 1987, when Congress allowed states to raise their speed limits on interstates as fuel became abundant. The resulting increased speed limits were followed by increases in traffic fatalities [57]. Lower speed limits were found to reduce the crashes only when the speed limits were obeyed by the drivers [57].

Automated enforcement:
Automated enforcement is used to reduce red light running and speeding. Red light cameras were first employed in the United States in 1993 [89]. As of July 2004, more than 100 communities in 17 states and District of Columbia were using red light cameras [90]. Though red light cameras increase rear end crashes, they reduced the side impact crashes, and the overall rate of injury crashes is reduced by 25% [91] [92][93]. A review of automated enforcement activities in 24 British jurisdictions over three years indicated personal injury crashes were reduced by 33% [94]. Though automated enforcement was found effective in reducing crashes they require a substantial investment to purchase, install and operate. This investment may be recouped through the increased number of violation tickets given out.

Penalty types and levels:
Penalty types and levels are a part of each state's driver control system for speeding and various other traffic offenses. Penalties are generally lower for first offense and they increase for the consecutive offenses. Most of the states also use a demerit point system to provide drivers an incentive to avoid committing traffic violations repeatedly; accumulation of sufficient points against a driver's license will result in a suspension or revocation of the license. License suspension or revocation was the most effective penalty by far. A traffic violation resulting in an injury or death is may carry criminal charges and more severe sanctions [57]. Masten and Peck [95] reviewed the effectiveness of 106 individual actions and penalties from 35 studies and found that all actions together reduced subsequent crashes by 6% and violations by 8%.

Communications and outreach supporting enforcement:
Effective communications and outreach programs can be used to support speed and aggressive driving enforcement [57]. Unless these programs are tied to vigorous enforcement, they generally do not have any effect on reducing speeding or aggressive driving. No studies have been done to evaluate the effectiveness of these programs but it is worthwhile to try to use communication and outreach programs as seen in the success of paid advertising in safety belt use campaign [57].

5.7.3 Distracted and fatigued driving

Distracted and fatigued driving are both common but difficult to define and quantify. Distraction takes the driver attention away from driving and it may be caused by the driver's lifestyle, behavior patterns, or a medical condition. The use of rumble strips has been proven to be an effective engineering measure to reduce crashes due to distracted and fatigued driving. Various countermeasures to reduce distracted and fatigues driving are listed below [57]:

1. Laws and enforcement

Countermeasure	Effectiveness	Use	Cost	Time
1.1 Cell phone laws	Uncertain	Low	Varies	Short
1.2 GDL requirements for beginning drivers	Proven	High	Low	Medium
1.3 General fatigue and distraction laws	Unknown	High*	Varies	Short

*Included under reckless driving; use of explicit fatigue and distraction laws is low

2. Communications and outreach

Countermeasure	Effectiveness	Use	Cost	Time
2.1 Fatigued or drowsy driving	Unknown	Unknown	Medium	Medium
2.2 Distracted driving	Unknown	Unknown	Medium	Medium

3. Other countermeasures

Countermeasure	Effectiveness	Use	Cost	Time
3.1 Employer programs	Unknown	Unknown	Low	Short
3.2 Medical conditions and medications	Unknown	Unknown	Variable	Medium

Summary of the proven or likely countermeasures for distracted and fatigued driving

GDL requirements for beginning drivers

Graduated driver licensing (GDL), as discussed earlier, is a three-phase system consisting of learners permit, provisional license, and a full license. A learner's permit allows the new drivers to drive under supervision for a specified period of time under low-risk situations. Upon completing a driving test the learner then obtains a provisional license with some restrictions on unsupervised driving. The driver gets a full license after he drives with a provisional license for a period of time defined by each state's GDL laws. As of August 2004, 47 states and District of Columbia had some form of GDL in place.

Cell phone usage laws

As cell phones are considered as a source of distraction for drivers [57], three states have laws restricting cell phone usage while driving, and five states prohibit cell phone usage by drivers in the learner's permit and provisional license stages of their GDL programs [57].

5.7.4 Motorcycle safety

A two- wheeled motorcycle is difficult to operate and is less stable than a four wheeled vehicle. Motorcyclists have little protection during a crash; 80% of motorcycle crashes injure or kill a driver according to NHTSA and motorcyclists are much more likely to be

injured or killed in a crash than drivers of four-wheeled vehicles. Figure 10 shows the motorcycle rider fatality rates per million VMT (vehicle miles traveled) which has been increasing since 1997.

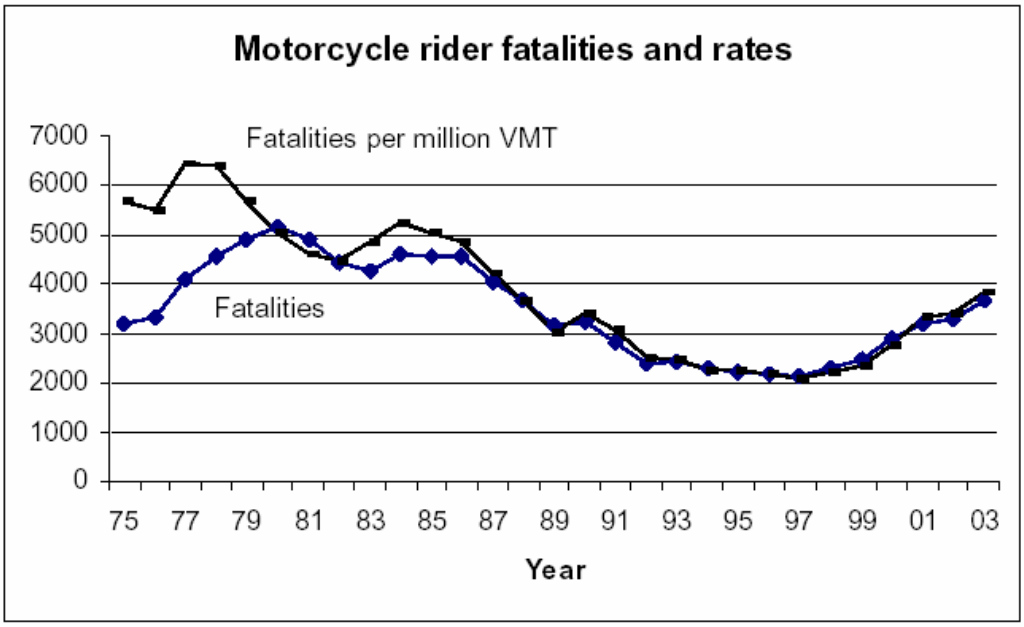


Figure 10: Graph showing motorcycle rider fatalities and rates from 1975-2003 [57].

The most important strategies to improve motorcycle safety are to increase helmet use, increase proper licensing and training and reduce alcohol impairment. The countermeasures used to increase motorcycle safety are listed in the tables [57] below:

1. Motorcycle operator licensing and training

Countermeasure	Effectiveness	Use	Cost	Time
1.1 Operator education and training	Uncertain	High	Medium	Medium
1.2 Operator licensing	Uncertain	High	Low	Medium

2. Motorcycle helmets

Countermeasure	Effectiveness	Use	Cost	Time
2.1 State motorcycle helmet use laws	Proven	Medium	Low	Short
2.2 Helmet law enforcement; noncompliant helmets	Unknown	Unknown	Low	Medium
2.3 Helmet use promotion programs	Unknown	Low	Varies	Medium

3. Alcohol impairment

Countermeasure	Effectiveness	Use	Cost	Time
3.1 Alcohol impairment: detection, sanction	Unknown	Unknown	Varies	Varies
3.2 Alcohol impairment: communications	Unknown	Unknown	Medium	Medium

4. Communications and outreach

Countermeasure	Effectiveness	Use	Cost	Time
4.1 Protective and conspicuous clothing	Unknown	Unknown	Varies	Medium
4.2 Other driver awareness of motorcyclists	Unknown	Unknown	Varies	Medium

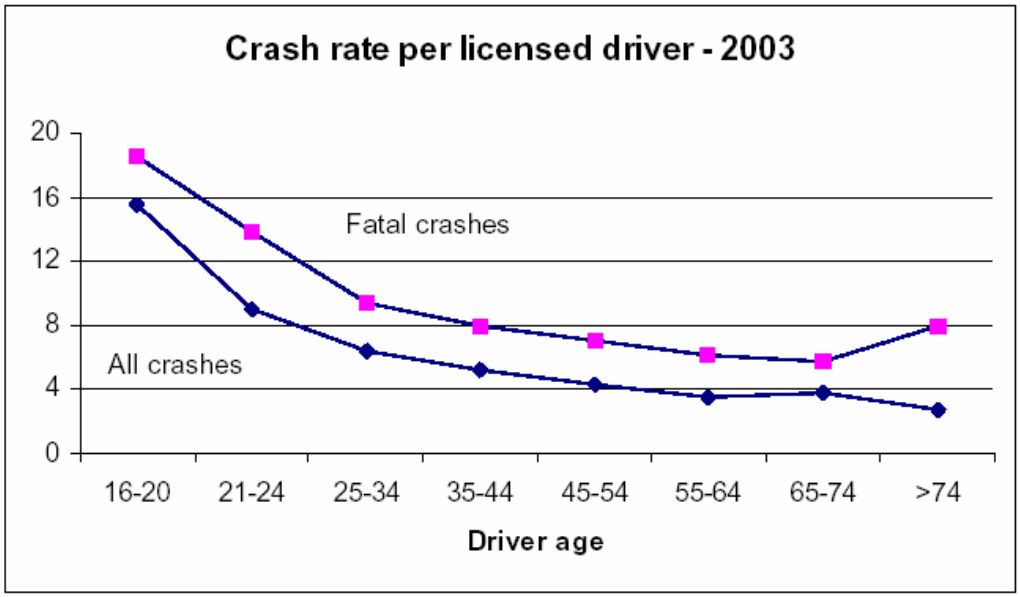
Summary of the proven or likely countermeasures regarding motorcyclists

State motorcycle helmet use laws

Motorcycle helmets are highly effective in protecting a motorcycle rider's head in crashes. Data from 1993-2003 showed that helmets reduced motorcycle fatalities by 37% [96] and brain injuries by 67% [97]. Many state laws were effective in increasing the helmet use by riders. With the introduction of a universal helmet law in 1975 in most of states, helmet usage increased to 90% [57]. The General accounting office (GAO) review of 46 studies related to helmet use published before 1990 concluded that fatalities were lowered by 20-40% after the universal helmet law was in place [98]. As of July 2005, 20 states and District of Columbia had helmet law covering all riders and other states had a law covering only riders under some specified age [99].

5.7.5 Young drivers

Young drivers under 21 are over-involved in crashes which can be seen from Figure 11. In 2003, drivers under 21 were 6.4 percent of all licensed drivers in the United States, 13.8 percent of drivers in fatal crashes, and 17.6 percent of drivers in all crashes.



Fatal: crashes per 30,000 drivers (FARS)
All: crashes per 100 drivers (GES)

Figure 11: Crash rates for drivers age ranging from 16-74 for the year 2003 for fatal (crashes per 30,000) and total crashes (crashes per 100) [57].

Young drivers have high crash rates because they are inexperienced in driving and lack experience to identify high risk situation during driving. Graduated driver licensing (GDL)

was introduced to help young drivers to get enough experience driving before they are issued a permanent license. Parents play an important role in teaching their children how to drive responsibly but their effectiveness has not been proven yet and may vary considerably given the type of behavior modeled or endorsed by particular parents. The different countermeasures to reduce the crashes involving young drivers are listed below [57]:

1. Graduated driver licensing

Countermeasure	Effectiveness	Use	Cost	Time
1.1 Graduated driver licensing (GDL)	Proven	High	Medium	Long
1.2 Learner's permit length, supervised hours	Proven	High	Low	Medium
1.3 Provisional - nighttime restrictions	Proven	High	Low	Medium
1.4 Provisional - passenger restrictions	Likely	Medium	Low	Medium
1.5 Provisional - belt use requirements	Uncertain	Unknown	Low	Medium
1.6 Provisional - cell phone restrictions	Unknown	Low	Low	Medium
1.7 Provisional - violation penalties	Uncertain	High	Low	Medium

2. Driver education

Countermeasure	Effectiveness	Use	Cost	Time
2.1 Prelicensure driver education	None	Unknown	High	Long
2.2 Postlicensure or advanced driver education	Unknown	Low	High	Long

3. Parents

Countermeasure	Effectiveness	Use	Cost	Time
3.1 Parent roles in teaching and managing	Varies	Medium	Low	Short

4. Traffic law enforcement

Countermeasure	Effectiveness	Use	Cost	Time
4.1 Enforcement of GDL and zero-tolerance laws	Likely	Unknown	Medium	Short

Summary of the proven or likely countermeasures for young drivers:

Graduated driver licensing

As discussed in the distracted and fatigued driving section, GDL serves to reduce risk and avoid dangerous driving situations. The effectiveness of GDL in reducing crashes has been discussed in the earlier sections of the report in detail.

Learners permit length and supervised driving times

This is part of the GDL program adopted by most states. As of August 2004, 37 states required learner's permit to be held for six months and another 9 had holding periods of 10 days to 5 months [57]. Some minimum number of supervised driving hours was required for the drivers in the permit stage: 15 states required at least 50 hours: 8 required 40 hours: 6 required 30 to 36 hours and 7 required 12 to 15 hours [100]. The crash rates in this stage are low as they are supervised by a driver with enough experience [57]. An increase in learner's permit length would help in making more safe drivers [57].

GDL provisional license passenger restrictions
Passengers increase the crash risk among teenage drivers, and to reduce it most of the states have passenger restrictions for provisional drivers. In contrast crash risk is decreased for drivers 30 to 59 years old who have passengers [101]. As of August 2004, 27 states had passenger restrictions for drivers with a provisional license, some applied to all passengers and some to passengers less than specified age [100]. A study in California revealed that most of the 16 year old drivers who were at fault in crashes were carrying teenage passengers and most of the times passenger restrictions are effective in reducing the number of passengers [102].

GDL provisional license nighttime restrictions
Driving at night increases the crash risk and it the risk is magnified for inexperienced teenage drivers [103] [104]. The restricted driving hours vary widely, and range from 6 PM to 6 AM in the most restrictive states to 1 AM to 5 AM in the least restrictive states [98]. An earlier starting time for driving restrictions will reduce more crashes as proposed by NCUTLO model law [105] as teenage drivers are more likely to be involved in crashes before midnight than after [106] [107].

5.7.6 Old drivers

With increase in a driver's age, his or her physical and mental abilities decline, driving behaviors change, and crash risk change. Age alone does not determine driving performance, but rather the physical health of the driver is key. Older drivers are also at increased risk because the current system of roads, laws, traffic rules etc were not designed to accommodate older drivers [57]. Of all the issues discussed so far in this guide, the older driver problem is the most complex as it involves issues beyond traffic safety. Countermeasures to reduce crashes due to older drivers are listed below in the table [57]:

1. Communications and outreach

Countermeasure	Effectiveness	Use	Cost	Time
1.1 Formal courses for older drivers	Uncertain	Low	Low	Short
1.2 General communications and education	Uncertain	Unknown	Low	Short

2. Licensing

Countermeasure	Effectiveness	Use	Cost	Time
2.1 License renewal policies	Unknown	Medium	High	Medium
2.2 Referring older drivers to DMVs	Proven	Low	Medium	Medium
2.3 License screening and testing	Proven	High	Medium	Medium
2.4 Medical advisory boards	Unknown	High	Varies	Medium
2.5 License restrictions	Likely	Unknown	Low	Short

3. Traffic law enforcement

Countermeasure	Effectiveness	Use	Cost	Time
3.1 Law enforcement responsibilities	Likely	Medium	Varies	Varies

Summary of the proven or likely countermeasures for older drivers:

Referring older drivers to licensing agencies:
More attention can be given to older drivers at the time of license renewal by licensing agencies [57]. Licensing agencies also accept reevaluation referrals for drivers of all ages. A survey of state licensing agencies found that 85% of the referrals came from three sources: 37% from law enforcement, 35% from physicians, 13% from family or friends, and 15% from crash or violation records, court orders etc [108]. A survey of the state licensing agencies found that nationally fewer than 100,000 (0.4%) drivers 65 and older are referred to each year [108]. The direct effect of these referrals in reducing the crashes has not yet been established.

License screening and testing
License screening and testing procedures vary considerably from state to state [57]. Many state guidelines are outdated, incomplete, not based on actual functional impairment, and do not take into account recommendations based on medical condition [57]. All states test drivers referred to them, but no state had adopted the *Model Driver Guidelines* [57] which has a complete list of driver screening, assessment, counseling, and licensing procedures. These programs are quite effective in identifying drivers who shouldn't drive or whose driving should be limited [57].

License restrictions
A driver can be issued a restricted license if a state licensing agency determines thorough screening, assessment, or medical referral that the driver poses a risk in certain situations [57]. Iowa and Utah have issued restricted licenses to older drivers. Most of the states surveyed opined that license restrictions are feasible but they would require legislative changes before their objective can be fully achieved. Studies have shown that license restrictions lower crash risk for these drivers [109].

Law enforcement responsibilities
Law enforcement plays three roles in improving the safety of older drivers by enforcing the traffic laws, by identifying drivers with impairment and referring them to licensing agencies, and by providing education to older drivers [57]. Law enforcement officers have partnered with many public and private organizations to teach safe driving courses and educate older drivers. Older driver programs are active in 28 states according to NHTSA [109].

Table 13 gives a summary of the all the crash reductions found for the countermeasures which were proven or likely for their effectiveness. It has to be noted that only 23 out of 71 countermeasures listed in [57] excluding seat belt countermeasures were proven for their effectiveness and the guide states that "Many countermeasures have not been evaluated well, or at all" [57] which means that further analysis is needed if any state wants to adopt any of the countermeasures.

Table 13: Summary of the crash reductions found from the proven\ likely effective countermeasures [57].

No	Countermeasure	Crash reductions found
1	Administrative license revocation or suspension [61][62]*	13%, 30%
2	Sobriety checkpoints [67]	20%
3	Integrated enforcement [69] [70]	10-35%, 42%
4	Alcohol problem assessment and treatment [81]	7-9%
5	Responsible beverage service [69]	23%
6	Mass media campaigns [88]	13%
7	Zero tolerance laws [69]	21%
8	Automated enforcement [91] [92,93,94]	25%, 32%
9	Penalty types and levels [95]	6%
10	State motorcycle helmet use laws [98]	20-40%
	* Reference numbers in the report	

6 Electronic survey and meetings with traffic safety experts:

Initially e-mail addresses were searched and e-mails were sent to various officials and agencies in all the 50 states of the United States and to offices in different Canadian provinces to obtain contacts who could provide information related to the existing practices in driver education, driver licensing, and traffic law enforcement in their respective jurisdictions. An initial response rate of approximately 28% obtained contacts for 20 states and 1 Canadian province. A final list of contacts was prepared from the responses obtained and these contact people were emailed and telephoned to ask about quantitative measures of crash reduction rates observed in their state/province as a result of implementing new innovative policies in driver education, driver licensing, and traffic law enforcement. All these contacts were contacted repeatedly by e-mail to get more information on driver education, driver licensing and enforcement programs. Very few replies were obtained about their ongoing projects and research innovations. Officials in the states of Missouri, Maine and Florida sent some of their reports on research already conducted and some crash data for different age groups. The information obtained directly from the contacts is summarized below:

- **Maine:** Bradford Foley, Director of Safety Office of the Maine Department of Transportation, stated that their various strategies for reducing fatalities and crashes fell into four major categories: seat belts and other passenger restraints, lane departures, younger and older driver programs, and aggressive driving. He also sent us a copy of "The status of transportation safety in Maine" which contains statistical crash data based on common causes of crashes.
- **Oregon:** Bill Merrill, Manager of the Driver Control Unit of Oregon Driver and Motor Vehicle Services in Salem stated that neither of their programs focused on specific education efforts. For example, in their driver improvement program, should an adult driver get four convictions within 24 months, their driving privileges would be automatically suspended for 30 days. These rules were a little different when dealing with teenagers. However they are not required to take any additional driver training classes. It is believed that the inconvenience of being suspended for a month will change a driver's behavior to result in fewer convictions or crashes, even without an educational requirement.
- **Montana:** Dr. Michael Kelly from the Western Transportation Institute stated that Montana is one of the few states that does not have a graduated licensing process. But one is being considered this year since it is reported to help bring down teen crash rates by about 20%.
- **Missouri:** Leanna Depue, Director of Highway Safety division, Missouri sent the blueprint for road safety measures that gives a summary of safety strategies used in their state.
- **Virginia:** Vanessa Wigand, Department of Education from the state of Virginia stated that they definitely have seen a reduction in crash rate after they increased the fines for seat belt usage violators but do not have any quantitative estimates. She replied on the lack of quantitative estimates for driver education, licensing and said that "To my knowledge there are no quantitative estimates of the

effectiveness of driver education and licensing. As far as enforcement goes, there are research studies that show that enforcement strategies like enforcement mobilizations, sobriety checkpoints, have impact on increased safety belt use and deterrence of drinking and driving. Again, however, I do not believe there are any quantitative estimates."

Many traffic safety experts at the NHTSA were contacted to get more information on driver education, driver licensing and enforcement measures. Two meetings were also arranged with the highway patrol in Athens County, Ohio to discuss their views on enforcement strategies. A list of enforcement strategies is included in the recommendations part of this report based on their inputs. Several meetings were arranged by Dr. Zwahlen with traffic safety and driver education professionals at the Swiss Council of Accident Prevention in Bern, Switzerland in August and September of 2005 to gather information related to their traffic safety countermeasures. The information obtained is analyzed and discussed in the subsequent sections of this report. The questions asked in the electronic survey for the driver education experts are listed below:

1. What are the present major topics that you teach the students?
2. What topics would you recommend in addition to the present major topics?
3. How much do you think would these additional topics help to reduce crashes?
4. How many hours of instruction are allotted for each topic?
5. Are multi-media resources used for training?
6. Would a driving simulator help in driver education? Yes/No Why?
7. What is taught in mandated driver rehabilitation classes?
8. In what ways are these driver rehabilitation courses and driver Education courses different?
9. What are the best driver education textbooks to educate novice and youthful drivers?
10. If the number of behind the wheel training hours were to be increased, what kind of training would you recommend?
11. Are there any restrictions on the number of hours of driver education training in a day?
12. Are driving ranges used for driver education? How many hours of training are done on driving ranges?
13. How can aggressive driving behavior be minimized or eliminated through educational efforts?
14. What additional efforts could be done to improve driver written tests?
15. What additional efforts could be done to improve driving tests?
16. In your opinion is the current driver education system for novice and youthful drivers the best?
17. Are you aware of a successful driver education or licensing program in another country?
18. Is there a way of measuring the effectiveness of the driver education program?
19. Are there any alcohol and drug awareness workshops being conducted as part of the driver education program?
20. Is there a driver education program specifically designed for older drivers?

21. Do you think such an older driver program should be introduced?
22. What type of curriculum do you recommend for an older driver education program?

A letter was sent out to our personnel in all 50 states and the Canadian provinces to obtain contacts to get information on driver education, licensing, and traffic enforcement; a follow-up letter was sent to the contact to get more information on driver education and licensing; a different follow-up letter was sent to each contact requesting information on traffic enforcement; and the letter sent out to the final list of contacts requesting more specific information on CRFs for education, licensing and enforcement. Sample letters sent to the contacts are provided in Appendix A to give more insight into how the information was requested in the survey.

7 Crash Reduction factors

7.1 Driver Education and Licensing

No quantitative CRFs are available for driver education and licensing measures in United States, except some estimated CRFs are available from some studies discussed in the literature review section. These are tabulated in Table 14. The CRFs obtained from these studies are based on meta-analysis or from an analysis of crash data. The validity of the results obtained from these studies is still questionable because of the lack of control groups.

Table 14: Crash reduction factors for driver education and licensing from the literature.

Measure	Place/State Implemented	Year Published	Implementation time	CRF
Two kinds of Driver Education curricula for High School students [9]	Dekalb County, Georgia	1996	3 years for education, reduction observed in next 6 years	6%
Graduated Driver Licensing Program [24]*	Maryland*	1998	1979	5%
	California*	1998	1983	5.30%
	Oregon*	1998	1989	16%
	North Carolina[1]	NP	NA	27%
	Michigan[1]	NP	NA	25%
	Florida[1]	NP	NA	9%
	Louisiana[1]	NP	NA	20%
	Kentucky[1]	NP	NA	32%
	Connecticut[1]	NP	NA	22%

*Note: NP- Not published; NA- Not available ; * from the same reference: [1] from [54]*

Some CRFs obtained for selected crash countermeasures from studies conducted in Switzerland are summarized in Table 15 from the VESIPO report [110]. These are estimates made by a group of traffic safety experts at Swiss Council for Accident Prevention (BFU is the acronym). Each crash countermeasure is designated with a capital letter K followed by a number. All Swiss traffic safety measures were also evaluated based on their relationship between benefits and costs. It should be noted that the Swiss don't use CRFs but they work with the actual rescue potential in terms of number of severe injuries and deaths prevented. The actual rescue potential of a measure is defined as the product of the relevant number of accidents times the applicability level times the efficacy level times the level of implementation times the level of compliance. The definitions of the applicability level, efficacy level, implementation time level and level of compliance are provided in the subsequent sections of the report. The CRFs given in Table 15 are calculated by dividing the fatalities saved by the total number of fatalities, or by dividing the number of severe injuries prevented by the total number of severe injuries. If the numbers of injuries/fatalities per crash before and after implementation of the measure are the same, then this estimate for the CRF will be valid.

If, as is likely for some measures, the severity of the average crash decreases along with the crash rate, then these computed CRFs will be perhaps slightly overestimated, while the actual costs will decrease because the costs per injury will decline with the severity.

Table 15: Measures from the Swiss VESIPO report for Driver Education and Testing adapted from [110].

Measure	Measure	Total		Average saved		Crash reduction factors	
No		Severely Injured	Fatalities	Severely Injured	Fatalities	Severely Injured	Fatalities
K 02	Drive with headlights in daytime	2351	192	56	5	2.38%	2.60%
K 03	Two phase driver education (two phase licensing with mandatory education in both phases)	869	85	130	14	14.96%	16.47%
K 04	Permanent campaign to make new drivers ages 18-24 more sensitive to traffic safety	1639	146	13	1	0.79%	0.68%
K 05	Mandatory 40 hours behind the wheel driver education in phase one for auto and motorcycle drivers	1001	85	24	2	2.40%	2.35%
K 06	Improvement of driver education for truck and bus drivers (commercial drivers)	288	88	13	3	4.51%	3.41%
K 07	Additional driver education for violators	293	39	22	2	7.51%	5.13%
K 08	Periodic and mandatory additional education for motorcycle drivers after 25 yrs of age	1411	89	69	4	4.89%	4.49%
K 10	Stricter conditions for loss of driving privileges and loss of driver's license	90	33	21	8	23.33%	24.24%
K 17	Testing of the driving capabilities of older drivers	452	68	34	5	7.52%	7.35%
K 18	Mandatory testing of visual capabilities of older drivers starting with 30 years of age	250	26	31	4	12.40%	15.38%
K 19	Performance limitations on vehicles driven by new drivers (auto and motorcycles)	1639	146	13	1	0.79%	0.68%
K 20	Insurance system liability change from vehicle owner to driver	4343	447	12	1	0.28%	0.22%
K 21	Change of criminal and civil legal responsibility from vehicle owner to driver	4343	447	15	1	0.35%	0.22%

7.1.1 Description of Swiss two-phase model for driver education based on approximate translation from the Swiss VESIPO report

Accident countermeasure K 03 in [110] is called a two-phase education model. It is in actuality a two-phase driver's license model with mandatory education in both phases. After completing the first portion of the education, which covers the fundamentals of vehicle control and traffic laws, and passing the exam, the driver receives a three-year probationary license. During the three years the driver is required to complete a second phase of driver education that comprises two full-day sessions that cover behavioral aspects such as drinking and driving. For each significant traffic-related violation during the probationary period, the probationary license period is extended by one year. After successful completion of the probationary period, the driver receives a standard unrestricted license. The two-phase driver education program was implemented in January 2006 and has not been evaluated yet. The two-phase driver education model is expected to contribute considerably towards the minimization of crashes by novice drivers.

7.1.2 Summary of expected results of Swiss two-phase driver education based on approximate translation from the Swiss VESIPO report

Table 16 and Table 17 show the summary of the results obtained for measure K 03, the two-phase driver education program. Table 16 shows the important parameters required for the calculation of actual rescue potential and Table 17 shows the number of fatalities for different vehicle types, pedestrian and other related crashes. The values tabulated in the tables are further used to calculate the rescue potential for severely injured people and fatalities.

Table 16: Summary of most important results for Swiss two-phase driver education program [110]. The letters (a), (b), (c), and (d) represent variables in Equation 1 below.

	Severely injured	Fatalities
Relevant Crashes (variable letter)	869	85
Applicability Level (a)	100%	100%
Efficacy (b)	50%	60%
	Severely injured and fatalities	
Level of Implementation (c)	max 100 %	100%
Level of Compliance(d)	max 30 %	30%

Explanations to terms used above

1. **Relevant crashes**: Total of the severely injured and fatalities which could be influenced through this measure (including estimated non-reported crashes).
2. **Applicability Level (a)**: Proportion of crashes where measure can actually be applied (proportion where measure has not been applied yet). (Example bicyclist helmet: 20% of bicyclists already wear helmet, so a mandatory bicycle helmet law would be applicable to the remaining 80%).
3. **Efficacy (b)**: What proportion of the severely injured people or fatalities can this measure actually prevent, if the measure is be applied. (Example: bicyclist helmet: 20 of 100 head injuries cannot be prevented by helmet, thus the efficacy of a helmet measure is 80%).
4. **Level of implementation (c)**: Level of incorporating of the measure under the existing conditions, maximum and average by 2020.
5. **Level of compliance (d)**: Level of adoption of the measure by drivers or other targeted groups – if the participants have the opportunity not to adopt the measure – is available to traffic participants over a determined time period in terms of maximum and average expected values.

Table 17: Number of traffic fatalities and severe injuries in Switzerland expected to be reduced by 2020 with two-phase education system for different types of vehicles, pedestrians and others [110].

	Maximum number saved		Average number saved	
	Severely injured	**Fatalities**	**Severely injured**	**Fatalities**
Automobiles	70	11	70	11
Motorcycles	34	2	34	2
Mopeds	6	0	6	0
Bicycle	9	0	9	0
Pedestrians	10	1	10	1
Others	1	0	1	0
Total	**130**	**14**	**130**	**14**

The Swiss used a structural approach to estimate the rescue potential for the two-phase model for driver education. As defined earlier the actual rescue potential of a measure is the product of the relevant number of accidents times the applicability level (a) times the efficacy level (b) times the level of implementation (c) times the level of compliance (d). The applicability level and the efficacy level are mainly based on information obtained in the literature. The level of implementation and the level of compliance represent consensus group estimates made by 5 to 7 experts working in the office of the Swiss Council for Accident Prevention (BFU). The Swiss BFU approach separates the severely injured from fatalities and looks at the numbers for automobiles, motorcycles, mopeds, bicycles, pedestrians, and others. In addition, the rescue potential is determined for a maximum and for an average number. The authors of this report divided the BFU rescue potential by the number of relevant accidents represents the estimate of the CRF of a measure.

In the example listed below the CRFs based on the totals are:

For maximum number of rescued:

Actual rescue potential = Relevant crashes*(a/100)*(b/100)*(c/100)*(d/100) (Eq. 1)

For Measure K 03, two-phase education model:

Relevant number of crashes for severely injured= 869

Rescue potential (total for severely injured)

= 869*(100/100)*(50/100)*(100/100)*(30/100)

= 130.35 or 130 (rounded to nearest integer)

CRF = 130/869 = 15% for severely injured

Relevant number of crashes for fatalities = 85

Rescue potential (total for fatalities) = 85*(100/100)*(60/100)*(100/100)*(30/100)

= 15.3 or 14 as shown in example, difference due to rounding of the individual values for automobiles, motorcycles, mopeds, bicycles, pedestrians and others.

CRF = 14/85 = 16.5 %

The necessity for such a measure is based on the crash situation. Traffic accidents are the most frequent cause of fatalities for 18-24 year old adults. The crash risk is approximately 2.5 times as large as for the general driving population. Among young automobile drivers and passengers there were 65 fatalities and 3968 injured in the year 2000 in Switzerland. The reasons for these high numbers are due not only to insufficient operating skills. Youthful driving behaviors are often not sufficiently adapted to the traffic situation, the driving style of youth is strongly influenced by momentary emotional states, and young drivers tend to accept greater risks than older drivers. With the two-phase model it is possible to influence and partially control these conditions. The additional driver education during the three-year probationary period has the aim to make novice drivers more realistically aware of their abilities and limitations. Because of the limited effect on the driving behavior through educational efforts, the threat of sanctions for major traffic violations during the probationary period is an additional feature to minimize the crashes of novice drivers. The two-phase education model contains all the important elements which contribute to the effectiveness for an improved driver education process. If the two-phase education model is correctly introduced and

executed one can expect with a reduction of severe injuries in crashes involving young people from 15 to 20%.
Note: The example shows the same numbers for the maximum and for the average number of severely injured and fatalities because BFU supplied the same numbers for both. Therefore the CRFs are the same for the maximum and the average numbers.

7.2 CRFs for Traffic enforcement measures

The CRFs obtained from different studies discussed in the literature review sections are tabulated in Table 18. Most of these come from Canada and Australia; there is a lack of published quantitative CRFs for traffic enforcement in the United States. The Swiss have rescue potentials calculated for some of their enforcement-based crash countermeasures which are shown in Table 19 along with CRFs estimated by the same process used in Table 15. The validity of these CRFs based on the Swiss estimates can be shown by the measure K11, a reduction in the legal BAC limit to 0.05% from 0.08%, which is the only enforcement-based measure which has actually been implemented to date in Switzerland. The Swiss authorities launched a major advertising campaign for this measure to see its effect on deaths and injuries due to DUI.

Table 18: Crash reduction factors for traffic enforcement measures from the literature

Measure	Place Implemented	Implementation or analysis time	CRF
Convictions for Traffic violation [29]	Ontario, Canada	1992-2003	35%
Manual Enforcement [29]	Ontario, Canada	1992-2003	2%
Automatic Enforcement [29]	Ontario, Canada	1992-2003	19%
Red light violation [29]	Ontario, Canada	1992-2003	11%
Drinking driving laws [29]	Ontario, Canada	1992-2003	4%
Aerial enforcement [39]	New South Wales, Australia	11 months	22%
Photo radar enforcement [34]	Norway	NA(Published in 1997)	26%
Enforcement Notification Signs [38]	Huntington Beach	1995	17%
Selective Traffic enforcement program [48]	Boise, Idaho	1983	17%
Photo radar enforcement [30]	Victoria, Australia	8 years(Published in 2002)	51%
	British Columbia, Canada	1996-1999	20%

Table 19: Enforcement–based measures from the Swiss VESIPO report for Traffic Enforcement [110].

Measure	Measure	Total		Average saved		Crash reduction factors	
No		Severely	Fatalities	Severely	Fatalities	Severely	Fatalities
		Injured		Injured		Injured	
K 09	Introduction of 50/30 km/h (31.1/18.6 mph) speed limits in all villages, towns, and cities	3333	218	116	19	3.48%	8.72%
K 11	BAC limit of 0.05 %	1211	189	320	48	26.42%	25.40%
K 12	Wearing of seat belts: Campaign and enforcement every four years alternating with K13, K14, and K15	445	136	11	4	2.47%	2.94%
K 13	Enforcement of speed limits: Campaign and enforcement every four years alternating with K12, K14, and K15	1334	229	15	3	1.12%	1.31%
K 14	Dangerous driving maneuvers: Campaign and enforcement every four years alternating with K12, K13, and K15	1973	117	16	0	0.81%	0.00%
K 15	Driver ability: Campaign and enforcement including enforcement of the off duty time for truck drivers every four years alternating with K12, K13, and K14	1001	153	5	1	0.50%	0.65%
K 22	0.02% BAC limit for new drivers, motorcycle drivers, and drivers of transport/cargo vehicles	398	77	62	12	15.58%	15.58%

7.2.1 Calculation of CRF for Swiss measure K 11- BAC limit of 0.05%

The Swiss measures began with a reduction in maximum allowed BAC from 0.08% to 0.05%. This change was accompanied by various enforcement and educational implementation steps. Here is a computation of an estimated CRF for the reduction in allowable BAC, starting from the number of relevant crashes per year from VESIPO report [110]:

Severely injured: 1211
Fatalities: 189
Estimated “saved” severely injured: 320
Estimated "saved” fatalities : 48
Estimated CRF for severely injured = (320/1211) = 26.4%
Estimated CRF for fatalities = (48/189) = 25.4%
Actual decrease in fatalities in 2005: 20 %
Estimated CRF for fatalities is 25.4/20 = 127% of actual observed fatality reduction

So it can be seen that the fatalities decreased by 20% and compared to an estimate of 25.4%, so 78% of the estimated CRF was actually realized in practice. Since all US states and the District of Columbia currently have a blood alcohol concentration (BAC) limit of 0.08% according to [111], it is apparent that if a blood alcohol level of 0.05% is adopted there would likely be a considerable reduction in crashes due to impaired driving.

7.2.2 Cost-benefit analyses for selected Swiss measures [114]

Table 20 shows the evaluation of different Swiss crash countermeasures based on their relationship between benefit and costs in thousands of Swiss Francs (CHF) and in US Dollars (US$). It can be seen that the measure K 03 "two-phase model for driver education" has a benefit/cost ratio of 3.5 which suggests that it is economically viable. It should be noted that measure K 16 "prohibition of two-way communication in vehicle (cell phone, paging etc)" has a benefit/cost ratio of 652 which makes the ban of the use of any communication device while driving justifiable. Some measures like K 06 and K 20 have a low benefit/cost ratio of 0.16 and 0.91 respectively which means they are not viable economically – the costs exceed the benefits.

Table 20: Evaluation of Swiss crash countermeasures based on their relationship between benefits and costs adapted from [114]. US Dollar amounts computed based on conversion of 1CHF=$0.76098.

		Benefit	Cost	Benefit	Cost	B/C
Topic	**Countermeasure**	**1000s CHF**	**1000s CHF**	**1000s US$**	**1000s US$**	**Ratio**
K 02	Drive with headlights in daytime	69015	9005	52519	6853	7.7
K 03	Two phase driver education (two phase licensing with mandatory education in both phases)	158080	44530	120295	33886	3.5
K 04	Permanent campaign to make new drivers ages 18-24 more sensitive to traffic safety	Not available	Not available	Not available	Not available	Not available
K 05	Mandatory 40 hours behind the wheel driver education in phase one for auto and motorcycle drivers	26824	25274	20412	19233	1.1
K 06	Improvement of driver education for truck and bus drivers (commercial drivers)	19515	125544	14850	95536	0.16
K 07	Additional driver education for violators	13447	824	10233	627	16
K 08	Periodic and mandatory additional education for motorcycle drivers after 25 yrs of age	46881	11976	35675	9113	3.9
K 09	Introduction of 50/30 km/h (31.1/18.6 mph) speed limits in all villages, towns, and cities	152451	16878	116012	12844	9
K 10	Stricter conditions for loss of driving privileges and loss of driver's license	35301	3336	26863	2539	11
K 11	BAC limit of 0.05%	331157	8504	252003	6471	39
K 12	Wearing of seat belts: Campaign and enforcement every four years alternating with K13, K14, and K15	16809	1427	12791	1086	25
K 13	Enforcement of speed limits: Campaign and enforcement every four years alternating with K12, K14, and K15	18414	7811	14013	5944	2.4
K 14	Dangerous driving maneuvers: Campaign and enforcement every four years alternating with K12, K13, and K15	19923	995	15161	757	20
K 15	Driver ability: Campaign and enforcement including enforcement of the off duty time for truck drivers every four years alternating with K12, K13, and K14	6210	3284	4726	2499	1.9
K 16	Prohibition of the two way communication in vehicle (cell phone, paging, or internet)	29338	45	22326	34	652
K 17	Testing of the driving capabilities of older drivers	42168	25183	32089	19164	1.7
K 18	Mandatory testing of visual capabilities of older drivers starting with 30 years of age	37452	42297	28500	32187	0.89
K 19	Performance limitations on vehicles driven by new drivers (auto and motorcycles)	13980	-54666	10638	-41600	<0
K 20	Insurance system liability change from vehicle owner to driver	13404	14767	10200	11237	0.91
K 21	Change of criminal and civil legal responsibility from vehicle owner to driver	168681	-2323	128362	-1768	<0
K 22	0.02% BAC limit for new drivers, motorcycle drivers, and drivers of transport/cargo vehicles	63613	901	48408	686	71

7.3 CRFs for Traffic Engineering Measures

The crash reduction factor (CRF) is a tool to provide an easy way of estimating crash reductions associated with a specific highway safety improvement treatment. The CRF can be used by agencies as a criterion in deciding whether to implement a specific treatment or as a measure for comparing different treatments. The CRF can also help in weighing the costs and benefits of the selected treatment. The National Cooperative Highway Research Program (NCHRP) research results digest [112] provides a summary of the best available CRFs for different kinds of traffic engineering safety treatments. The relationship of the digest with the ongoing research in the field is also discussed to give an insight to the reader about the current CRFs available. CRFs are defined as the fraction or percentage by which accidents are reduced by a particular measure. CRFs are related to accident or crash modification factors (AMFs or CMFs) which are the factors that one multiplies the present crash rate by to get the crash rate after the measure is implemented. The AMFs are derived from the corresponding CRFs by the relationship AMF=1-CRF. AMFs are currently used by the Interactive Highway Safety Design Model (IHSDM) and safety analysts to predict future safety for different traffic safety improvement treatments. AMFs will be a major component of the highway safety manual which is being produced by a Transportation Research Board (TRB) Task Force and NCHRP. The AMFs are expected to help American Association of State Highway and Transportation Officials (AASHTO) and NCHRP to update the guides developed now or in the near future and will assist the states and the local jurisdictions in implementing the AASHTO Strategic Highway Safety Plan.

The availability of reliable AMFs or CMFs is important for states and municipalities to achieve the best return on the investment in traffic safety funding. Reliable AMFs can also be used to develop broad based policy decisions related to traffic safety, but there are some obstacles to the extensive use of AMFs which are summarized from [112] as follows;

- **Origins/Transferability:** The extent to which AMFs are valid when transferred to other jurisdictions having different traffic conditions, roadways, weather, driver characteristics, accident investigation procedures, or other relevant characteristics is not known.
- **Methodological issues:** Most of AMFs are derived from before and after studies of the actual treatment implementation. The best AMF estimates can be produced using this approach instead of the cross-regression type analysis only if the derivation is properly conducted. This may be due to methodological problems including small sample size (e.g. the number of sites selected for a counter measure may be less than that needed for a statistically robust analysis), use of comparison groups which are not suitable, presenting the results without a statement of accuracy, or incorrect interpretation of the accuracy of the estimates.
- **Variability:** Because the value of an AMF depends a lot on a variety of factors such as traffic volume, crash experience, and site characteristics, research that results in single AMF will be of limited applicability. Therefore there is a need for accident modification functions dependent on relevant variables rather than a fixed AMF.
- **Crash migration and spillover effects:** After a treatment has been implemented at a site, crashes may migrate to an adjacent location. For example, prohibition of

left turns at one intersection may lead to more left turn crashes at up-stream and down-stream intersections. The existing AMF methodology does not account for this phenomenon.

- **Lack of information on effectiveness:** AMFs have not been developed for the recent Intelligent Transportation Systems (ITS) improvements or other operations strategies developed. For example, no AMF exists for the use of safety service patrol on the freeways which are used to reduce the impact of crashes and reducing secondary crashes.
- **Combination of treatments:** Most of the AMFs are computed for individual treatments rather than for a combination of two or more treatments. Little research is been done on the effects of the use of different combinations of treatments currently in use. It is not likely that the combined effect of two treatments at a location will be the product of the two AMFs.
- **Publication and citation issues:** The quality of the research material available in development can be questionable because of the publication bias or selective citing of the results. The research sponsoring agency may not want the negative aspects of the results obtained in the study which affects the future development of any AMF which is based on the low quality research material.

These obstacles also often apply to the CRFs and AMFs for driver education, licensing, testing, and enforcement. The main objective of the NCHRP project was to improve the quality of the existing AMFs and to develop additional AMFs wherever there are voids. The digest also provides a status report on the quality of the AMFs (AMF knowledge matrix) for a large number of treatments, summaries of the AMFs that are credible and also the present research going on to improve AMFs.

7.3.1 Accident Modification Factor (AMF) Knowledge Matrix

The states of practice for the development, application, and validity of existing AMFs were documented and the user priorities for the improved AMFs were determined in [112]. An extensive review of the literature and a survey of state DOTs were also conducted to determine the accuracy of the above process for 100 different treatments. Literature reviews pertaining to different combinations of treatments were also conducted, but no published AMFs were found for any combined treatments. The matrix provides information for each treatment which is described in the following sections:

- **User priority level:** As a part of the survey, respondents were asked to rate the importance of having an AMF for each of the 100 treatments. The respondents were asked to give a rating of low, medium, or high to each treatment. The top 25 treatments as rated by the state DOT respondents were highlighted in the matrix.
- **Level of predictive certainty:** This level of predictive certainty indicates the confidence level one can have in the AMF for a treatment on the basis of the critical reviews conducted. The important factor in determining the level of predictive certainty was the rigor of the methodology used in the study in which the AMF was developed. The following definitions were used to establish the level of predictive certainty:
    1. **High**: The AMF was developed in a rigorous before and after study which has the best available design study and statistical analysis methods. Empirical Bayesian methodology was considered as the best available approach.

2. **Medium-High:** The AMFs were determined through a rigorous meta-analysis by a recognized meta-analysis expert or a before-and-after study incorporating sound statistical methods were both considered to have medium-high level of predictive certainty. This level also included AMFs developed by an expert research panel consolidating the findings of research studies and also cross-sectional studies.
3. **Medium-Low:** AMFs which have some value and were developed by a cross-sectional analysis or from a less rigorous before-and-after study.
4. **Low**: AMFs determined using questionable modeling techniques for cross-sectional studies or a simple before-and-after study with no control over the biases.
5. **Non-existent:** AMFs were not found in the studies for this treatment.

- **Ongoing research/Future work:** A review of ongoing research-in-progress databases, discussion with highway safety researchers, and conversation with FHWA and other research sponsors identified those studies which had a high potential for producing good AMFs for specific treatments. These studies were listed so that the future results from these studies could be used to update the level of predictive certainty for a particular AMF.

7.3.2 Credible Accident Modification Factors

The number of treatments or programs exceeded 100, counting those enumerated in the survey sent to the DOTs and those added by survey respondents. Twenty of the 100 treatments were considered to be credible, meaning a high or medium-high level of predictive certainty was found in the literature search to find the best AMF for each treatment. The top 20 treatments are listed in Table 21 and a summary of the research results were presented in a table for each of these treatments. For example, Table 22 shows the research summary results for installing a roundabout treatment at an intersection.

Table 21: Treatments with AMFs that have a high or medium-high level of predictive certainty [112].

Treatment	Level of Predictive Certainty
Intersection Treatments	
Install a roundabout	High
Add exclusive left-turn lane	High
Add exclusive right-turn lane	High
Install a traffic signal	High
Remove a traffic signal	High
Modify signal change interval	Medium-High
Convert to all-way stop control	Medium-High
Convert stop-control to yield-control	Medium-High
Install red-light cameras	High
Roadway Segment Treatments	
Narrow lane widths to add lanes	Medium-High
Add passing lanes (two-lane roads)	Medium-High
Add two-way left-turn lane (TWLTL	Medium-High
Increase lane width	Medium-High
Change shoulder width and/or type	Medium-High
Flatten horizontal curve	Medium-High
Improve curve superelevation	Medium-High
Add shoulder rumble strips	Medium-High
Add centerline rumble strips	Medium-High
Install/upgrade guardrail	Medium-High
Miscellaneous Treatments	
Install raised medians at crosswalks	Medium-High

As one can see from the Table 22, the AMF for the treatment of installing a roundabout for all crashes is 0.6 and for injury crashes is 0.2. So the CRF for all crashes is 1-0.6=0.4 or 40% and for injury crashes the CRF is 1-0.2=0.8 or 80%. The treatment sites included 23 intersections of which 19 were previously controlled by stop signs and 4 were previously controlled by traffic signals. A crash reduction factor of 0.4 is highly desirable in terms of safety improvements at an intersection which is why the level of predictive certainty is high for the treatment. Table 23 summarizes the crash reduction factors calculated for the 13 out of the 20 treatments mentioned in Table 22 for which the AMFs were available. It should be noted that some CRF values are negative which means the crashes increased by that percentage after implementation of the treatment. For example one can see that for the measure of "installing a red light camera" the number of rear end crashes of all severity levels increased by 15% and the number of rear end crashes with injuries increased by 24%. The full cost-benefit analysis of implementing these measures is not available and needs to be further investigated; in this case, the cost of the increased rear end crashes may be more than offset by benefits realized in preventing other types of crashes.

Table 22: Summary of the research results for installing a roundabout at an intersection [112]. CRFs were computed by the authors of this report by subtracting the AMFs from 1.

TREATMENT: Install Roundabout

METHODOLOGY: Empirical Bayes Before-After

REFERENCE: Persaud, Retting, Garder, and Lord - 2001 (*5*)

STUDY SITES:

- Treatment sites included 23 intersections that were converted between 1992 and 1997 to roundabouts (19 were previously controlled by stop signs, and 4 were controlled by signals) from the states of Colorado, Florida, Kansas, Maine, Maryland, and Vermont.
- The roundabouts were in rural, suburban, and urban environments.
- Single-lane and multilane roundabouts were included; traffic volumes at the treatment sites in the after condition ranged from 4,600 vpd to 31,500 vpd.

AMF Level of Predictive Certainty: High

CRASH TYPE STUDIED AND ESTIMATED EFFECTS

Lane - Environment	No. of Improved Sites	AMF	CRF
Single Lane - Urban (prior control - stop sign)	8		
All Crashes		0.28	**0.72**
Injury Crashes		0.12	**0.88**
Single Lane - Rural (prior control - stop sign)	5		
All Crashes		0.42	**0.56**
Injury Crashes		0.18	**0.82**
Multilane - Urban (prior control - stop sign)	6		
All Crashes		0.95	**0.05**
Injury Crashes		—	
Single/Multilane - Urban (prior control - signal)	4		
All Crashes		0.65	**0.35**
Injury Crashes		0.26	**0.74**
All Conversions	23		
All Crashes		0.60	**0.40**
Injury Crashes		0.20	**0.80**

COMMENTS:

- The authors were not able to determine the safety effects for pedestrians and bicyclists, but refer the reader to the positive results that have been found in Scandinavian evaluations.[A]
- No evidence was found to indicate roundabouts result in more difficulties for older drivers.
- Results from NCHRP Project 3-65, Applying Roundabouts in the United States, include a more extensive analysis of crashes at roundabouts in the United States but were not available for release at the time of this publication. The AMFs from that effort should be used in place of those presented here when they become available.

FOOTNOTES:

[A] Ulf and Jörgen - 1999 (*72*)

Table 23: Summary of AMFs and CRFs for different traffic engineering treatments adapted from [112].

No	Treatment	LOPC	Crash Type studied and estimated effects					
				N	One approach		Both approaches	
1	Add Exclusive Right turn Lane	High	**Total Intersection Accidents**		AMF	CRF	AMF	CRF
			Rural Stop-controlled Intersection(4 legs)	28	0.86	14%	0.74	26%
			Urban Signalised Intersection(4 legs)	18	0.96	4%	0.92	8%
			Fatal and Injury Intersection Accidents					
			Rural Stop-controlled Intersection(4 legs)	29	0.77	23%	0.59	41%
			Urban Signalised Intersection(4 legs)	17	0.91	9%	0.83	17%
2	Add Exclusive Left turn Lane	High	**Total Intersection Accidents**					
			Rural Stop-controlled Intersection(4 legs)	25	0.72	28%	0.52	48%
			Rural Stop-controlled Intersection(3 legs)	36	0.56	44%		
			Rural Signalised Intersection(4 legs)		0.82	18%	0.67	33%
			Rural Signalised Intersection(3 legs)		0.85	15%		
			Urban Stop-Controlled Intersection(4 legs)	9	0.73	27%	0.53	47%
			Urban Stop-Controlled Intersection(3 legs)	8	0.67	33%		
			Urban Signalised Intersection(4 legs)	39	0.90	10%	0.81	19%
			Urban Signalised Intersection(3 legs)		0.93	7%		
			Fatal and Injury Intersection Accidents					
			Rural Stop-controlled Intersection(4 legs)	24	0.65	35%	0.42	58%
			Rural Stop-controlled Intersection(3 legs)	11	0.45	55%		
			Urban Stop-Signalised Intersection(4 legs)	9	0.71	29%	0.50	50%
			Urban Signalised Intersection(4 legs)	39	0.92	8%	0.83	
			Project Related Accidents					
			Rural Stop-controlled Intersection(4 legs)	23	0.63	37%	0.40	60%
			Rural Stop-controlled Intersection(3 legs)	35	0.38	62%		
			Urban Stop-Signalised Intersection(4 legs)	7	0.74	26%	0.55	45%
			Urban Signalised Intersection(4 legs)	35	0.87	13%	0.76	

Table 233: Summary of AMFs and CRFs for different traffic engineering treatments adapted from [112] (continued).

No	Treatment	LOPC	Crash Type studied and estimated effects			
				N	AMF	CRF
3	Remove a Signal	High	**Type of collision(all severities)**			
			All crashes	199	0.76	24%
			Right angle and turning crashes		0.76	24%
			Rear end crashes		0.71	29%
			Pedestrain crashes		0.82	18%
			Fixed object crashes		0.69	31%
			Light condition (all severities)			
			Day	199	0.78	22%
			Night		0.70	30%
			Injury severity (all collision types)	199		
			Severe		0.47	53%
			Minor		0.76	24%
4	Install a Traffic Signal	High	**Intersections**			
			3-leg Intersections	22		
			All crashes		0.86	14%
			Right angle crashes		0.66	34%
			Rear end crashes		1.5	-50%
			4-leg Intersections	100		
			All crashes		0.77	23%
			Right angle crashes		0.33	67%
			Rear end crashes		1.38	-38%
5	Install Red-Light cameras	High	**Crash Severeties**			
			All crash severities	132		
			Rear end crashes		1.15	-15%
			Right-Angle crashes		0.75	25%
			Injury crashes only	132		
			Rear end crashes		1.24	-24%
			Right-Angle crashes		0.84	16%
6	Convert to All Way Stop Control	Med-	**Type of collision(all severities)**	360		
		High	All crashes		0.53	47%
			Right angle crashes		0.28	72%
			Rear end crashes		0.87	13%
			Left end crashes		0.80	20%
			Pedestrain crashes		0.61	39%
			Crash Severity(all collision types)	360		
			All crashes		0.53	47%
			Injury crashes		0.29	71%
7	Modify Signal Change Interval	Med-	**Accident Type (all severities)**			
		High	All crashes	40	0.92	8%
			Multiple vehicle crashes		0.95	5%
			Rear end crashes		1.12	-12%
			Right angle crashes		0.96	4%
			Pedestrain/Bicyclist crashes		0.63	37%
			Accident Type (injury crashes only)			
			All crashes	40	0.88	12%
			Multiple vehicle crashes		0.91	9%
			Rear end crashes		1.08	-8%
			Right angle crashes		1.06	-6%
			Pedestrain/Bicyclist crashes		0.63	37%

Table 233: Summary of AMFs and CRFs for different traffic engineering treatments adapted from [112] (continued).

No	Treatment	LOPC	Crash Type studied and estimated effects			
				N	AMF	CRF
8	Convert Stop-Control to Yield Control	Med-	**Total accidents(all severities)**			
		High	All crashes	141	2.37	-137%
9	Add Passing Lanes(Two lane roads)	Med-	**Type of Passing Lane**			
		High	One way (single direction of travel)		0.75	25%
			Two way (short four lane sections)		0.65	35%
10	Narrow Lane Widths to Add Lanes	Med-	**Conversions**			
		High	**4-Lane to 5-Lane converions**	79		
			All crashes		1.11	-11%
			Fatal, Injury and PDO-Towaway crashes		1.10	-10%
			Fatal and Injury crashes		1.11	-11%
			5-Lane to 6-Lane conversions	45		
			All crashes		1.03	-3%
			Fatal, Injury and PDO-Towaway crashes		1.04	-4%
			Fatal and Injury crashes		1.07	-7%
10	Add shoulder Rumble Strips	Med-	**Freeways**	55		
		High	All freeways (Rural and Urban)		0.82	18%
			All single vehicle run-off road crashes		0.87	13%
			Injury Single-vehicle run-off road crashes			
			Rural Freeways	29		
			All freeways (Rural and Urban)		0.79	21%
			All single vehicle run-off road crashes		0.93	7%
11	Add Centerline Rumble Strips	Med-	**Accident Type (all severities)**	98		
		High	All crashes		0.86	14%
			Frontal/Opposing direction sideswipe crash		0.79	21%
			Accident Type (injury crashes)	98		
			All crashes		0.85	15%
			Frontal/Opposing direction sideswipe crash		0.75	25%
12	Install/Upgrade Guard rail	Med-	**Run-Off-Road Accidents**			
		High	Fatal Injury crashes		0.56	44%
			All Injury crashes		0.53	47%
13	Install Raised Medians at Crosswalks	Med-	**Total pedestrain Accidents**	173		
		High	Marked Crosswalks		0.54	46%
			Unmarked Crosswalks		0.61	39%

7.3.3 Related Research

The project in [112] was undertaken to document the state of art practices in AMF development, determine which additional AMFs need to be determined, and measure as many of these as possible within the project budget. Other NCHRP projects have been undertaken with objectives similar to this project, for example NCHRP project 17-27, Parts I and II [113]. The FHWA has a pooled fund study to evaluate the safety effect of a set of safety improvements with a budget of around $4 million with 24 participating states. The objective of this pooled fund study [113] is to conduct a rigorous scientific evaluation such as an empirical Bayesian before-and-after study analysis for as many different safety improvements as possible.

8 Conclusions and discussion

1. According to [5] the ratio of total crashes to number of fatalities was approximately 300 (381639/1162) which means that any fatality saved can reduce the number of total crashes by 300.
2. A limited number of statistically sound studies where crash reduction factors (CRFs) for selected driver education, licensing, or enforcement measures were calculated were found in the literature. This contrasts to the NCHRP study of engineering measures [112], where some AMF values were found to have High or Medium-High levels of predictive certainty.
3. CRFs computed using the rescue potentials in the Swiss VESIPO report [110] appear to be somewhat reliable but even then these rely on estimates by a group of experts from Swiss Council for Accident Prevention, rather than on actual measurements.
4. In addition no cost/benefit figures are available for any driver education, licensing, or enforcement measure in the US, although the Swiss consulting company Basler and Hoffman report [114] has cost/benefit figures for some selected driver education, licensing, and enforcement measures under consideration there.
5. There appears to be a complete lack of any published controlled studies where the effectiveness of driver education, licensing, and enforcement measures are studied in the United States.
6. An evaluation of the level of completeness and the quality of driver education, licensing, and enforcement efforts in each state was published by the Insurance Institute of Highway Safety [49]. This evaluation did not relate the measures to actual crash data. This study can be used to at least determine how the state of Ohio could make improvements in selected areas to improve its rating from "Fair" to the top of the "Good" category.
7. The range of CRFs obtained in the literature and the Swiss VESIPO report [110] are summarized in Table 24 as follows:

Table 24: Summary of the ranges obtained for CRFs from literature and Swiss VESIPO report [110].

Program	Measures from	Number of measures	Range of CRFs (in %)
Driver Education	Swiss VESIPO report [110]*	6	<1%-16.47
	Graduated Licensing program, USA	10	5-32
Testing	Swiss VESIPO report [110]*	1	24.24[1]
Enforcement	Swiss VESIPO report [110]*	7	0-25.4
	USA	2	17[1]
	Canada	6	4-35
	Australia	2	22-51
	Norway	1	26[1]

*Note: * for fatalities; Rest of them are for total crashes;* [1] *No range as only one CRF found for the measure*

9 Recommendations and proposed strategies for crash reduction

Based on the analysis of the literature and information from experts the following recommendations are proposed. Very few reliable CRFs are available for the recommendations proposed for traffic enforcement. Any future implementation of these measures by the state should include a carefully planned evaluation based using before and after crash data and with properly selected control groups as was done by [53].

9.1 Driver Education and Licensing

Based on the Insurance Institute for Highway safety [49] rankings, the following recommendations are proposed for the state of Ohio to bring it into top of the "Good" category:

1. Increase minimum licensure age to sixteen years.
2. Increase minimum age to sixteen and half years for intermediate stage restrictions on driving while unsupervised.
3. Extend prohibited hours of unsupervised driving from 9 PM to 5AM.
4. Restrict the number of teenage passengers to one passenger even after six months of obtaining intermediate license.
5. Increase the minimum age for all the restrictions to be lifted off to 18 years or more.

These five driver education and licensing modifications would help increase the ranking according to [49] for the state of Ohio to move it into the "good" category from "fair" category. Following are the lists for additional topics that can be covered for driver education in classroom and practical driver training considerations which can augment the state effort in improving driver education.

Additional Topics to cover in more depth in classroom teaching (3 hrs. per topic including 1 hr. of small group discussion)

1. Aggressive driving (Aggressive driving is a traffic offense or combination of offenses such as following too closely, speeding, unsafe lane changes, failing to signal intent to change lanes, and other forms of negligent or inconsiderate driving [115]).
2. Road rage (Road rage is a criminal offense. For example, a person may become so angry over an aggressive driving incident that he or she overreacts and retaliates with some type of violence [115]).
3. Consequences of drinking and driving.
4. Night driving.
5. Attitude towards traffic safety.
6. Knowledge about the physical operating limitations of the car such as the safe maximum speed as a function of road conditions, maneuverability etc.
7. Use of driving simulator to model emergency situations.
8. Distractions while driving (example: cell phones, 11 states in the US have laws against cell phone use for teenage drivers [49].

Additional Practical Driver Training considerations (At least an additional 8 hours)

1. Night Driving: At least 40% of total practical driving experience should be done at night. Practical experience of how high beams can cause a blinding glare at night and where to look when approached by opposing traffic.
2. Driving in bad weather conditions, including rain, fog, ice, and snow. What to do when the car starts skidding.
3. Driving in cities and heavy traffic.
4. Freeway driving.
5. Driving through school zones and in traffic with school buses.
6. Driving on curved roads and entrance/exit ramps.
7. Vehicle control on gravel roads.
8. Use of ABS: training on the use and benefits of an anti-lock braking system or any other safety systems the driver has in his vehicle.
9. Emergency situations and maneuvers.
10. Driving around bicycles and pedestrians.

Older Drivers licensing considerations

1. Some drivers have "night blindness" caused by a defective retina or a vitamin-A deficiency. No states test for night blindness during vision tests for driver license renewal [116]. All the old drivers can be screened before their license is renewed after 60 years of age.

9.2 Traffic Enforcement

Based on the literature review and NHTSA report [57] the following recommendations are proposed for traffic enforcement. All the recommendations are prioritized based on the crash reductions found from the literature:

1. Motorcycle helmet laws: The General Accounting office (GAO) review has found that fatalities have reduced by 20-40% with universal helmet law at place [98]. So the state of Ohio can strictly enforce the universal helmet law for drivers of all ages rather than making it compulsory for only drivers below 18 years of age.
2. Integrated enforcement: Integrated enforcement integrating impaired driving enforcement with speed and safety belt use can be done which was effective in reducing the alcohol related crashes by 10-35% [69].
3. Deploy automatic speed limit enforcement systems in areas of special interest such as work zones, school zones, high traffic volume areas, and high crash rate sections of highways using cameras. There appears to be a real opportunity to increase the enforcement efficiency using these devices. When applied in areas with high rates of violation, the devices may pay for themselves even though they are costly for installing, operating and maintenance. Red light cameras were quite effective in reducing overall injury crashes by 25% according to [91], [92], [93].
4. Strictly enforce and publicize zero tolerance law which was found to reduce the alcohol related crashes for drivers younger than 21 years of age by 25% [69] or more.

5. Sobriety and drug testing check points on a wider basis combined with an effective public education and advertising campaign, such as is done in Switzerland.
6. Introduce and implement mandatory sever training and responsible beverage service programs which will lead to responsible alcohol consumption and decrease nighttime alcohol related crashes.
7. Enforcement of license suspension and revocation laws which have reduced the alcohol related crashes by 13% [61].

Additional considerations for traffic enforcement:

1. Implement and maintain the highest possible level of technology and communications equipment in patrol cars and patrol posts. It appears that the state of Ohio is doing an excellent job by monitoring locations of patrol cars with GPS and using computer to computer links between patrol cars and dispatches, among other means. These efforts should be continued and evaluated as technology evolves.
2. Increase the number of Highway Patrol officers, patrol cars, and support personnel at each highway post. There appears to be a lack of enforcement personnel on the road.
3. Based on crash data, violation data, traffic volume, and traffic mix data analysis; tailor the enforcement allocation and enforcement effort to affect the highest crash risk areas.
4. Periodic seminars attended by highway patrol officers and driver education and licensing personnel in all areas of the state.
5. Periodic seminars with ODOT, traffic engineering, road engineering, and road maintenance personnel.
6. Increase speeding and aggressive driving fines. Initiate and develop a more severe moving traffic violation fine structure and make traffic fines uniform statewide
7. Extend use of aircraft for enforcing speed limits
8. Publicize enforcement efforts and increase periodic public education and advertising campaigns. Education efforts should include middle schools and high schools so that drivers start to learn early about the need for safe driving.
9. Station unmarked highway patrol cars at each patrol post.
10. The prohibition and strict enforcement of a ban on cell phone use while driving. This recommendation requires approval of the legislature.

10 Implementation

An implementation plan based on the literature reviewed and the CRFs found for some of the measures is provided. A stepwise implementation plan is provided to help ODOT attain its goal to reduce crashes by 10% by 2015. The driver education and licensing programs were given high priority so as to target young people who have higher crash rates and also improve the driver licensing program in the state of Ohio. All the measures given for enforcement can be implemented in conjunction with the driver education and licensing measures so as to achieve maximum crash reductions.

1. One of the highest priority measures for implementation is to improve the driver education and licensing program for the state of Ohio. The following five measures are proposed: Increasing minimum age to obtain a learner's permit to sixteen years; increasing the minimum age for unsupervised driving with intermediate stage restrictions ("probationary license") to sixteen and a half years; extending the prohibited hours of unsupervised driving during the probationary license period to include the range from 9 PM to 5 AM; restricting the number of teenage passengers even during the probationary license period; increasing the minimum age for a full license to at least 18 years. These steps can be implemented within three years. Even though no reliable CRFs are available for the proposed measures, it is expected that these refinements to the graduated driver licensing program will help the state of Ohio to achieve the optimal rating by the Insurance Institute of Highway Safety (IIHS) for driver education and licensing system. These ratings are based on a national review of state practices by the IIHS and should yield crash reductions. Most of these measures will require legislative changes which may take some time before they can be implemented.

2. Based on the information found in the literature and in the National Highway Traffic Safety Administration report on highway safety countermeasures, the following traffic enforcement measures which had higher crash reductions can be implemented in the next two to five years:
    - Motorcycle helmet laws (CRF: 20-40%). Implementation costs are minimal once legislation is enacted.
    - Integrated enforcement (CRF: 10-35%). The costs include law enforcement time and publicity.
    - Automatic speed limit enforcement systems (CRF: 25%). These systems are expensive to install, operate and maintain, but the cost is often recouped through increased number of violations processed.
    - Zero tolerance law (CRF: 25%). Requires moderate cost for training, publicity and equipment.
    - Sobriety and drug testing checkpoints (CRF: 20%). These checkpoints will require additional law enforcement time and publicity. The costs will be based on the extent of use of these checkpoints.
    - Responsible beverage service programs (CRF: 23%). The costs for training can be paid by the servers, their employers, or the state. Note that

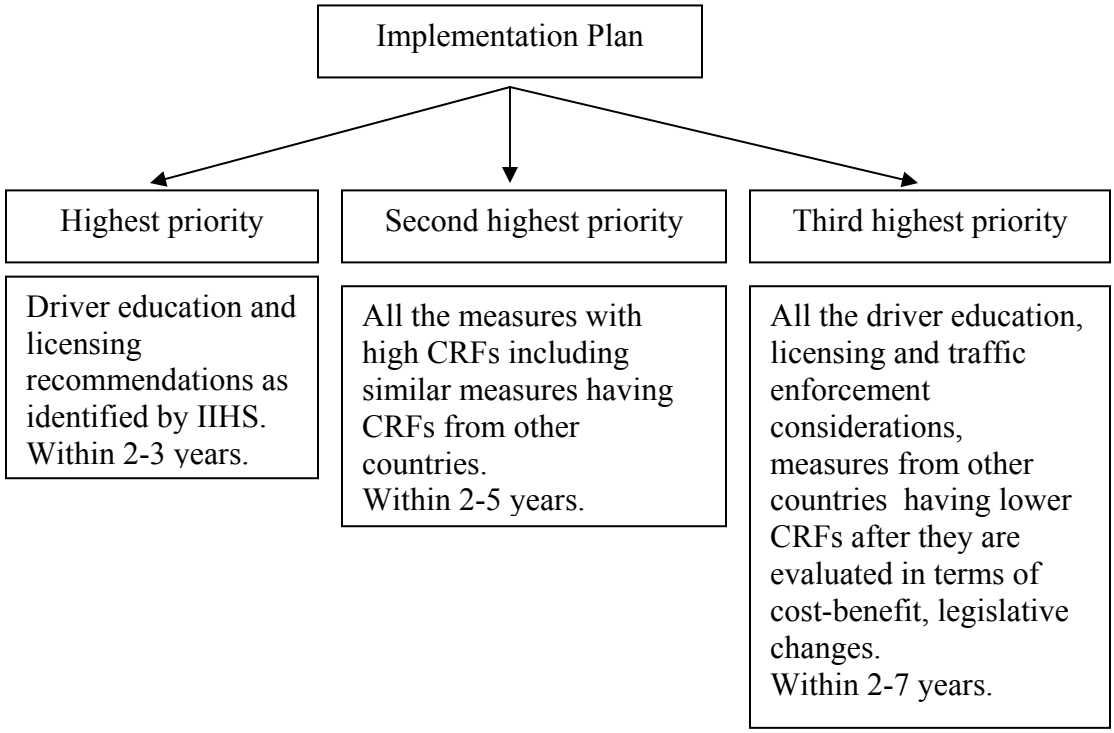
servers, who may not be well paid, and/or employers may regard this as an "unfunded mandate" and an imposition. It may be possible to cover the costs with an increased liquor license fee.

- Strict enforcement of administrative license suspension and revocation laws (CRF: 13%). It is expensive to implement and operate a system to process the administrative license actions.

Some of the measures also investigated in other countries like the 2-phase driver education model , reduction of BAC limit from 0.08% to 0.05% from the Swiss VESIPO report which had high CRFs can be implemented in conjunction with the measures above. All these measures need to be further evaluated in terms of costs and benefits. Some of these measures will require legislative changes before they can implemented which may take some time.

3. All the additional driver education, driver training and traffic enforcement considerations, measures from other countries which had lower crash reductions can be implemented within two to seven years for highest crash reductions to achieve ODOT's goal. All these measures have to be evaluated in terms of costs and benefits. Some of the recommended measures may require legislative action before they are implemented; the need for legislative action will need to be determined which will take some time.

The following chart provides a brief summary of the implementation plan to be adopted for reducing crashes:



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Appendix A : Sample Letters Sent To Contacts for the Electronic Survey

SAMPLE LETTERS SENT TO ALL CONTACTS REQUESTING INFORMATION ON DRIVER EDUCATION, LICENSING AND ENFORCEMENT

Driver Education Official, Traffic Enforcement Official in your Province

Dear ,

We at the Ohio Research Institute for Transportation and the Environment (ORITE) Human Factors and Ergonomics Laboratory at Ohio University are conducting a research project "**Crash Reduction Factors for Education and Enforcement Strategies in Ohio**" for the Ohio Department of Transportation (ODOT). The aim of this project is to investigate recently introduced innovative driver education, licensing, traffic enforcement and traffic crash evaluation efforts used by authorities in different provinces and countries and determine how effective these strategies are in reducing the crash rates.

As a preliminary step to this study we are looking for officials in your province who are knowledgeable about new innovative driver education, licensing, traffic enforcement and traffic crash evaluation programs in your province. We will be highly obliged if you could lead us to contacts (Contact person, title, email, phone and fax number) who will have this kind of information.

Thank you very much for your help,
Maimuna Rangwala
Research Assistant.
For,
Helmut T. Zwahlen, Ph.D.
Russ Professor Emeritus of Industrial and Manufacturing Systems Engineering
Research Professor
Ohio Research Institute for Transportation and the Environment (ORITE)
114 Stocker Center
Ohio University
Athens, OH 45701-2979, USA
Phone Office: 740/597-1790 or 740/593-2476
Fax Office: 740/593-0625

SAMPLE LETTER SENT OUT TO THE CONTACTS FOR INFORMATION ON DRIVER EDUCATION AND LICENSING PROGRAMS

Dear Marilyn,

We at the Ohio Research Institute for Transportation and the Environment (ORITE) Human Factors and Ergonomics Laboratory at Ohio University are conducting a research project "**Crash Reduction Factors for Education and Enforcement Strategies in Ohio**" for the Ohio Department of Transportation (ODOT).Your name was referred to us by Craig Copelan as the expert official in driver education and licensing in your state.

ODOT has a goal of reducing total traffic crashes in Ohio by 10% by 2015. It was found that driver error was the major cause of about 80% of the total crashes in Ohio during 2002 especially in the teenager and older driver age group. Hence driver education and licensing need to be better tailor made to reduce traffic crashes if possible. This means applying new innovative techniques in driver education and licensing both initial and continuing. In order to determine which strategies are likely to provide the best results, we need to have some quantitative estimates of the effectiveness of each strategy (driver education, driver licensing) in terms of the amount of crash reduction it would provide. This will help ODOT in following a systems approach toward driver education and licensing policies and help in determining how much of the transportation funds should be allocated toward driver education and licensing besides the traditional allocation of funds to road building and maintenance.

Likewise we need information about the best practices and innovative countermeasures that have been implemented in your state to reduce crashes with regard to driver education and licensing. In addition we are interested in knowing from you how much have these efforts helped in reducing the crash rate. . If actual crash reduction figures are unavailable, we request that you give us your best estimate of crash reduction that you expect.

If you think you will be unable to provide us with this kind of information kindly refer us to someone (Contact person, title, email, phone and fax number) who is knowledgeable in this area and can help us.

We appreciate all your help in this matter,
Thank you very much,
Maimuna Rangwala
Research Assistant.
E-mail: mr216603@ohio.edu
Phone:740-597-1790
For,
Helmut T. Zwahlen, Ph.D.
Russ Professor Emeritus of Industrial and Manufacturing Systems Engineering
Research Professor
Ohio Research Institute for Transportation and the Environment (ORITE)
114 Stocker Center
Ohio University
Athens, OH 45701-2979, USA
Phone Office: 740/597-1790 or 740/593-2476
Fax Home: 740/592-2856

SAMPLE LETTER SENT TO CONTACTS REQUESTING INFORMATION ON TRAFFIC ENFORCEMENT

Dear Mr. John,

We at the Ohio Research Institute for Transportation and the Environment (ORITE) Human Factors and Ergonomics Laboratory at Ohio University are conducting a research project "**Crash Reduction Factors for Education and Enforcement Strategies in Ohio**" for the Ohio Department of Transportation (ODOT).

Your name was referred to us by Craig Copelan as the expert official in traffic enforcement in your state.

ODOT has a goal of reducing total traffic crashes in Ohio by 10% by 2015. It was found that driver error was the major cause of about 80% of the total crashes in Ohio during 2002 especially in the teenager and older driver age group. Hence driver education, licensing and training programs need to be better tailor made to reduce traffic crashes if possible. This means applying new innovative techniques in enforcement of traffic laws. In order to determine which strategies are likely to provide the best results, we need to have some quantitative estimates of the effectiveness of each traffic enforcement strategy in terms of the amount of crash reduction it would provide. This will help ODOT in following a systems approach toward traffic enforcement policies and help in determining how much of the transportation funds should be allocated toward traffic enforcement efforts besides the traditional allocation of funds to road building and maintenance.

Likewise we need information about the best practices and innovative countermeasures that have been implemented in your state to reduce crashes with regard to traffic enforcement. In addition we are interested in knowing from you how much have these efforts helped in reducing the crash rate. If actual crash reduction figures are unavailable, we request that you give us your best estimate of crash reduction that you expect.

If you think you will be unable to provide us with this kind of information kindly refer us to someone (Contact person, title, email, phone and fax number) who is knowledgeable in this area and can help us.

We appreciate all your help in this matter,
Thank you very much,
Maimuna Rangwala
Research Assistant.
For,
Helmut T. Zwahlen, Ph.D.
Russ Professor Emeritus of Industrial and Manufacturing Systems Engineering
Research Professor
Ohio Research Institute for Transportation and the Environment (ORITE)
114 Stocker Center
Ohio University
Athens, OH 45701-2979, USA
Phone Office: 740/597-1790 or 740/593-2476
Fax Office: 740/593-0625

SAMPLE LETTER SENT TO CONTACS IN THE FINAL LIST REQUESTING MORE INFORMATION ON DRIVER EDUCATION, LICENSING AND TRAFFIC ENFORCEMENT

Dear Mr. Matt,

We at the Ohio Research Institute for Transportation and the Environment (ORITE) Human Factors and Ergonomics Laboratory at Ohio University are conducting a research project "**Crash Reduction Factors for Education and Enforcement Strategies in Ohio**" for the Ohio Department of Transportation (ODOT).

Your name was referred to us by Mr. Mike Gostovich as the expert official in driver education, licensing and traffic enforcement in your state.

ODOT has a goal of reducing total traffic crashes in Ohio by 10% by 2015. It was found that driver error was the major cause of about 80% of the total crashes in Ohio during 2002 especially in the teenager and older driver age group. Hence driver education, licensing and training programs need to be better tailor made to reduce traffic crashes if possible. This means applying new innovative techniques in driver education and licensing both initial and continuing and better enforcement of traffic laws. In order to determine which strategies are likely to provide the best results, we need to have some quantitative estimates of the effectiveness of each strategy (driver education, driver licensing and traffic enforcement) in terms of the amount of crash reduction it would provide. This will help ODOT in following a systems approach toward driver education, licensing and traffic enforcement policies and help in determining how much of the transportation funds should be allocated toward driver education, licensing and traffic enforcement efforts besides the traditional allocation of funds to road building and maintenance.

Likewise we need information about the best practices and innovative countermeasures that have been implemented in your state to reduce crashes with regard to driver education, licensing and traffic enforcement. In addition we are interested in knowing from you how much have these efforts helped in reducing the crash rate. If actual crash reduction figures are unavailable, we request that you give us your best estimate of crash reduction that you expect.

If you think you will be unable to provide us with this kind of information kindly refer us to someone (Contact person, title, email, phone and fax number) who is knowledgeable in this area and can help us.

We appreciate all your help in this matter,

Thank you very much,

Maimuna Rangwala
Research Assistant.
E-mail: mr216603@ohio.edu
Phone:740-597-1790
For,
Helmut T. Zwahlen, Ph.D.
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