



# Transport and Communications Bulletin for Asia and the Pacific

No. 83

## Designing Safer Roads

ESCAP is the regional development arm of the United Nations and serves as the main economic and social development centre for the United Nations in Asia and the Pacific. Its mandate is to foster cooperation among its 53 members and 9 associate members. ESCAP provides the strategic link between global and country-level programmes and issues. It supports the Governments of the region in consolidating regional positions and advocates regional approaches to meeting the region's unique socio-economic challenges in a globalizing world. The ESCAP office is located in Bangkok, Thailand. Please visit our website at <[www.unescap.org](http://www.unescap.org)> for further information.



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COMMUNICATIONS BULLETIN  
FOR ASIA AND THE PACIFIC

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# **Transport and Communications Bulletin for Asia and the Pacific**

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## RECENT PROGRESS IN ROAD SAFETY IN THE ESCAP REGION

A.S.M. Abdul Quium and Thanattaporn Rasamit<sup>1</sup>

### ABSTRACT

Road safety in developing countries of the ESCAP region is a development issue of serious concern, considering its magnitude and consequent negative impacts on the economy, public health and general welfare of the people, particularly low-income groups. While many countries in the region have launched road safety programmes, recent data suggests that the overall situation in the region is still far from satisfactory.

The current article provides an update of overall progress in road safety in ESCAP member States and describes some of the measures which countries are implementing with regard to vulnerable road users (pedestrians, cyclists and motorcyclists) and road traffic related laws. It also describes several trends regarding safety along the Asian Highway, based on what data is available from countries. The last section describes a number of key road safety initiatives which are being implemented by multilateral agencies in support of the global Decade of Action for Road Safety (2011-2020).

### INTRODUCTION

Road safety in developing countries of the ESCAP region is a development issue of serious concern, considering its magnitude and consequent negative impacts on the economy, public health and general welfare of the people, particularly low-income groups. In view of the gravity of the problem, many countries in the region have begun to implement road safety improvement programmes. As a result, some countries have made some progress in improving their road safety records. However, recent data suggests that the overall situation in the region is still far from satisfactory.

Globally, road crashes kill an estimated 1.24 million people and injure about 50 million each year. As reported in the Global Status Report on Road Safety 2013 by the World Health Organization, road traffic injuries are the 8th leading cause of death globally and the number one leading cause of death of young people (15-29 year old). While middle-income countries have the highest road traffic fatality rates, low-income countries shoulder a disproportionate share of road fatalities: despite having only 1 per cent of the global vehicle population and 12 per cent of global population, their share of global road fatalities is estimated to be 12 per cent.

The economic cost of road crashes has been estimated at between 1 and 3 per cent of gross domestic product (GDP) on average, and up to as high as 5 per cent for some developing countries. For example, it is estimated that India loses around 750 billion rupees (\$17 billion) per year due to road traffic accidents, which is 2-3 per cent of the GDP<sup>2</sup>. In the ASEAN subregion, the estimated cost of road crashes is more than 2.2 % of GDP. The estimated annual economic losses from road accidents in Cambodia and Myanmar are among the highest at 3.2 and 3 per cent of their GDP, respectively<sup>3</sup>.

This paper provides a broad overview of the recent progress made by countries in the ESCAP region in road safety. The analyses and findings presented are based primarily on data received from the Global Health Observatory Data Repository<sup>4</sup> of the World Health Organization (WHO) and the Global Status Report on Road Safety 2013.<sup>5</sup> It also draws on information collected from member

<sup>1</sup> Both authors are Economic Affairs Officers in the Transport Division, UNESCAP.

<sup>2</sup> Sikdar, P.K. and J.N. Bhavsar, Road safety scenario in India and proposed action plan, Transport and Communications Bulletin for Asia and the Pacific No. 79, p. page 5, available at: [http://www.unescap.org/ttdw/Publications/TPTS\\_pubs/bulletin79/b79\\_fulltext.pdf](http://www.unescap.org/ttdw/Publications/TPTS_pubs/bulletin79/b79_fulltext.pdf)

<sup>3</sup> UNESCAP Transport and Communications Bulletin for Asia and the Pacific No. 74, page 7

<sup>4</sup> See, <http://apps.who.int/gho/data/node.main.A989?lang=en>

<sup>5</sup> The WHO report is available at: [http://www.who.int/violence\\_injury\\_prevention/road\\_safety\\_status/2013/en/index.html](http://www.who.int/violence_injury_prevention/road_safety_status/2013/en/index.html)

countries by the ESCAP secretariat and data from the Asian Highway database maintained by ESCAP. The paper also discusses some recent multilateral road safety initiatives and activities in the region. Finally, it provides some policy recommendations for the consideration of relevant road safety stakeholders.

## I. RECENT PROGRESS IN ROAD SAFETY IN ESCAP MEMBER COUNTRIES

### 1.1 The overall situation

The Global Status Report on Road Safety 2013 by the World Health Organization<sup>6</sup> shows that 777,000, or more than half of the world's total road traffic deaths in 2010, occurred on roads in the ESCAP region. While the number of global fatalities in 2010 remained similar to that of 2007, road fatalities in the ESCAP region as a whole has risen considerably in 2010. The situation in most developing countries (which includes countries with high death tolls) further worsened. Nevertheless, between 2007 and 2010, 21 countries in the region succeeded in reducing the number of deaths on their roads. Table 1 shows road traffic deaths by subregion.

**Table 1. Progress in reducing road traffic deaths in ESCAP region**

Sub-region	Reported death (adjusted for 30-day definition) <sup>1</sup>		Estimated number of deaths (using a model)
	2007	2010	2010
Pacific <sup>2</sup>	2,471	2,151	2,876
North and Central Asia <sup>3</sup>	12,041	9,574	11,332
East and North-East Asia <sup>4</sup>	145,950	108,455	319,064
South-East Asia <sup>5</sup>	53,586	775,454	117,360
South and South-West Asia <sup>6</sup>	151,203	172,361	326,381
ESCAP	365,251	367,995	777,013
<i>ESCAP as percentage of world total</i>	<i>55.23%</i>	<i>57.72%</i>	<i>62.67%</i>
World	661,319	637,584	1,240,000

Source: Based on information available at:

[http://www.who.int/violence\\_injury\\_prevention/road\\_safety\\_status/2013/data/en/index.html](http://www.who.int/violence_injury_prevention/road_safety_status/2013/data/en/index.html)

Notes:

1. For definitions of reported death and estimated deaths, see Global Status Report on Road Safety 2013 by WHO.
2. Australia, Fiji, Kiribati, Marshall Islands, Micronesia (Federated States of), New Zealand, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu
3. Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan
4. China, Democratic People's Republic of Korea, Japan, Mongolia, Republic of Korea and Russian Federation
5. Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste and Viet Nam
6. Afghanistan, Bangladesh, Bhutan, India, Iran (Islamic Republic of), Maldives, Nepal, Pakistan, Sri Lanka and Turkey

The data shows that the number of road traffic deaths in the Pacific and North and Central Asian subregions, and in some countries of other subregions (for example, Russian Federation and Turkey) has gone down. However, the situation in East and North-East Asia, South-East Asia and South and South-West Asia, the three most populous subregions of ESCAP, worsened in 2010.

<sup>6</sup> The Global Status Report on Road Safety 2013 is available at: [http://www.who.int/violence\\_injury\\_prevention/road\\_safety\\_status/en/index.html](http://www.who.int/violence_injury_prevention/road_safety_status/en/index.html)

The average road traffic death rate (deaths per 100, 000 population) for ESCAP countries in 2010 (18.7) was higher than the world average (18.1). Road traffic death rates in 14 countries (including China, India, Islamic Republic of Iran, Kazakhstan, Malaysia, Russian Federation, Thailand and Viet Nam) were higher than the global average. Of these countries, four countries succeeded in reducing their death rates from their previous levels in 2007.

By subregion, road traffic death rates in East and North-East Asia and South-East Asia were higher than the world average. At 19.8, the traffic death rate in South-East Asia was the highest among the five subregions of ESCAP. Table 2 provides death rates in 2010 for all subregions of ESCAP.

**Table: 2. Road traffic death rates (deaths per 100, 000 population)**

	<b>Number of countries</b>	<b>2010</b>
Pacific <sup>1</sup>	12	8.05
North and Central Asia <sup>2</sup>	8	15.67
East and North-East Asia <sup>3</sup>	6	18.84
South-East Asia <sup>4</sup>	11	19.78
South and South-West Asia <sup>5</sup>	10	18.37
ESCAP	47	18.62
World		18.04

*Notes: Death rates are based on point estimates of road traffic deaths. For list of countries in each sub-region, see notes at the bottom of table 1.*

More recent data on road traffic deaths (unadjusted reported data of 2011 and 2012 as received by the ESCAP secretariat from countries) compared with similar data for previous years indicate that the upward trend of road traffic deaths may have declined, if not reversed, in some countries such as China and Viet Nam. However, the trend is still upwards in many other countries, such as Myanmar and Nepal.

It can also be noted from the data of 2011 and 2012 that in some countries, the increase in the number of road crashes and road traffic deaths has been substantially low compared with the increase in vehicle number or vehicle-km (for example, Turkey), which may also be considered as an indication of progress.

## **1.2 Road fatalities among pedestrians, cyclists and motorcyclists**

Road fatalities among pedestrians, cyclists and motorcyclists (collectively referred to as vulnerable road users or VRUs) are a cause of serious concern in many countries of the ESCAP region. While globally half of road traffic deaths occur among VRUs, in 17 countries of the ESCAP region, more than half of all road traffic deaths are among such road users. In 8 countries (Cambodia, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Pakistan, Singapore and Thailand), more than 70 percent of road traffic deaths occur among VRUs.

Road traffic deaths among motorcycle riders account for between one-third and three-fourths of all road traffic deaths in 10 countries (including two small island countries) of the region. Motorcyclists alone share more than half of all road traffic deaths in four countries (Cambodia, Lao People's Democratic Republic, Malaysia and Thailand).

Over a third of road traffic deaths in low- and middle-income countries of the world are among pedestrians and cyclists, but less than 35 percent of low- and middle-income countries have policies in place to protect these road users.<sup>7</sup> In the ESCAP region, pedestrian deaths are more than one-third of all road traffic deaths in eight Asian countries (Armenia, Azerbaijan, Bangladesh, Japan, Pakistan, Republic of Korea, Russian Federation and Tajikistan). In another eight countries (China, Georgia, Islamic Republic of Iran, Kazakhstan, Mongolia, Myanmar, Singapore and Sri Lanka) road

<sup>7</sup> Global Status Report on Road Safety 2013, p. ix



traffic deaths among pedestrians are higher than the world average of 22 percent. Meanwhile, in China and Japan, deaths among cyclists account for more than 10 percent of traffic accident deaths.

In recent years, most developing countries in the region have experienced a rapid growth in their vehicle population. The rapid growth of motorized vehicles makes roads more dangerous for vulnerable road users. The high rate of deaths and injuries among VRUs in the region, however, are not merely due to growth of vehicle numbers or a different vehicle mix, which is common in many countries. There is also a clear link between road safety and provision adequate and appropriate infrastructure facilities for different types of road users. Although countries have taken initiatives in this respect, high rate of pedestrian deaths in many countries for example, clearly indicates inadequacy of appropriate type of infrastructure facilities as well as the road safety behaviour of all road users.

### 1.3 Road traffic related laws and enforcement

The World Health Organization identified five key risk factors in road safety, namely speed, drink-driving, helmets, seat-belts and child restraints. Each of these risk factors was considered to be essential components of a comprehensive national legislation on road safety.

In most countries, there are laws covering all of these risk factors except for child restraint laws. However, their level of enforcement widely varies between countries of the region. Also, in many countries these laws are not comprehensive to cover all aspects of the risk factors.

**Table 3. Legislation on road safety in the ESCAP region**

Subregion	National speed limit law	Drink-driving law	Helmet law	Seat-belt law	Child-restraint law	Mobile phone law
	Number of countries					
Pacific	4	4	4	4	4	4
North and Central Asia	7	7	7	7	5	7
East and North-East Asia	6	6	6	6	4	6
South-East Asia	11	11	9	8	4	10
South and South-West Asia	10	8	9	9	1	8
ESCAP	38	36	35	34	18	33

*Notes: For this table, the Pacific subregion includes only Australia, Fiji, New Zealand and Papua New Guinea only. Other subregions are the same as given in Table 1.*

As indicated in the Global Status Report, except in a few developing countries (for example, Azerbaijan, Uzbekistan, Turkey) and five developed countries of the region (Australia, Japan, New Zealand, Republic of Korea and Singapore) the level of enforcement of the laws in most of the countries may be considered as low to medium. In some developing countries, the level of enforcement for selected areas, particularly on drink-driving and the wearing of motorcycle helmets, was high, but not for all laws.

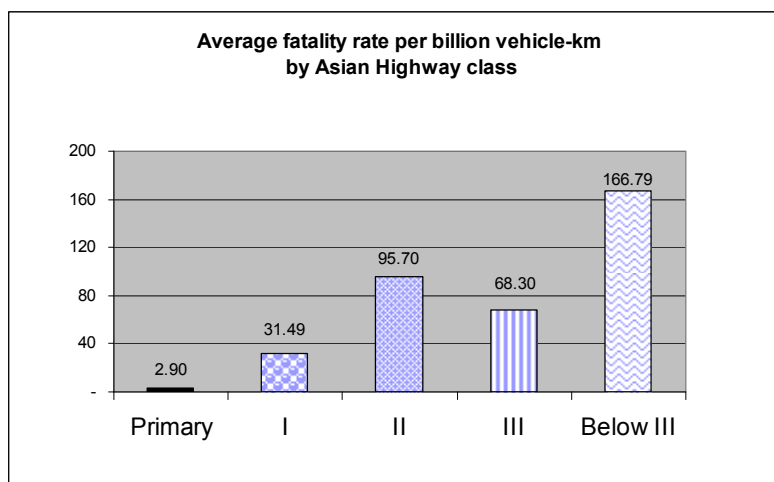
## II. ROAD SAFETY ON THE ASIAN HIGHWAY

The number of road users killed in road traffic crashes per population has been particularly high in emerging economies and newly industrialized economies. Regardless of motorization level, higher road traffic death rates per population are also linked to higher vehicle densities (i.e., vehicles per kilometre of road), which shows an important link between road safety and infrastructure development in general.

This paper also makes an attempt to see if there is any link between road safety and the quality of road infrastructure using data from countries of the region. The Asian Highway Database maintained by ESCAP contains, among other data items, data on the number of road crashes and fatalities for Asian Highway sections. Road safety data (2010) are available for 45.5 per cent of the

length of the Asian Highway, including 695 road sections (or 46.6 per cent of all sections), covering 64,818 km in 24 countries. Figure 2 shows average fatality rates per billion vehicle-km by Asian Highway class. It clearly shows that the higher class of roads are generally much safer than the lower class of roads, and that significant improvement in road safety may be achieved through upgrading of Asian Highway routes and safer infrastructure design. These findings should also remain generally valid for all other similar roads that are not part of the Asian Highway network.

**Figure 2: Average fatality rates per billion vehicle-km by Asian Highway class**



*Source: Based on information available from the Asian Highway database*

*Note: The fatality rates in the figure are based on reported fatalities on 24.12 per cent of the length of the Asian Highway network, which includes 485 road sections (or 32.5 per cent of all sections) covering 34,370 km of highways in 23 countries for which the required data for calculation was available in the Database.*

According to the latest data available from the Asian Highway Database (2010),<sup>8</sup> primary class Asian Highway roads have the best safety record in terms of fatalities per billion vehicle-km, while those below class III have the worst record. The upgrading of roads to access-controlled primary class and other higher classes has significant benefits in reducing fatality rates.<sup>9</sup> Substantial improvement in terms of safety can also be gained when roads below class III are upgraded to the minimum class III standards. The road safety record for class II, however, show worse performance compared to class III, possibly due to other factors such as higher traffic flows, higher shares of motorized vehicles, and greater average travel speeds.

The upgrading of roads has also been linked to improved Asian Highway safety in many countries, particularly when the upgrades involved: (a) the construction of barriers to separate opposing directions of traffic and different types of vehicles; and/or (b) the improvement of road shoulders. Two companion articles in the current issue of the Bulletin discuss further the role of safe road infrastructure design in improving the road safety situation on the roads of the region.

### III. MULTILATERAL APPROACHES TO ROAD SAFETY

With the alarming rate of increase in casualties from road crashes, the issue of road safety has been on the global and regional transport and development policy agenda. In order to focus global and regional attention on this issue, the United Nations General Assembly, has adopted seven resolutions calling for strengthened international cooperation and multisectoral national action to

<sup>8</sup> In the Asian Highway Database (2010), road safety data are available for 45.5 per cent of the length of the Asian Highway, including 695 road sections (or 46.6 per cent of all sections), covering 64,818 km in 24 countries.

<sup>9</sup> The average fatality rate for primary class roads was 2.90 fatalities per billion vehicle km, the lowest rate among all types of roads and 166.79 fatalities per billion vehicle km for below class III roads the highest among all types of roads; the average fatality rates for other classes of AH routes were 31.49 fatalities per billion vehicle km (class I), 95.70 fatalities per billion vehicle km (class II), and 68.30 fatalities per billion vehicle km (class III).

improve road safety situation since 2003. The United Nations Road Safety Collaboration (UNRSC) was established as an informal consultative mechanism to facilitate international cooperation and strengthen global and regional coordination among UN agencies and other international partners to implement UN General Assembly Resolutions. It is comprised of the World Health Organization (WHO) and the United Nations regional commissions, as well as other partners.

In its resolution 64/255 of 10 May 2010 on improving global road safety, the General Assembly proclaimed the period 2011-2020 as the Decade of Action for Road Safety with a goal to stabilize and then reduce the forecast level of road traffic fatalities around the world. It also requested the World Health Organization and the regional commissions of the United Nations system, in collaboration with the UNRSC and other stakeholders, to prepare a Plan of Action for the Decade as a guiding document to support the implementation of its objectives.

The Global Plan for the Decade of Action for Road Safety 2011-2020<sup>10</sup> provides an overall framework for activities at the local, national, regional and global levels and calls upon member States to implement road safety activities in a holistic manner, giving due attention to five “pillars”<sup>11</sup>: (a) building road safety management capacity, (b) improving the safety of road infrastructure, (c) further developing the safety of vehicles, (d) enhancing the behaviour of road users, and (e) improving emergency and other post-crash services.

Under the framework of the UNRSC, WHO and UN regional commissions are responsible for coordinating the regular monitoring of global progress in meeting the targets identified in the Plan of Action and to develop global status reports on road safety and other appropriate monitoring tools.<sup>12</sup> Among many monitoring efforts, the Global Status Report on road safety is one of the key monitoring tools. So far, WHO has launched two global status reports - the first in 2009, and the second report in May 2013.

A number of high-profile events have been organized which have drawn attention to road safety from the highest political levels. These global events include the first Ministerial Conference on Road Safety (November 2009), the launch of the Decade of Action for Road Safety (May 2011), the World Day of Remembrance for Road Traffic Victims (November 2012), the launch of the Global Status Report on Road Safety (March 2013), the first and second United Nations Global Road Safety Week (May 2012 and 2013), and the launch of the Global Alliance for Care of the Injured (May 2013).

The following sections describe some of the many initiatives which have been launched to support the Global Plan for the Decade of Action.

- **ESCAP Activities:**

ESCAP promotes a multilateral approach in the area of road safety, and has been working in partnership with the Asian Development Bank (ADB), the Global Road Safety Partnership (GRSP), the International Road Federation (IRF), the United Nations regional commissions and the World Health Organization (WHO).<sup>3</sup> As a regional organisation, ESCAP advocates global and regional road safety best practices and supports the networking of road safety experts, government officials, and representatives from international organizations and charities active in the Asia Pacific region. It also organizes national workshops on road safety to help Governments to develop and refine their national road safety goals, targets and indicators in support of the Decade of Action for Road Safety, as well as disseminates road safety information, data and statistics collected from member States.

- **Multilateral Development Banks:**

Development banks participating in the Multilateral Development Bank Road Safety Initiative continue to harmonize practices over the Decade and have collaborated in the development of client capacity in road safety management in several countries, including Cambodia, China, and India. The World Bank developed projects incorporating the “safe system” philosophy and has started to build capacity at the government-level in China and India to manage the multisectoral road safety agenda.

<sup>10</sup> Available from [http://www.who.int/roadsafety/decade\\_of\\_action/plan/en/index.html](http://www.who.int/roadsafety/decade_of_action/plan/en/index.html).

<sup>11</sup> Based on the recommendations of the WHO World report on road traffic injury prevention and proposed by the Commission for Global Road Safety.

<sup>12</sup> Paragraph 17 of General Assembly Resolution 64/255.

- **International Road Assessment Programme (iRAP):**

The International Road Assessment Programme specializes in risk mapping or star rating roads for safety. It has applied the star rating in many countries, such as the three-star minimum targets in Bangladesh and India, and has also established ChinaRAP to focus on assessing road safety assessments in China.

- **Global New Car Assessment Programme:**

Launched in 2011, the Global New Car Assessment Programme serves as a platform for cooperation for new car assessment programmes and to encourage their development in all regions of the world, especially among rapidly motorizing countries supports the development of new car assessment programme in ASEAN. The ASEAN NCAP has conducted crash test and yielded satisfactory result.

- **Bloomberg Philanthropies Global Road Safety Programme:**

The Bloomberg Philanthropies Global Road Safety Programme continues to support implementation of practical measures to reduce road traffic deaths and injuries in Cambodia, China, India, the Russian Federation, Turkey and Viet Nam and the legislative improvements concerning several of the five behavioral risk factors in China and Viet Nam.

- **Global Road Safety Partnership (GRSP):**

The Global Road Safety Partnership focuses on building and supporting the humanitarian work of the International Federation of Red Cross and Red Crescent Societies through advocacy to reduce vulnerability and to prevent road crashes and provide an effective post-crash response. The Partnership continued with good-practice implementation in various countries including countries in Asia region.

- **WHO Global Alliance of Care for the Injured:**

The WHO Global Alliance of Care for the Injured was launched in May 2013 to provide guidance and support to Governments to improve the care of the injured. It advocates the systematic provision of essential trauma services.

#### **IV. POLICY RECOMMENDATIONS**

Analysis of road traffic death rates shows large differences between countries in the Asia Pacific region.<sup>13</sup> Consequently, concerted action to significantly reduce the levels of road traffic deaths as well as injuries and property damage is urgently required. In view of limited resources and in order to optimize the impacts of future activities, priority areas within road safety should be identified according to the status and needs of countries.

Given the low level of road safety law enforcement in most developing countries of the region, governments should give greater attention to law enforcement and do more to enforce the road safety laws effectively.

In recent years, most developing countries in the region have experienced rapid growth in vehicle population. This trend, together with the changing vehicle mix and lack of appropriate infrastructure facilities to accommodate this mix, is resulting in a high rate of deaths and injuries among VRUs in the region. Although some authorities, particularly in major cities, have taken steps to address this gap, governments need to increase their investment in appropriate infrastructure facilities for all road users, as well as take urgent action to reduce high risk behaviour of different types of road users.

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<sup>13</sup> Refer to Tables 1 and 2 in this document.

Countries may also emulate the success of other countries by implementing similar measures which have proven to bring down road traffic deaths. As a case in point, Viet Nam's experience in increasing motorcycle helmet-use offers a model for many countries in the region. The high level of helmet law compliance is believed to have contributed significantly to the reduction of road accident deaths in the country in recent years.<sup>14</sup>

A number of countries have prepared or are in the process of finalizing draft national strategies and action plans on road safety. Governments should initiate policy measures and implement national road safety action plans and programmes according to the global, regional and national goals and targets, as well as establish effective mechanisms to monitor their achievements.

Finally, national, regional and global stakeholders should work hand in hand with governments to achieve more effective, stronger and wider collaboration.

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<sup>14</sup> See also, Kathryn Lankester and Greig Craft (1979). "Sustainable and replicable road safety solutions for the lower-and lower middle-income countries based on the Viet Nam model for increasing motorcycle helmet use", available at: [http://www.unescap.org/ttdw/Publications/TPTS\\_pubs/bulletin79/b79\\_fulltext.pdf](http://www.unescap.org/ttdw/Publications/TPTS_pubs/bulletin79/b79_fulltext.pdf).

## SAFE ROAD INFRASTRUCTURE DESIGN FOR HIGHWAYS

K.K. Kapila,<sup>1</sup> Aseem Prabhakar,<sup>2</sup> and Sandip Bhattacharjee<sup>3</sup>

### ABSTRACT

Road safety has become a global issue of concern and concerted efforts need to be initiated at the ground level to avoid the thousands of lives being lost in road crashes around the world. Considering Road Safety as an area of immediate concern around the world, the United Nations (UN) has declared Decade 2010-2020 as the Decade of Action for Road Safety. The International Road Federation (IRF) has also taken many initiatives towards road safety, such as the development of the Road Accident Data Recorder (RADAR) which will help in the systematic storage of data and scientific analysis of accidents.

One of the most important measures for the reduction of fatalities is to put in place a good infrastructure regime. By comparing desirable standards for Safe Road Infrastructure Design with undesirable standards for each of the key elements, engineers can play a crucial role in building safer roads. Uniformity of standards is a key element in design of safe roads. Developing country engineers can also learn from proven practices of Safe Road Infrastructure Design from developed countries.

### INTRODUCTION

Global facts and figures on the road safety scenario around the world reveal some startling statistics. More people die on the world's roads each year than the total number of people who die from malaria. The WHO estimates almost 1.3 million people die each year, equivalent to six jumbo jet crashes every day. However, while the crash of a single jumbo jet makes headlines in the media, road fatalities, even in such large numbers, do not get the same attention. Worryingly, death by road accidents is the No.1 cause of death for young people worldwide, and the economic cost to the global economy is estimated to be a staggering \$1.2 trillion a year.

Furthermore, 50 million people are injured annually, many of whom are left disabled. As shown in Figure 1, Road Traffic Injury (RTI) is the highest cause of global injuries. Ninety per cent of these casualties occur in developing countries. With the number of annual deaths occurring from road accidents forecast to rise to 1.9 million by 2025 (Figure 2), there is an urgent requirement to act now to prevent unnecessary deaths from road accidents in the future.

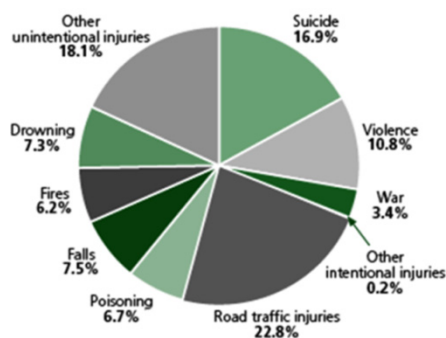


Figure 1: World-wide Cause of Injuries

Source : World Report on Road Traffic Injury Prevention (WHO).

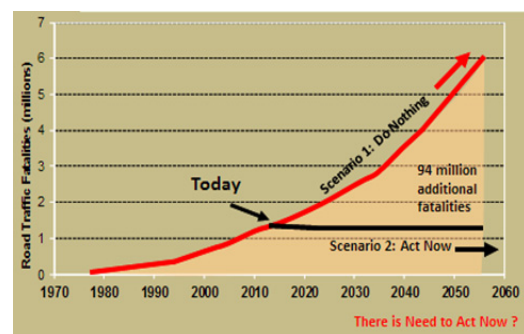


Figure 2: Projection of Global Road Traffic Fatalities

Source: Report on Safe Roads by Guria, J (2009).

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In response to these trends, the United Nations declared 2011 to 2020 as the Decade of Action for Road Safety. It aims to save 5 million lives by 2020. One of the five “pillars” of the Decade is on “Safer Roads and Mobility”.



## SAFE ROADS FOR ALL

The International Road Federation, or IRF, has several major road programmes on road safety in different regions of the world. Its Regional Offices provide training programmes on road safety, each different but complimentary to each other. For example, in collaboration with the UN Economic Commission for Africa and other international agencies, the IRF supports the Trans-African Highway Network. In Africa, the IRF also provides help and technical assistance on public-private partnerships, road safety, and Statistical Data Collection and Training. In the Mediterranean region, IRF designs personalized training seminars and regional conferences. The IRF Geneva Programme Centre develops customized training and visual materials such as videos.

Another major initiative under the IRF is the Road Accident Data Recorder (RADAR) developed by IRF is an innovative and scientific crash data collection and reporting system, designed as an application for use in a tablet with Android OS.<sup>4</sup> It provides paper-less digital accident data collection from the accident site/scene, and a device free delivery of the application to the customers. RADAR application is equipped to use the GSM Network, GPS, and digital camera facilities of the tablet.

The output from the Reporting Tool of RADAR Application can be used by all concerned actors connected to Road Accidents/Crashes, such as policy-makers, politicians, lawyers, road engineers, enforcement agencies, education and awareness groups, health professionals, researchers, insurance companies, vehicle manufacturers, and NGOs and community groups. This system for secured and scientific data on road accidents is expected to revolutionize road safety engineering and all other aspects of road safety across all boundaries.

### I. ENGINEERING ASPECTS OF SAFE ROAD INFRASTRUCTURE DESIGN

In general, it can be said that the “5Es” of Safe Road Operations are:

- **Engineering** – Defining the Built Environment including the road design and vehicle design.
- **Enforcement** – Strict application of law.
- **Education** – Teaching good road behavior through awareness campaigns.
- **Encouragement** – Rewarding people for good road behavior.
- **Emergency Care** – Road side medical care and access to para-medics in the “Golden Hour”, or the hour immediately following a road accident during which the provision of first aid can greatly enhance the prospects of the accident victim’s survival.

In this regard, the role of engineers is paramount to ensuring roads are as safe as possible. From an engineering perspective, road safety can be enhanced by Highway Engineers into various stages of road projects, as follows.

- **Planning Stage** - through land use control policies; providing by-passes for congested towns and linking them by spurs; and creating Self Contained zones to avoid nonessential traffic in the neighborhood
- **Design Stage** - designing “Self Explaining Roads” and “Forgiving Road Side” by selecting the most desirable design standards (and NOT the minimum standards) involving:

<sup>4</sup> Further information about the Road Accident Data Recorder (RADAR) can be found on the IRF’s website at: <http://www.irfnet.ch/index.php>.

- i. Design speed
  - ii. Horizontal and vertical geometry
  - iii. Cross-sectional elements
  - iv. Design of at-grade and grade separated junctions
  - v. Provision of service roads for segregation of slow and fast traffic
  - vi. Designing effective road furniture, vis-à-vis guard rails, traffic signage, road-side illumination provisions, etc.
- **Construction Stage** - Proper separation of the construction zone through effective barricading; construction of proper traffic diversions; provision of road signage; environmental controls for reducing noise, dust, etc.
  - **Maintenance and Operation Stage** - providing an Automated Traffic Management System (ATMS) for safe operation of Traffic and Incident Management. This includes providing Mobile Communication Systems, Variable Message Signs, Weigh-in-Motion System, and Central Control Room.

The key to Safe Road Infrastructure Design is consistency of standards so that road users do not encounter unexpected situations. While road crashes are overwhelmingly caused by human failings, the greatest untapped potential to prevent death and injury is through the roads themselves. For example, there has to be a clear distinction between inter-urban roads for high speeds and urban roads for lower vehicle speeds and priority for vulnerable road users.

By making the roads more predictable, consistent and forgiving, we can produce a long-term solution that helps save lives and reduce injuries. For example, between 1980 and 2000, in Sweden, the Netherlands and the United Kingdom, infrastructure treatments combined with speed management measures reduced the number of deaths of vulnerable road users by around a third. In this regard, it is important for all road engineers to acknowledge the key elements of safe road infrastructure design.

## II. KEY ELEMENTS OF SAFE ROAD INFRASTRUCTURE DESIGN

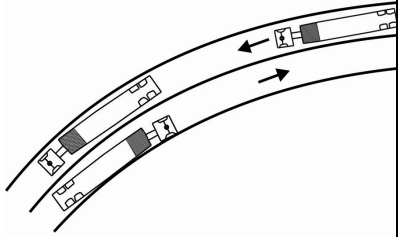
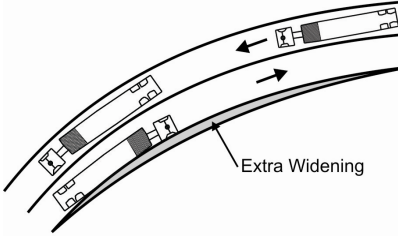
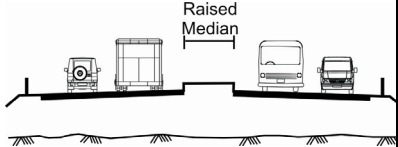
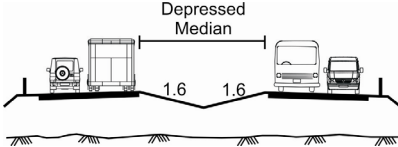
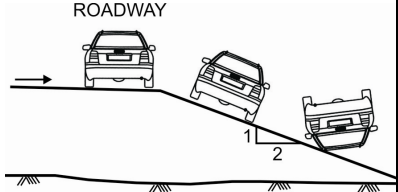
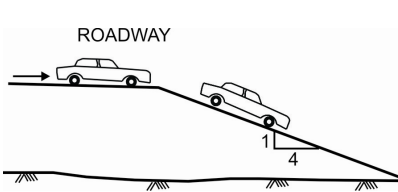


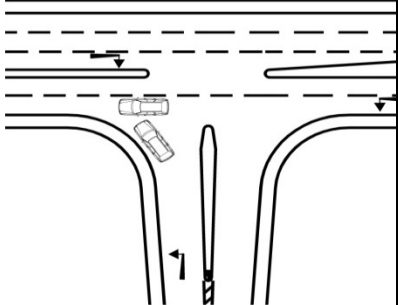
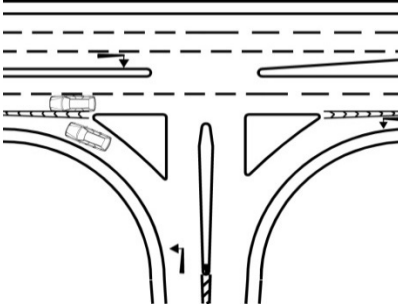
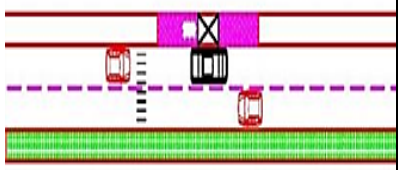
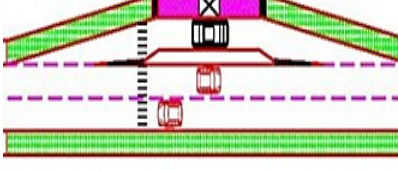
Some of the key elements of Safe Road Infrastructure Design are given in Table 1 below and are further illustrated in the table below.

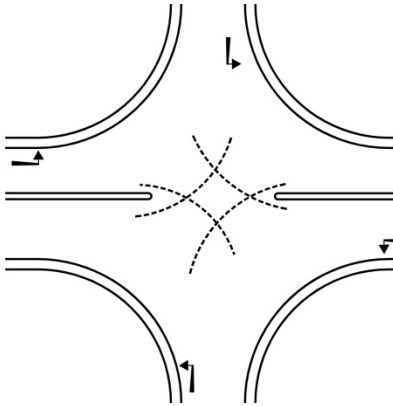
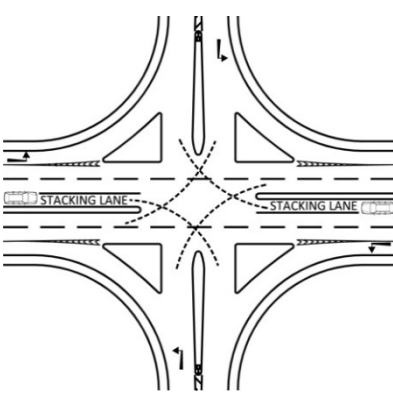
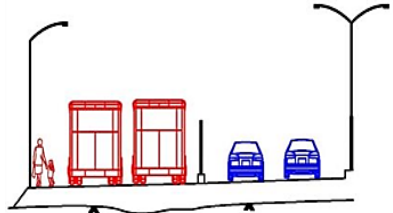
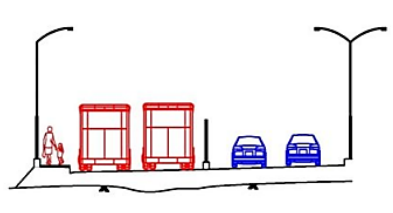
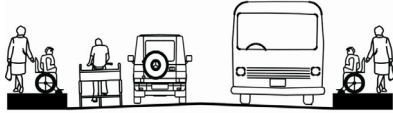





- a) Major arterials and expressways should bypass major towns which should be connected by spurs. There should be clear zones identified for linear land use control.
- b) Consistency of horizontal geometry avoiding monotonous straight lines or abrupt change of speed.
- c) Adequate off-set distance from natural road side features.
- d) Undivided carriageways designed for Overtaking Sight Distance.
- e) Wider lane widths and shoulders for High Speed Roads.
- f) Inside widening for sharp curves.
- g) Recoverable slopes for out-of-control vehicles.
- h) Segregation of the slow moving non-motorized traffic from fast moving traffic.
- i) Provision of raised footpath for pedestrians in Urban Areas.
- j) Barriers should be designed to deflect the vehicle and not crash it.
- k) Road Signs should be standardized throughout the country.
- l) Properly designed traffic calming measures like the speed humps, rumble strips, small roundabouts, etc.
- m) Entry / Exit only through Slip Lanes with proper Acceleration and Deceleration Lanes.





Table 1. Key Elements of Safe Road Infrastructure Design

Design/ Planning Element	Undesirable	Desirable	Principle applied
Alignment Selection and Land Use			Major arterials and expressways should bypass major towns which should be connected by spurs. There should be clear zones identified for linear land use control
Horizontal Geometry			Consistency of horizontal geometry avoiding monotonous straight lines or abrupt change of speed.
Horizontal Geometry			Adequate off-set distance from natural road side features.
Vertical Geometry			Undivided Carriageways designed for desirable Overtaking Sight Distance (OSD)
Cross-sectional Elements			Wider lane widths and shoulders for high speed roads

Design/ Planning Element	Undesirable	Desirable	Principle applied
Cross-sectional Elements			Inside widening for sharp curves
Cross-sectional Elements			Wider depressed median for high speed roads to prevent glare and jumping of vehicles
Cross-sectional Elements			Recoverable slopes for out of control vehicles
Cross-sectional Elements			Separate slow moving non – motorized traffic (cycles, rickshaws, etc.) from fast moving traffic
Entry/ Exit			Entry Exit only through slip lanes with proper acceleration and deceleration lanes
Passenger Transit			Separate Lay bye for buses and taxis to facilitate segregation and improve visibility

Design/ Planning Element	Undesirable	Desirable	Principle applied
Junction Design			Channelization, provision of stacking lanes, adequate turning radii
Pedestrian Facilities in Urban Areas			Provision of raised footpath for pedestrians in Urban Areas
Facilities for differently abled	 Road Crossing Location	 Road Crossing Location	Footpath merging in a slope with a cross street, bus bays flushed with foot boards etc.
Barriers			Barriers should be designed to deflect the vehicle and not crash it.
Road Signs			The road signs should be standardized throughout the country

Design/ Planning Element	Undesirable	Desirable	Principle applied
Traffic Calming	 <i>Non-standard Hump</i>	 <i>Standard Hump</i>	Properly designed traffic calming devices like speed humps, rumble strips, small roundabouts

### III. EXAMPLES OF GOOD PRACTICES IN SAFE ROAD INFRASTRUCTURE DESIGN

Around the world, there are many examples of good practices in Safe Road Infrastructure Design. Some of these are elaborated below and illustrated in Figure 3.

- Mild Slope Treatment (Forgiving Road Side Treatment) to absorb impacts of vehicle turnover
- Recovery Zone (Hard Shoulder) to allow Safe Recovery
- Road Side Feature (Protected with guardrails)
- Recoverable Fill Slope (for adequate protection)
- Rock face Cutting (Shielded with safety barrier)
- Roundabout (At grade with Non-Motorized Mode of Segregation)
- Grade separation at busy intersection (with segregated passage for pedestrians and local traffic)
- Depressed Median (Prevent run-off accidents)
- Speed Camera/Radar Photo (Speed control)
- Speed Limit on the Asphalt (to limit the speed)
- Speed Calming Measures (to limit the speed)
- Adequate Design for Non-Motorized Traffic
- Adequate Refuge for Pedestrians

**Figure 3: Examples of Good Practices of Safe Road Infrastructure Design**



*Forgiving Road Side Treatment*



*Recovery Zone (Hard Shoulder)*





*Recoverable Fill Slope*



*Rock Face Cutting (Shielded with Safety Barrier)*



*Roundabout  
(At Grade with Non-Motorized Mode Segregation)*



*Speed Humps: Speed Calming Measures*



*Grade Separation at Bust Intersection*



*Speed Camera/Radar (Speed Control)*

#### IV. CONCLUSIONS

The road fatality trajectory is going up alarmingly around the world. Following the example of developed countries, where road fatalities through infrastructure safety and other educational and enforcement programs have drastically reduced the number of accidents, developing countries need to put in place a good regime of Safe Road Infrastructure Design to improve road safety scenario and reduce road casualties/fatalities.

Immediate implementation of successful road safety models in some regional countries may also require institutional reforms/change in legislation. However, safety engineering can be carried out without any structural change in existing implementation framework. To improve infrastructure safety, the major steps which need to be implemented are:

1. Road Agencies to adopt road safety audit in all stages of road development and to make them mandatory.
2. Training and Capacity Building to enhance Safety Engineering Expertise.

3. Revise Codes and Manuals for improved vehicle technology and prevailing road user behavior.
4. Initiate Peer-to-Peer Program at National Level and establish Center of Excellence and Road Safety Auditor's Accreditation system.

## ROAD INFRASTRUCTURE AND ROAD SAFETY

Ishtiaque Ahmed<sup>1</sup>

### ABSTRACT

Roadway Factors, including roadway and roadside design elements, play an important role in determining the risk of traffic accidents. Negative road engineering factors include those where a road defect directly triggers a crash, where some element of the road environment misleads a road user and thereby creates human errors. In particular, the geometry of the road influences both the frequency and severity of road crashes. In this regard, concepts such as the “Forgiving Road Side Design” and the “Positive Guidance” approach need to be integrated into the engineering design of roads to minimize the risk of road accidents. Tools such as the International Road Assessment Program (iRAP)’s road safety audits (“Star Rating” reports) can help countries to identify the risk factors in road design.

### INTRODUCTION

The road network has an effect on crash risk because it determines how road users perceive their environment. In this sense, the roadway provides instructions to the road users on what they should be doing. Negative road engineering factors include those where a road defect directly triggers a crash, where some element of the road environment misleads a road user and thereby creates human errors.<sup>1</sup>

A framework for relating the series of events in a road crash to the categories of crash-contributing factors is the Haddon Matrix. According to the matrix developed by Dr. William Haddon Jr. in 1970, there are three different types of factors that contribute to road crashes: a) Human Factors b) Vehicle Factors and c) Roadway/Environment Factors.<sup>2</sup> Roadway Factors include roadway and roadside design elements. According to the Highway Safety Manual (HSM) of the American Association of State Highway and Transportation Officials (AASHTO), three percent (3%) of road crashes are due to only roadway factors, but thirty four percent (34%) of road crashes are a combination of roadway factors and other factors (Figure 1). Research also showed that road and environment factors were responsible for seventeen percent (17%) of total expressway crashes in the Republic of Korea during the year 2011.<sup>3</sup>

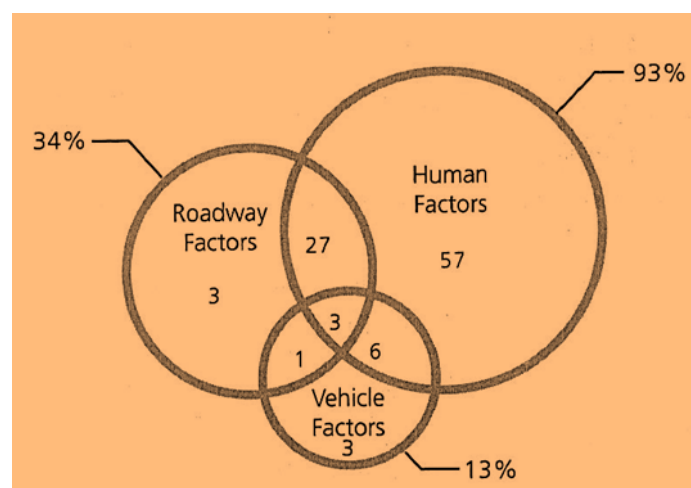


Figure 1 Contributing factors to Vehicular Crashes (Source: AASHTO)

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Safer roads and the mobility is one of the five pillars of the UN Global Plan for the Decade of Action for Road Safety 2011-2020. The pillar emphasizes the need to raise the inherent safety and protective quality of road networks for the benefit of all road users. This can be achieved through measures including improved safety-conscious planning, design, construction and operation of roads. The activities under this pillar include encouraging governments to set a target to "eliminate high risk roads by 2020", identify hazardous road locations or sections where excessive numbers or severity of crashes occur and take corrective measures accordingly; and also to promote the development of safe new infrastructure that meets the mobility and access needs through use of independent road safety audit findings in the design and other phases of new road projects. One of the pillar activities also emphasizes research and development in safer roads and mobility by completing and sharing research on the business case for safer road infrastructure.<sup>4</sup>

## **I. ROAD PARAMETERS AFFECTING THE ROAD SAFETY**

The geometry of the roadway plays a significant role in road crash frequencies as well as the crash severity level. Different elements of the road design are important. However, a few parameters are considered to be more prominent and are discussed below.

### **1.1 Cross-section of the Roadway**

The vertical cross section of the roadway parameters include the width of the travel lane, width and type of the shoulder, and skid resistance of the surface of the travel way.

The width of the travel lane does not only influence the comfort of driving and operational characteristics of a roadway, but is also an important parameter affecting the road crash frequency as well as crash severity. For any functional classification of roadway, whether it is an arterial road or a local road, and for any environment of the roadway, whether it is an urban road or a rural road, when the lane width reduces, the probability of crashes increases drastically. For example, a study which looked at safety risks on a two-lane undivided highway, found that when the lane width was increased from 2.75 meter to 3.65 meter, the probability for head-on or other related crashes was reduced by fifty percent (50%).<sup>5</sup>

When the traffic volume is higher and the lane width is less, the probability for crashes, especially crashes like head-on or run-off the road, are greater. For example, in a multi-lane rural highway where the average annual daily traffic volume is greater than 2,000, the probability for a crash on a narrow lane i.e. 9 feet (2.75 meters) increases by more than thirty percent (30%).

A shoulder is the portion of the roadway contiguous with the travel lane that accommodates stopped vehicles, emergency use etc. Generally, the shoulder width varies from 0.6 m to 3.6 m but there are places where no shoulder can be accommodated. While it is desirable that a shoulder be wide enough for a vehicle to be driven completely off the travelled way, narrow shoulders are better than no shoulder at all. One study found that the probability for a road with a 60 cm wide shoulder on each side, has thirty percent (30%) more crash risk than a road having a 1.8 metre wide shoulder on each side.<sup>6</sup>

Regardless of the width, a shoulder should be continuous and intermittent shoulders are better than no shoulders. The importance of wider shoulders is more acute in two-lane two way roads. For a two-lane two-way road, if the daily average traffic volume is greater than 2,000, the probability of crashes for a very narrow width or no shoulder increases drastically, and if no shoulder is present the chance of a crash increases by fifty percent (50%).

The shoulder type also governs the crash frequency. The shoulder material and thus the surface condition have at least some impact on the recovery of an errant driver going out of the travel lane. A paved shoulder is the best type of shoulder in terms of road safety and better than gravel shoulders. A gravel shoulder is better than a composite shoulder (combination of different types). However, a turf shoulder is considered to be the worst in terms of road safety and can lead to ten percent (10%) more crashes.

Literature shows that skidding crashes are a major concern in road safety. When the surface friction is not adequate to help stopping a vehicle, a vehicle goes out of control and crashes occur.



Vertical and horizontal alignment, pavement types and texture affect a roadway's skid resistance. Different pavement distresses or faults like rutting, polishing, bleeding and also dirty pavements cause poor skid resistances of road surfaces.

## 1.2 Roadside Condition

The safety of the road does not depend only on the characteristics of the roadway but also depends on the condition of the roadside. The term "clear zone" is used to designate the unobstructed, traversable area provided beyond the edge of the travel way for the recovery of the errant vehicle. The clear zone includes shoulders, bicycle lanes and any additional space, if available.

The greater the width of the clear zone, the more room is available for an errant driver to recover before hitting an object; thus a greater clear zone means a safer road. In locations where right of way or the width available for providing clear areas is not sufficient, it is not practical or feasible to consider the concept of clear zones as expected in general. This type of environment is more common in densely populated urban areas. Considering safety aspects, a lateral offset to vertical obstructions (signs, utility poles etc.) is needed to avoid crashes.

The presence of a median is another important factor governing crashes, especially head-on collisions. Most two-lane highways do not have median barriers to avoid capacity reduction of the roadway. However, median barriers are highly desirable in multi-lane highways in terms of safety and operational efficiencies. Generally, the median width varies between 1.2 to 4 meters. The wider the median, the better the safety situation is: Harkey et al conducted a study that revealed that a multilane divided highway with a 3.0 meter wide median has a four percent (4%) greater probability of crashes than a highway with a 9.0 meter wide median.<sup>7</sup> Even for urban arterial roads, one study found that conversion from an undivided urban arterial to one with a raised-curb median could result, on average, in a ten percent (10%) reduction in road crashes.<sup>8</sup>

## 1.3 Curvature of the Roadway

The horizontal curvature of a roadway is important because when a vehicle moves in a circular path, it undergoes a centripetal acceleration that acts toward the centre of the curvature. In other words, centrifugal forces try to move away the vehicle from its desired line of movement i.e that is the curved roadway. The roadways at curves are provided with a geometric feature on the curved portion of the roadway known as "super elevation". In other words, the outer sides of the roadways at curves are elevated with respect to the inner part, so that a component of the self-weight of the vehicle helps to prevent the vehicle to move away in the outward direction.

However, the travel speed of the vehicle is also an important factor. If the travel speed of a vehicle exceeds the suitable limit or design limit of the curve, then the vehicle loses control and a serious "out of control" crash may take place. For example, on a curved portion of a two-lane highway, if the provided super-elevation is lower than two percent (2%) of the desired level, the probability of road crashes increases by six percent (6%).<sup>9</sup>

Transition curves are used between the straight part of the road and circular curves. This transition is provided through introducing spiral curves. If a transition curve is not properly provided, then centrifugal force will be applied to a vehicle all of a sudden, and depending on the speed and weight of the vehicle may translate into lack of control of the vehicle. Therefore, improper transition curve is more risky for heavier and fast moving vehicles

The vertical grades or curvature of vertical curves of the roadways are also related to road safety. When steeper slopes are provided, it becomes more difficult for a vehicle to be controlled. This is a more significant problem for heavier vehicles like trucks. A heavy truck faces difficulty in climbing steep ascending grades, causing them to slow down. This in turn results in differential speeds among different types of vehicles. A two-lane highway located in steep terrain can have 15% more road crashes than a similar road located in a level terrain condition. Therefore, presence of a climbing lane (additional lane) for heavier vehicles can reduce probability of crashes by 25% on a two-lane roadway section.

#### 1.4 Sight Distance

The alignment of the roadway has a great impact on road safety because a driver's ability to see ahead is necessary for the safe operation of the vehicle and thus for the overall safety of the system. A sight distance of sufficient length is necessary so that a driver can control the operation of their vehicles to avoid hitting an unexpected object on the road. This is known as "Stopping Sight Distance (SSD)". Another concept, of the sight distance is the "Passing Sight Distance (PSD)". For a two-lane road where the speed is 60 kmph the SSD and PSD are 85 meters and 180 meters respectively on level roadways. The passing sight distance is applicable to two-lane roads to enable drivers to use the opposing traffic lane for passing (overtaking) other vehicles without interfering with oncoming vehicles.

While the concept of the SSD and the PSD are the prime importance in terms of road safety, the "Decision Sight Distance (DSD)" is another important topic to be addressed for the safety of the road users. SSDs are sufficient for reasonably competent and alert drivers to come to hurried stops under ordinary circumstances, but greater distances are needed for drivers to take complex decisions.

The DSD is the distance needed for a driver to detect an unexpected or otherwise difficult to perceive information source or condition in a roadway environment; to recognize the conditions or its potential threat; to select an appropriate speed and path; and to initiate and complete complex maneuvers.<sup>10</sup> DSD provides drivers additional margins for errors whenever there is likelihood for errors in information reception, decision making or taking actions by the drivers. The DSD varies depending on the level of complexities and also on the road environment (e.g. urban, rural). To accommodate the variation in human capabilities in driving, a roadway is recommended to have Decision Sight Distances provided for drivers at all locations.

Table 1, extracted from the AASHTO Green Book, shows the DSD for different levels of complexities in different roadway environments.

**Table 1 Decision Sight Distance (DSD)**

Metric						U.S. Customary					
Design Speed (km/h)	Decision Sight Distance (m)					Design Speed (mph)	Decision Sight Distance (ft)				
	Avoidance Maneuver						Avoidance Maneuver				
	A	B	C	D	E		A	B	C	D	E
50	70	155	145	170	195	30	220	490	450	535	620
60	95	195	170	205	235	35	275	590	525	625	720
70	115	325	200	235	275	40	330	690	600	715	825
80	140	280	230	270	315	45	395	800	675	800	930
90	170	325	270	315	360	50	465	910	750	890	1030
100	200	370	315	355	400	55	535	1030	865	980	1135
110	235	420	330	380	430	60	610	1150	990	1125	1280
120	265	470	360	415	470	65	695	1275	1050	1220	1365
130	305	525	390	450	510	70	780	1410	1105	1275	1445
						75	875	1545	1180	1365	1545
						80	970	1685	1260	1455	1650

Avoidance Maneuver A: Stop on rural road— $t = 3.0s$

Avoidance Maneuver B: Stop on rural road — $t = 9.1s$

Avoidance Maneuver C: Speed/path/direction change on rural road— $t$  varies between 10.2 and 11.2s

Avoidance Maneuver D: Speed/path/direction change on suburban road— $t$  varies between 12.1 and 12.9s

Avoidance Maneuver C: Speed/path/direction change on urban road— $t$  varies between 14.0 and 14.5s

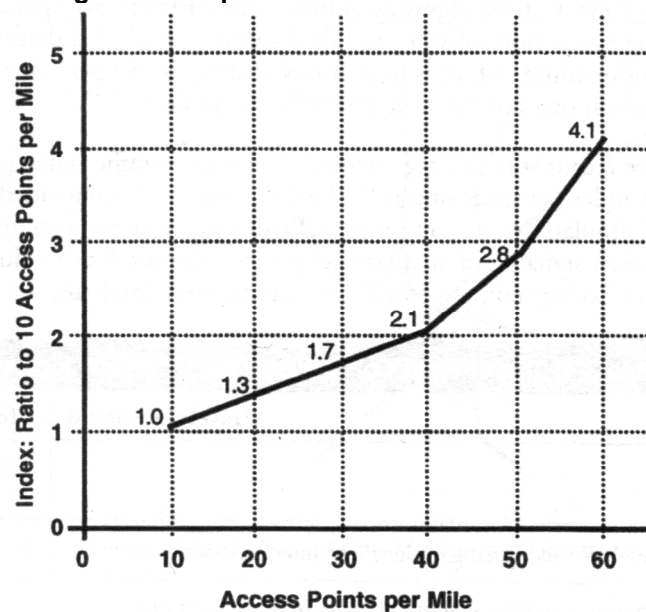
Source: The AASHTO Green Book

### 1.5 Access Management

Access management is the concept that access-related vehicular maneuvers and volumes can have serious consequences on the performance of traffic operations and road safety. The benefits are significant, particularly in urban street environments where access points are numerous and traffic volumes are high.

Access management complements geometric design by reducing the likelihood of access related vehicular conflicts or reducing the severity of the conflicts, by reducing the frequency of major conflicts of movements. Generally, it can be expected that a doubling of access point frequency from 10 to 20 per kilometer increases crash rates by roughly thirty percent (30%). Another doubling of access frequency from 20 to 40 driveways per kilometer is expected to increase crash rates by sixty percent (60%). Applications of access management principles alone to existing urban corridors generally results in reducing road crashes between 30 to 60 percent.<sup>11</sup> In Malaysia, poor access controlled or uncontrolled Federal Highways have much greater road crash rates than the well-controlled expressways.

**Figure 2 Composite Crash Rate Indices**



Source: ITE (2008) *Urban Street Geometric Design Handbook*

## II. THE CONCEPT OF “FORGIVING ROAD SIDE DESIGN”

Roadways should be designed to reduce the need for driver decisions and to reduce unexpected situations. The number of crashes increases with the number of decisions that need to be made by the road user. Uniformity in highway design features and traffic control devices plays an important role in reducing the number of required decisions, and by this means, the driver becomes aware of what to expect on a certain type of highway.

The concept of the “forgiving road side design” includes the provision for a clear recovery area. When a vehicle leaves the roadway in a crash, the driver no longer has the ability to fully control the vehicle. In general, this means, when a driver commits a mistake due to unavoidable circumstances, his or her mistakes will be forgiven by the design concept. The concept of “forgiving roadside design” should not be independently applied to each design element but rather adopted as a comprehensive approach to highway design.<sup>12</sup>

### III. THE “POSITIVE GUIDANCE” APPROACH IN ROAD DESIGN

Basic knowledge of human characteristics and limitations, and human reliance on expectation to compensate for those limitations in information processing, is important in road design. This led to the development of the “positive guidance” approach in road design. Information processing demands beyond the drivers’ capabilities overload and confuse drivers. A common characteristic of high risk road locations is that they place large or unusual demands over the information-processing capabilities of a driver.

There are long-term and short-term expectations developed in the driver’s minds. For example, a long-term expectation includes no Stop sign will be placed at an approach location on a high speed road; however, there are places where high speed roads do have Stop signs. Short-term expectations include after negotiating a series of gentle slopes, the driver will find a sudden change in the type of slopes.

Knowledge of both engineering principles and the effects of human factors can be applied through the positive guidance approach. The “positive guidance” approach means that road design that is based on the drivers’ limitations and expectations, increases the likelihood of drivers responding to the situations as necessary thus preventing crashes. Potential driver behaviour can be anticipated in the road design process to assess the design and when trade-offs are appropriate, should be applied. Properly designed highways that provide positive guidance to drivers can operate at a high level of safety and efficiency.

### IV. SOME FINDINGS FROM THE INTERNATIONAL ROAD ASSESSMENT PROGRAM (IRAP)

International assessments have shown that in low and middle-income countries, reasonable investments for improving road geometry can be easily recovered through benefits from road crash savings. One useful tool is the International Road Assessment Program, or iRAP. For example, one iRAP report<sup>13</sup> showed that widening of selected 40-km road sections in Bangladesh could prevent 8,400 deaths with a benefit-cost ratio of five. Similarly, providing 270-km of motor cycle lanes in Malaysia could save 900 lives with a benefit-cost ratio of fifteen.

Star ratings are an objective measure of the likelihood of a crash occurring and its severity. They draw on road safety inspection data and the extensive real-world relationships between road characteristics and crash data. Thus, a methodology based on one to five (1-5) star ratings on the crash risk of any given roadway developed by the International Road Assessment Program (iRAP) helps to prevent road accidents through prioritization of road infrastructure proactively.

The Karnataka State Highway Improvement Project (KSHIP) funded by the World Bank in India, set a good example of how road design can help to improve the road safety situation. The initial target set was to have “three-stars” for the demonstration corridors. The process ultimately resulted in the design of better roads. These new designs were expected to result in fifty five percent (55%) fewer deaths and serious injuries than the baseline condition.

### V. CONCLUSIONS

“Road infrastructure” plays a vital role in road safety. Although a small proportion of crashes are exclusively caused by roadway factors, a significant number involve roadway factors in some way. The second pillar of the UN Global Plan for the Decade of Action for Road Safety 2011-2020 thus puts a lot of emphasis on raising the safety and protective quality of road networks for the benefit of all road users.

Knowledge of roadway parameters affecting road safety can help to plan, design, build and maintain the road infrastructure to facilitate a safe road environment. The design of roads plays a major role in terms of road safety. The concept of “forgiving roadside design” should be applied and the “positive guidance” approach should be adopted to reduce the road crash frequency and severity. International experiences show that interventions in terms of road infrastructure to improve the road environment can pay for themselves and the financial investments can be recovered within a reasonable period of time.

## ENDNOTES

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## ENGINEERING DESIGN STANDARDS TO ENSURE ROAD SAFETY: EXPERIENCES FROM INDIA

Atul Kumar<sup>1</sup>

### ABSTRACT

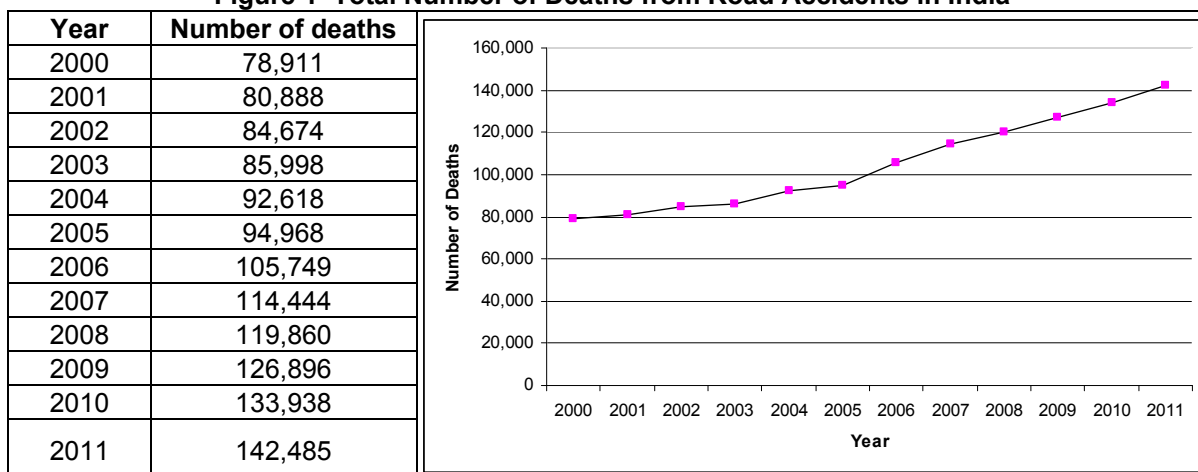
The primary goal of designing roads with adequate standards is to achieve a safer transport facility for both motorized and non-motorized road users. However, the responsibility of road safety has traditionally been placed on the individual road user rather than on the designers of the system. Thus in practice, the upgrading of roads results in increasing accident rates, despite attempts by engineers to follow the appropriate standards.

Drawing on experiences from India, this article deals with the key aspects of the causes of road accidents from the viewpoint of design standards. It highlights best practices from the aspect of design, which if applied can help to reduce road accidents and fatalities. The design aspects dealt with in this article looks especially at the eradication of road injuries for non-motorized transport and vulnerable road users.

### INTRODUCTION

The road safety record on Indian roads has steadily worsened over the past decade. As can be seen from Figures 1 – 3 below, the number of persons killed or injured in road accidents has been steadily rising since 2000. It is a matter of serious concern for all stakeholders. One issue of particular concern is that around 60% of victims are Vulnerable Road Users (VRUs) such as pedestrians, bicyclists and so on.

**Figure 1 Total Number of Deaths from Road Accidents in India**



Source: Ministry of Road Transport and Highways, Government of India

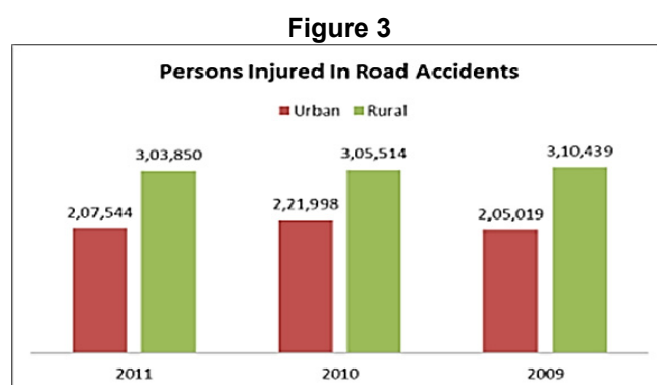
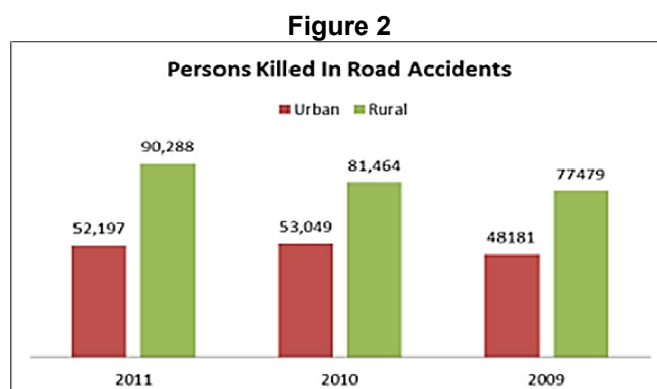
There are many reasons for the rise in traffic fatalities. Among them, the following are three major causes of road crashes in India:

- Though mobility has been improved, Vulnerable Road Users (VRUs) are sharing the same road space and the roads have inadequate safety measures for VRU.

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- Inadequate enforcement of traffic rules and lack of awareness by the road users.
- Engineering measures to upgrade the highways are inadequate.

Figures 2 and 3 show the number of persons killed and injured in urban and rural areas between 2009 and 2011. This data suggests that road safety in both types of areas is poor, but there are more people affected in rural areas.



It is an accepted norm that whenever a highway is upgraded in terms of width and other engineering features, one of the primary considerations is that it should become safer for users. However, this may not be the case if the engineering measures adopted are not done with due diligence and are not suitable for local requirements. In fact, in many cases, it has been observed that the accident rate increased after highways are upgraded, in spite of good enforcement of regulations and a large proportion of relatively new automobiles.

### I. HIGH ACCIDENTS DUE TO INADEQUATE ENGINEERING MEASURES

Since 2000, India has undertaken a massive highway up-gradation programme, the “National Highway Development Programme (NHDP)”, totaling 55,528 km of highways. As of October 2013, over 21,000 km of highways had been upgraded/constructed and over 12,000 km was under construction in different stages. The highways have been upgraded to international standards. However, the existing road accident scenario on Indian highways is very grim and is increasing exponentially.

Table 2 shows monthly accident data collected from the Concessionaire for a recently completed national highway in South India, the NH 9 from Hyderabad to Vijayawada, shows that where mobility has been improved, the total number of accidents has also gone up. In the Indian context, causes like contra-flow and speeding, which is associated with lack of enforcement of highway regulations, are usually involved.

**Table 2 Accident Totals in a Recently Upgraded 4-lane Highway (180 km)**

Months	Fatal	Grievous Injury	Minor Injury	Total Accidents
2012 December	27	15	48	65
2013 January	13	36	53	52
2013 February	9	44	64	10
2013 March	23	16	79	59
2013 April	7	15	67	69
2013 May	21	42	130	107
2013 June	13	27	63	98
2013 July	14	16	48	73
2013 August	6	26	73	79
2013 September	6	17	67	66
2013 October	11	31	117	89
	<b>150</b>	<b>285</b>	<b>809</b>	<b>767</b>

Source : Concessionaire, M/S. GMR Hyderabad Vijayawada Expressways Pvt. Ltd. & Independent Engineer, ICT Pvt. Ltd.

It is worth noting that these accidents have been caused despite high standards for the new highway. In this regard, it is necessary to look at some of the most important areas where there may have been faults in the engineering design.

## II. BEST PRACTICES IN ENGINEERING DESIGNS FOR ROAD SAFETY

The Ministry of Road Transport and Highways<sup>2</sup> and the National Highway Authority of India (NHAI)<sup>3</sup> of the Government of India has circulated the examples of good practices for road safety. The ten most important areas which require attention are:

- 1) Geometry of the road
- 2) Segregation of local traffic
- 3) Pedestrian facility
- 4) Bus bays
- 5) Illuminations
- 6) Development of Junction
- 7) Signage
- 8) Traffic calming & Safety Management Measures
- 9) Bridges/CD structures
- 10) Road Safety Audit

### 1) Geometry of the Road:

Geometry of the road can be said to be the most important element in the road design. Faulty design/engineering measures will result in "Black Spots" i.e. areas of high accidents. Following aspects are key to good design:

<sup>2</sup> Letter No. RW/NH-35072/04/2004-S&R® dated 27<sup>th</sup> April, 2010 as a follow-up of 4<sup>th</sup> IRF Regional Conference Recommendations "Accident Prevention : Road Safety Measures"

<sup>3</sup> Circular No. NAHI/2008/Road Safety/IRF/588 dated 12<sup>th</sup> July, 2010.



- (a) Width: In urban areas, all through lane should be of normal width (3.5m) except the approaches through the junctions where the speed is expected to be very low, the lane width can be reduced to a minimum of 3.1metre [Indian Road Congress Code] for a length of at least 50metre in approach road. It is desirable to keep lateral clearance along multi-lane highway of at least 1.5m width from the edge of the carriageway without any obstacles. When a permanent object cannot be removed, provision of fenders and hazards markers with reflectors, frangible lighting column and speed posts need to be used for minimizing severity in case of collision.



*Hazard protected from collision  
on urban roads.  
Photo No- 1*

- (b) Slope: For green field projects of high speed highway/expressway for ensuring effectiveness of recovery zone a slope of 1:4 is required to be provided, and slopes steeper than 1:4 shall be provided with W-beam crash metal carrier.



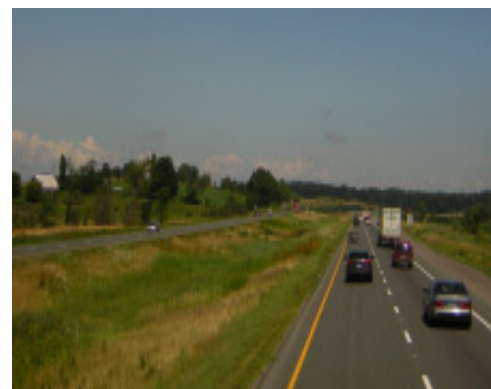
*Steep Side Slope with Guard Rail*

- (c) Median & crash barrier: Wherever adequate land is available, it is preferable to provide wide depressed median having width of 12m or more and in any case not less than 1.5 to 2m with W-beam metal crash barriers at the edge of the median.

In the case of narrow medians, 2m or less wide, are generally provided in urban areas, New Jersey type concrete crash barriers should be used along with anti-glare screen.

In the case of raise median, it is essential to provide W-beam metal crash barriers in the median along both the carriageways.

When two carriageways are at different levels, the median edge of the higher carriageway shall be provided with a W-beam metal crash barrier. Whenever embankments height is 3m or more, the W-beam metal crash barrier must be provided at the edge of the formation.



*Depressed Median*

## 2) Segregation of Local Traffic:

For safety of traffic operation, in cases of all multi-lane highways, local traffic has to be separated/segregated from the through traffic plying on the carriageway by service roads (minimum 5.5m wide) with safety fence, railing, etc. of robust and vandal proof design. Wherever service roads cannot be provided due to space constraints, then to protect the traffic it is essential to provide an additional width of paved shoulder with edge marking and ribbed pavement of at least 0.25m width. Adequate cattle underpasses, pedestrian underpasses and vehicular underpasses, truck lay-by should be provided at the important locations.

## 3) Pedestrian Facility

In urbanized sections, adequate pedestrian facilities are to be provided so that the pedestrians are not required to enter the main carriageway. All pedestrian underpasses wherever provided shall have a minimum 7m width, with a vertical clearance of 3.5m.



*Lane marking*

## 4) Bus bays

Suitably design bus bays at desired locations shall be provided along the main carriageway by using extra width together with approach and exit transition lanes. In no case, pedestrian should be required to enter in the main carriageway for cross-over or even to move along the highway. The safety features such as pedestrian foot over bridges, underpasses, etc. should be provided wherever required.

## 5) Illuminations

Stretches of highways in urban built up areas, underpasses and foot bridges shall be adequately illuminated so that a minimum 40 lux is available with 24 hours power supply, if required, supported by solar power.

## 6) Development of Junction

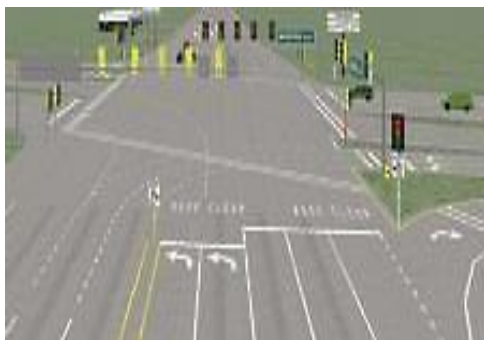
The crossing of a multi-lane highway by a primary road (National Highway/State Highway) shall preferably be through a grade separator. In case of other categories of roads (Major District roads, village roads), the excess should be preferably provided through service road.

When cross roads are to be brought to level of the service road and flared for appropriate length, stop/yield line and center markings shall be preferably provided. Rumble strips/speed breaker shall be provided on each cross road with warning sign and road marking. At all entry and exit, to and from the high speed highway, the merging and the diverting shall be only through suitable design acceleration lanes.

## 7) Signage

All signs preferably shall be of retro-reflective type. All curves with radius  $<750\text{m}$  be delineated on outer side of the curve from both the directions (for RH curve it will be on shoulder and for LH curve it will be on median) by chevron signs. The W-beam metal crash barriers will be fitted with delineating reflectors when they are installed on embankments with 3m or above.

In embankments and flat curves, where crash barriers are not provided, these need to be delineated by 1.5m high reflectorized delineators. One-way reflective road studs shall be provided on edge lines and lane lines on approach to inter-section or high level bridge/culvert/ROB etc. with high embankments and along the sharp curves.



*Lane Marking at Junctions*



*Traffic Calming Measures*

## 8) Traffic Calming & Safety Management Measures

Whenever a multi-lane highway passes through built-up areas, design should be such to bring about reduction in speed to the level of 60/70 km for which repeated bar markings with hot applied retro-reflective thermoplastic. White paint lines can also be provided at the approaches to such built-up areas.

## 9) Bridges / CD Structures

In the approaches to the to & exist form, bridges and other CD structures, W-beam metal crash barrier shall be provided in continuation of the parapet on both the carriageways for at least 30m in addition to hazard sign marking.

## 10) Road Safety Audit

A Road Safety Audit should be carried out at all stages of road development viz. planning, design, construction and operation. Black spots (locations of high accidents) should be identified and removed. All road safety audit recommendations should be implemented and followed religiously.

## III. CONCLUSION

In the 2011 report "Road Accidents in India", the Government of India acknowledges that "road accidents are a human tragedy."<sup>4</sup> In this regard, it recognizes that "data and analysis on road accidents contained in this volume will help create awareness and assist in informed decision making in the area of road safety". It is encouraging to see that under the 12<sup>th</sup> Five Year Plan, the Government has incorporated road safety audits as well as training of both engineers and road safety auditors as part of its strategy to design safer roads.

<sup>4</sup> <http://morth.nic.in/writereaddata/mainlinkFile/File835.pdf>