A SYSTEMATIC APPROACH TO ROAD SAFETY IN DEVELOPING COUNTRIES

by

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The World Bank
Washington, D.C.
The World Bank undertook this study in collaboration with the Swedish Road and Traffic Research Institute and the Swedish National Road Administration to contribute to a better understanding of the road safety problem in developing countries.

The main purpose of this report is to formulate a systematic approach to tackling the formidable problem of road accidents in developing countries by identifying suitable methods and approaches needed for efficient road safety work. The annexes to the study include a summary of the current knowledge of the magnitude and nature of road accidents in developing countries, examples of some road safety measures and their impact, and proposals for further work.

The report is mainly intended for government officials responsible for road safety programs in developing countries. The report should also be of interest to the staff of the World Bank and other organizations interested in road safety issues in developing countries.
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ABSTRACT

Road traffic accidents exact a heavy toll in developing countries. The magnitude of the problem is now recognized in most countries, and authorities have started to show an increasing concern to reduce accidents and their severity.

Safety improvements consume scarce resources. It is, therefore, important to develop cost-effective approaches and methods for allocating an optimum level of resources for road safety programs in developing countries.

This study, initiated by the World Bank in 1986, describes a systematic approach to address the road accident problem. The study identifies information and analytical methods needed for efficient road safety work and provides a framework for road safety activities. Institutional aspects of road safety are discussed including organization and staffing, information systems, and research and development.

The study proposes a series of studies and guidelines to provide a suitable knowledge base for organizing road safety activities in developing countries. It is suggested that the World Bank, the World Health Organization, concerned UN organizations, and other research and academic institutions working on road safety issues in developing countries coordinate their activities to improve the road safety situation in developing countries.
SUMMARY

Road traffic accidents constitute a serious and growing problem in many developing countries. When compared to industrialized countries, accident risks are higher and the effects of accidents are much more serious. In the developing countries one death per annum is recorded for every 50 to 500 motor vehicles, whereas the corresponding range in the industrialized countries is 2,000 to 5,000 motor vehicles. The directly quantifiable cost of road accidents in the developing countries is about one percent of the GNP, which implies a significant loss of efficiency in road transport, apart from human grief and suffering. Developing countries must reduce the fatality risk at a faster rate, as compared to industrialized countries during their early phase of motorization. Failure to do so will increase fatalities between 50 and 100 percent above present levels by the year 2000.

The magnitude of the problem is now recognized in most developing countries and government authorities have started to take measures to reduce accidents and their severity. Safety measures will inevitably consume scarce resources. It is therefore important to develop cost-effective approaches and methods and to provide information and knowledge which can be used in determining the most efficient safety measures and the most appropriate level of resources needed for their implementation.

The main purpose of this study is to present an overall, systematic approach on how to attack the accident problem and improve the present situation. The study provides a basis for identification of information and methods needed for efficient road safety work. It should be seen as the first of a series of studies and guidelines to provide a suitable knowledge base for supporting road safety initiatives in developing countries.

It is important to recognize that road transport activities inevitably generate road accidents resulting in fatalities, injuries, and property damage. Accidents and their consequences cannot be fully eliminated, only reduced. The selection of safety measures, in principle, should be based on an appraisal of all relevant effects, whether directly or indirectly related to accident prevention. If only some of the effects and costs are taken into account, the measures selected may lead to sub-optimal allocation of resources.

To choose efficient safety measures it is important to know the causes of accidents and how people are killed and injured. It has been a common practice to try to isolate the main component responsible for the accidents (the road, the vehicle or the road user) and to improve that component. Extensive research in the industrialized countries has, however, shown that this approach alone is not sufficient. In almost every accident there are several contributing factors which interact. Many of these factors have been identified in statistical investigations and countermeasures designed to reduce their impact. A substantial part of the knowledge and experience about safety improvements should be transferable from the industrialized to the developing countries, even though conditions among them vary widely.
There are three principal ways to reduce the incidence of road accidents: controlling road traffic, reducing the risk of accidents, and reducing the severity and consequences of accidents. Practical measures to reduce traffic accidents include a gamut of technical interventions -- land use, planning and control; road planning, design and maintenance; traffic operations and control; road user education, training and information; vehicle design, utilization, and inspection; medical care services; and traffic legislation, regulations, and enforcement. Safety can also be enhanced by 'institutional' measures, such as improvements in coordination of safety activities, staff education and training, and safety research and development. In addressing the road safety problem, all these measures need to be examined and assessed comprehensively.

The complexity of the subject, the wide array of available countermeasures, the need to take all relevant effects into consideration, and the level of coordination required among the many parties involved call for the development of a broad and systematic approach. Although difficult to implement at first, because of the lack of basic information and methods, it is still recommended that road safety work in developing countries should be based on a comprehensive, inter-disciplinary approach to start a continuous process resulting in progressively well-balanced safety programs.

Road safety activities must be adapted to the cultural, social, economic and technological environment of a given country, the educational level of the population, and the safety organization. The state of the road transport system (road network and the vehicle fleet) to a large extent influences the scope and extent of road safety improvements.

The first step in the road safety process is the setting of goals. They must be based on the current accident situation, and the resources and opportunities available for improving safety. The setting of safety goals is important if effective coordination among the various parties involved in the safety process is to be achieved. Quantitative goals, sometimes called target values, facilitate the management and control of a safety program.

After goals have been set, planning of safety measures can follow. The purpose of planning is to determine the problems to be remedied, the measures to be used, their priority and timing. Planning consists mainly of the following activities:

(a) data collection and analysis;
(b) identification of safety measures;
(c) setting of priorities; and
(d) design of safety programs.

* Data collection and analysis is an important step in safety work. From collected data, it is possible to assess the magnitude and the nature of the accident problem and to identify specific troublesome areas. Resources can then be targeted to those areas and thus used most efficiently. Accident analysis normally involves the study of accident statistics, and in some cases proxy-variables. It should
Identification of safety measures involves a more in-depth analysis of the accident patterns, their causes, preliminary choice of a number of potential countermeasures, estimation of their benefits and costs, and final selection of the best remedial actions for each problem. This problem-oriented approach should be supplemented by a more measure-oriented approach based on the study of other safety-related areas, such as road and vehicle conditions, and driver education. The choice of road safety measures should be based on estimates of benefits and costs.

Setting of priorities involves choosing safety initiatives that should be carried out first, based on available funds and the cost-effectiveness of the measures, relative to established safety goals.

Design and organization of a safety program involves development of an integrated program to improve safety more rapidly and more efficiently than would have been otherwise possible. Safety experts believe that the design and implementation of efficient safety programs requires a multi-disciplinary approach. The success of such an integrated effort demands an input from many disciplines to be incorporated in the work of the various entities involved in the program. Preferably, overall coordination should be entrusted to a special unit with the ability and authority to integrate the work of established institutional structures. In developing countries, where data and expertise are often scarce and coordination among authorities and organization difficult to achieve, it is often necessary to begin with a more modest approach, involving a limited number of key 'technical' improvements, together with some basic 'institutional' changes.

The financing of safety programs is often a constraint in developing countries where road safety may be perceived as a luxury compared to other urgent needs. It is thus important to show the benefits to be derived from the suggested safety measures. During recent years the prospects of foreign financing through bilateral and international sources have increased.

The implementation of a safety program should include monitoring as well as normal implementation activities, such as the designation of the competent agency responsible for safety programs; the appointment of staff and managers; assignment of authority, responsibility, and resources; and the design of detailed action plans, and their execution. Monitoring is intended to help program management to assess progress and to take appropriate action in order to complete the program in the best possible way.

Evaluation aims to assess the overall results of the measures undertaken during the program in terms of direct outputs, effects and costs, and, to the extent possible, the causal links and long-term impact. The results of
Evaluation provide valuable insights for future programs. Evaluation serves as an important planning tool and provides inputs for the development of the safety process.

To follow the approach outlined above it is necessary to have methods and knowledge, to carry out the different safety activities in an effective way; information systems to have access to the information needed; and research and development to improve the state of the art in road safety. Areas requiring urgent attention are: road safety indices, appraisal and evaluation methods, effects of safety measures, and monetary valuation of accidents.

- **Safety indices** have to be defined and it is important that they can be calculated with sufficient accuracy. There are many measures possible: number of accidents and casualties; risk of accidents and casualties; and number of accidents weighted according to their severity and expressed in terms of accident costs or severity indices. Safety could also be determined by safety-proxies, such as conflicts and other measures of road user behavior and attitudes.

- It is important to use appropriate methods for the appraisal of different safety measures. If the overall objective is the efficient use of scarce economic resources, then cost-benefit analysis is suitable. If the only objective is the effective use of a specified safety budget, then cost-effectiveness analysis could be used. In most cases, however, when all effects have to be taken into account and when there is no specific safety budget, cost-benefit analysis, combined with a multi-criteria analysis for intangibles, is probably the most suitable appraisal method.

- Knowledge of the effects of safety measures is needed to appraise different improvement options and to design effective safety projects and programs. It is therefore important to compile and analyze information from different sources to make reliable estimates of the effects of safety measures under different circumstances. Such information should be assembled in special handbooks, to be updated as new information becomes available. A state of the art compilation of current practice and its applicability to conditions in developing countries would be valuable in determining more reliable estimates of the effects of safety improvements.

- Cost-benefit analysis requires explicit monetary values attributed to accident prevention or risk reduction. Countries whose policies are oriented towards output objectives can best determine such values by using the gross output approach. Another possibility is to use the willingness-to-pay approach. This method, however, is not easy to apply because of the lack of data. It is therefore suggested that gross output values be used as a lower limit, as long as relevant data are lacking.

- There are different statistical methods for evaluation of the effects of safety measures: statistical experiments, before-and-after
studies, and regression and correlation studies. From a theoretical point of view, statistical experiments offer the best method, but in practice they are very difficult to implement. A reliable evaluation of a safety program is a difficult task which requires careful planning and experienced, highly qualified staff. Evaluation is closely connected to research and there is a need to develop evaluation methods adapted to specific situations in different developing countries.

To carry out efficient safety work, it is necessary to have access to reliable information on accidents, traffic, and factors contributing to road accidents. Appropriate safety information systems can provide an effective means of collection, storage, processing, analysis and presentation of data. The information is needed for describing the safety situation, setting goals, analyzing safety problems, evaluating safety measures, and for research and development. Developing such systems, therefore, should be one of the first steps in safety work. Initially, the systems could be rather simple and contain basic statistics about accidents and casualties. In the following stages, however, the systems should be developed into more complete information systems, incorporating information on traffic, roads, vehicles, road users and other factors influencing road safety.

Research and Development (R&D) is an integral part of safety work. R&D generally aims to improve knowledge about accident-contributing factors and the effects of different countermeasures, and to develop new and more effective safety measures. Safety R&D should be interdisciplinary involving engineers, statisticians, behavioral and social scientists, and economists. In the developed countries, extensive safety R&D has been carried out, and there is need to analyze what results are transferable to the developing countries. It is, however, perhaps even more important for the developing countries to build up their own road safety R&D resources because the applicability of research results from developed countries can always be questioned, and because domestic R&D is essential for understanding and generating interest in safety.

This report has identified a number of areas where there is an urgent need for studies and guidelines adapted to the specific conditions in developing countries. The most important are:

- information systems for road safety;
- effects of road safety measures;
- determination of monetary values of accident prevention;
- monitoring and evaluation of road safety measures and programs;
- road safety organization, management and staff;
- review of models, guidelines, and standards concerning safety-related areas; and
- road safety research and development.

This is an extensive agenda and it is important that available resources be used in an efficient way. The United Nations, the World Health Organization, national
Aid organization and research institutions have shown increasing concern for the road accident problem in the developing countries. It is suggested that the Bank actively seek to improve cooperation and coordination among the parties concerned. The Bank is in an ideal position to promote road safety given its long-standing support for highway and urban development projects and its close association with road transport development in developing countries. The Bank should also strengthen its institutional contacts on road safety matters with the UN organizations and other international (e.g. OECD), regional (e.g. Asian Development Bank) and national organizations, as well as research organizations and the academic community.
I. INTRODUCTION

The Road Accident Problem

With the rapid pace of motorization and the associated growth in road transport, road accidents have become a major cause of human fatalities and injury worldwide. Road accidents exact a heavy toll indeed (ref. 1):

- some 300,000 individuals killed annually;
- 10 to 15 million persons injured annually;
- more than 10% of all hospital beds occupied by road casualties;
- substantial economic and social costs besides grief and physical suffering; and
- a level of risk higher than in most other human activities.

In many industrialized countries road casualties have started to show an upward trend after declining for the last 10-15 years. In the developing world the road accident problem is already quite serious (see Annex A for details). In many developing countries, road accidents are a leading cause of death and road casualties put a heavy burden on the already overloaded medical facilities and services.

The accident risk (number of accidents per traffic exposure, such as vehicle-km) is normally higher in developing countries, and the consequences are far more serious. Annual fatalities per 1,000 motor vehicles range from 2 to 20 in developing countries compared to 0.2 to 0.5 in industrialized countries. Expressed differently there is one death per year for every 50 to 500 motor vehicles in developing countries, whereas in industrialized countries the comparative figure is one death for each 2,000 to 5,000 motor vehicles.

During their earlier stages of motorization, the industrial countries experienced fatality rates per motor vehicle as high as those experienced by developing countries today. A rather consistent relationship between the fatality rate per motor vehicle and the level of motorization (motor vehicles per inhabitant) emerges from cross-sectional analysis comparing countries at different levels of motorization and from time-series analysis comparing different levels of motorization in the same country. Using this relationship and assuming a 5 - 10% annual increase in the number of motor vehicles, and a 2 to 3% annual increase in population, it is estimated that road accident fatalities in developing countries will be 50 - 100% higher by the year 2000 as compared to the current levels, unless these countries achieve a more rapid decrease in the fatality risk than has occurred in developed countries during their corresponding phase of motorization.

The costs of road accidents in developing countries are already considerable; a conservative estimate is about 1% of the Gross National Product (GNP) (ref. 22). High accident costs imply a substantial loss of efficiency in
road transport, apart from grief and suffering which are undoubtedly the gravest consequence of road accidents.

The seriousness of the road accident problem is recognized in most developing countries, and national authorities have started to show an increasing interest in reducing road accidents and their severity. Safety improvements, however, will consume scarce resources for which there are many other urgent and competing demands. It is therefore important to promote a better understanding of the road accident problem and its consequences, to find the most efficient safety measures, and to provide information and knowledge which can be used to determine a cost-effective allocation of resources for safety improvements.

Bank Involvement in Road Safety

Road safety improvements have become an integral element of Bank-financed urban transport and road construction, improvement and maintenance projects. Over the last 15 years, the Bank's involvement in road safety has become more explicit and the lending for safety has increased (ref. 40). In addition, the Bank has actively supported several international seminars and symposia concerning road safety. In 1982 the Bank issued internal guidelines for road safety lending and related operational work (ref. 41).

A 1981 review (ref. 3) identified specific road safety components in some 40 Bank-financed transportation and urban development projects. At that time, about 50% of the projects in the Latin America and Caribbean region, and in the region comprising Europe, Middle East, and North Africa contained such safety components, while the corresponding figure for the remaining developing countries was 10%, an indication that the more developed and motorized of the Bank's borrowers had already realized the need for road safety improvements.

A review of some 90 highway projects in 1986 showed that about 30% of these projects, mostly in African and Asian countries, contained an explicit road safety component. The costs of these components, however, were normally low, in the range of US$0.2 to 1.0 million, corresponding to 1 to 5% of total project costs. A typical safety component included road safety studies, vehicle inspection centers (including equipment), civil works (such as 'black spots' improvements, road signs and markings and equipment for such works), equipment and vehicles for police, and technical assistance. Bank lending for identified road safety components in highway projects has averaged US$10 to 12 million per annum over the last five years. This amount represents about 1% of the annual Bank lending for highways. Not included in this amount is a large sum for implicit safety components in urban development and rural roads projects.
II. GENERAL BACKGROUND

The Road Safety Environment

In discussing road safety, it is useful to delineate the main focus of interest, that is, the road transport system. The system consists of three main physical components: road users (including drivers), vehicles, and roads (including their environment). These components and their interaction, which constitute road traffic, are influenced by, and have an effect upon, a variety of economic, social and technological factors.

Some of these factors -- such as driving schools, vehicle manufacturing, licensing, and inspection, land use in the immediate surroundings of the roads, and traffic legislation and its enforcement -- are closely related to the three improvements of the road transport system. Other more external factors such as education, emergency medical services, and land use in general, are linked to other sectors of the economy but still have an influence on, and are affected by, the operations of the system.

The direct purpose of improving road transport conditions is to promote and improve the mobility of people and goods. Good accessibility and low transport costs are therefore concomitant objectives. Changes in road transport conditions besides affecting the volume and type of traffic can influence a variety of related factors:

- site accessibility;
- travel speed, delays, and travel time;
- vehicle operating costs;
- accidents and their consequences;
- comfort and convenience;
- noise and other vibrations;
- air and water pollution;
- visual scenery, esthetics;
- physical and social barriers;
- land use; and
- natural environment (geology, flora and fauna).

The determination of what actions should be taken to improve road safety is usually complicated by the number of parties involved, who often have conflicting interests, some of which are directed at achieving objectives other than public welfare. The decision on what actions should be taken by a public authority (for example a Department of Transport) should, in principle, be based on estimates of all relevant future effects of different possible actions, and on appraisals of their relative advantages and disadvantages. These appraisals should include the extent to which the potential actions contribute to the solution of safety problems, the attainment of safety goals, and efficient use of scarce economic resources. Not until such analyses have been completed should actions be selected and prioritized for implementation.
If, for example, a national road authority is planning minor road improvements to reduce accidents, it is normally possible to estimate not only the safety effects, but also the effects on travel time and vehicle operating costs, and, in the final appraisal, to compare the relevant costs and benefits. If, on the other hand, a national Parliament has decided that road safety in general must be improved, and that all parties concerned should coordinate their efforts, then it becomes far more complicated to take all relevant effects into consideration in a uniform manner. This is mainly because the actions and their effects involve many different organizations and decision-making processes within these organizations can be quite variable.

Causes of Road Accidents

Searching for causes of road accidents has always been an important task in the effort to improve road safety. Earlier attempts to formulate theories or models of the occurrence of accidents was predicated on the assumption that one factor could be singled out as the main cause of an accident. The factors were normally grouped according to the components of the road transport system, that is, the road user, the vehicle, and the road and its environment. Early accident investigations showed that about 90% of all accidents could be attributed to road user characteristics. The main problem with this approach is that the basic assumption compels the investigator to choose a single factor from many which could have contributed to the accident. Normally the road conditions are compared to prevailing road standards, the vehicle conditions are checked against vehicle standards and regulations, and road-user behavior is examined for compliance with existing traffic rules and regulations. Even if accidents must be reviewed in the context of traffic regulations, a strictly legalist approach is inadequate to pinpoint their causes. The following example illustrates the point.

"A drunken driver drives his car off the road on a sharp horizontal curve and hits a tree. He is not wearing his seat belt and there is no legal requirement in the country that he should. The driver is killed on the spot."

There are many possible reasons why the accident happened and the driver lost his life:

- the driver was drunk — it is known that intoxicated drivers are exposed to higher accident risks;
- the curve was sharp — sharp curves increase the accident risk, even if they conform to standard design practice and even when negotiated by sober drivers;
- the tree was there — if hard objects near the road are removed accident consequences are likely to be less serious; and
- the driver did not use his seat belt — seat belt legislation will increase their use substantially and therefore reduce accident severity.
A more analytical description of the accident provides many more clues on how to improve safety compared to the very obvious legal approach that the driver caused the accident because he was drunk.

Careful and very extensive investigations of road accidents have shown that almost always there are several factors that probably contribute to an accident. Most researchers today agree that in almost all cases it is not correct to try to isolate a single main cause of an accident. Moreover, it can even be misleading to use the concept of explicit causality in road accidents. A more appropriate and preferred usage is the concept of accident-contributing factors or risk-increasing factors. The high incidence of road accidents has made it possible to analyze the statistical relationship between the number and severity of accidents and different explanatory factors. In this way it has been possible to isolate factors which are important in explaining accident-related situations. Some important factors, which are known to increase the risk of accidents and/or increase the severity of accidents, are listed below (ref. 23, 25, 26 and 27):

**Road User Factors**
- road users under the influence of alcohol and other drugs;
- young and inexperienced drivers;
- very old road users;
- speeding drivers;
- reluctance to use safety devices (seat belts, helmets, etc.); and
- stress, fatigue, illness.

**Vehicle Factors**
- motorcycles;
- lack of seat belts;
- poor crashworthiness design;
- worn tires;
- poor brakes; and
- non-functional lights.

**Road Factors**
- intersections;
- narrow roads;
- low alignment standards (especially combinations of severe grade and curve);
- uncontrolled access;
- poor visual guidance (lack of road markings etc.);
- low friction;
- hard objects near the road, steep ditches; and
- high or/no speed limits.

**Traffic and Environmental Factors**
- mix of slow and fast vehicles;
- interaction between motor vehicles and pedestrians;
mix of heavy and light vehicles;
* animals on the road;
* poor surveillance and enforcement;
* inadequate emergency medical services; and
* darkness, fog, rain, and snow.

Many studies have shown that the factors mentioned above contribute to higher accident risks and/or to more serious accidents. The analytical methods used in these studies include: simple correlation analyses, more advanced multivariate analyses, and before-and-after investigations. In these investigations, however, the road transport system is considered as a black-box and very little is known about how different factors interact. The main limitations of these studies are insufficient accident data and inadequate information on road users, vehicles, and road conditions. Another limitation of this approach is that it gives only a very fragmentary picture of the accident problem and of the most cost-effective countermeasures. There is, however, an increasing awareness that, in order to be successful, the study of road safety has to be predicated upon a broader understanding of the complete accident picture, including the accident and casualty generation process.

In recent years, many countries have launched integrated road safety programs which attempt to incorporate all the diverse elements related to accidents and casualties, starting from the traffic generation process to the treatment and rehabilitation of the accident victims (ref. 28). Such safety programs are likely to increase the efficiency of road safety work and should generate new solutions to the accident problem.

Safety Measures

Road safety can be improved by a number of measures, which may be classified into two broad groups:

* direct measures intended to mainly improve safety; and
* indirect measures intended to mainly improve road conditions, or the transport system in general, but also affecting safety.

Direct measures include road safety activities, such as road user education and training; vehicle safety equipment (e.g., seat belts) and inspection; road safety equipment (e.g., break-away lighting columns) and 'black-spot' improvements; and safety regulations and enforcement. Indirect measures include activities concerning land use, road construction and maintenance, vehicle design and equipment, and medical care services.

Theoretically, there are five principal approaches to reducing road accidents and casualties:

* by reducing personal travel and transport demand in general;
* by reducing road traffic in particular;
* by reducing the risk of road accidents;
* by reducing the severity of road accidents; and
* by reducing the consequences of accidents.
In practice, these methods can be applied in a variety of ways. The most important measures are illustrated in Figure 1.

Improvements in communication, for instance, tele- and data-communication, can probably, but only to a limited extent, reduce the demand for travel and transport in general, and thus reduce road accidents. Changes in taxes, fees, and regulations can modify the demand for travel and transport. Increased prices of automobiles and fuel, as well as increased charges on usage and parking, may help to reduce automobile traffic and so may improvements in other modes of transport.

Land use and urban development affect the need for travel and transport. Improved road safety can be achieved if land use is controlled to shorten travel distances, to promote the use of safe means of transport, and to reduce potential conflict points between crossing traffic flows.

Built-up zones are normally divided into more or less clearly defined areas (so called neighborhoods), with certain uniform characteristics, for example, residential areas with private homes, local playgrounds, primary and secondary schools, and local shops. In order to reduce the risk, and to some extent the severity, of accidents, through traffic should be directed around the neighborhood and only local traffic allowed to enter the area. Through traffic should be routed to major roads with fairly high speed limits and where little delay will be experienced. Local traffic, on the other hand, should be forced to drive at relatively low speeds, possibly with the aid of speed-reducing devices, such as bumps. In general terms, there should be a differentiation of different types of traffic in order to avoid unnecessary traffic in the neighborhoods and to make the traffic more homogeneous on each class of road. There should also be a separation of different types of road users, that is, motor vehicles should be separated from slow-moving traffic, such as pedestrians, bicycles and animal-drawn carts. This is most important for roads with heavy and fast traffic. The separation should preferably be spatial, for instance, by using special pedestrian and bicycle routes and exclusive pedestrian precincts, but could also be in time, for example, by using traffic signals.

Road characteristics affect the risk of accidents, and, to some extent, the severity of the accidents. In order to reduce risk, roads should be adapted to the perceptual and behavioral performance of the road users. This implies that roads should be designed, equipped, maintained and operated in such a way that sudden elements of surprise are avoided and that information acquisition and decision-making are facilitated. This could, for example, be achieved by sufficient road width, smooth alignment, suitable location and design of intersections, sufficient sight distances, clearly visible markings and signs (fixed and variable message), good lighting, and sufficient friction. In addition, roads and their equipment should be designed to reduce the severity of accidents, that is, they should be 'forgiving.' This means that side slopes should be flat, guard rails and lighting columns should have 'break-away' design, and fixed roadside hazards should be removed.

The road users are the critical element in the system. Their skills are often very difficult to improve. Their basic perceptual characteristics can
Figure 1. Classification of road safety measures
hardly be changed at all; while their information acquisition, decision-making and behavior characteristics can be influenced to some extent, their crash tolerance can only be improved by artificial means (ref. 1). The methods to improve road user performance are primarily: screening, education, training and testing, publicity campaigns, and surveillance and enforcement. Screening should be used to make sure that the road users, mainly the drivers, fulfill certain basic requirements concerning vision, hearing, and physical and mental capability. Education and training is used to teach the users how to behave in traffic, for example, to obey traffic laws and regulations, such as not to exceed speed limits, not to drive when intoxicated, and to use seat belts. Education and training should preferably start in kindergarten and continue in public schools and in special driving schools. Testing should be carried out by experienced examiners to check the theoretical and practical skills of potential drivers. Media should be used to inform the public about new rules and regulations, particularly hazardous conditions, and suitable safety improving actions. Such information and safety propaganda is often produced and disseminated by special safety organizations. Surveillance, enforcement, and finally penalties have to be used to ensure that the road users adhere to the rules. In addition, the road users' crash tolerance should be improved, for example, in the case of motorcyclists, by the mandatory use of safety helmets and protective clothing.

The characteristics of vehicles also affect the risk and severity of accidents. To ensure a high level of safety, vehicles should be designed, equipped, and maintained to avoid crashes, and to protect occupants and pedestrians. Accidents can be avoided if vehicles have good stability, effective steering and braking performance, well-functioning lights and reflectors, and good visibility characteristics. Occupants can be protected by sufficient exterior and interior deformation zones and certain safety features, such as seat belts, headrests, and special seats for children, while pedestrians can be protected by suitable exterior design, such as bumper height. As vehicles age, resulting in worn tires, faulty brakes and lights, etc., safety-related components should be properly maintained. This could be achieved by occasional or periodic vehicle inspections, which in turn require experienced inspectors and adequate facilities.

Traffic legislation, regulations and enforcement, which are closely connected to several of the other activities, also affect road safety. The aim of traffic legislation is to establish general rules for road users, vehicles and roads, and their interaction in traffic. Some of the rules also regulate the design, maintenance, and control of vehicles and roads. Most of the rules, however, are aimed at regulating the traffic on the roads and at improving the behavior of road users. Examples of the former are one-way traffic regulations, speed limits, and stop and yield signs. Examples of the latter are rules concerning use of alcohol and drugs while driving and the use of seat belts. In order to be effective, the rules must be perceived as reasonable. In most cases, however, legislation and regulations alone are not sufficient. They have to be supported by effective enforcement, usually by the police. Examples of such activities are speed and alcohol checks.
When accidents occur, suitable medical care services are required to reduce the consequences of the accidents. These services should include alarm systems for calling rescue services, ambulances with trained personnel and equipment and wayside telephones, hospitals with emergency care units, and clinics for rehabilitation.

Road safety can further be improved by other measures taken within or outside of the road transport system. Examples of the former are motor vehicle insurance premiums reflecting the accident records of the driver and the type of vehicle, and reduced taxes on safety related car equipment. Examples of the latter are improved general education and improved channels for safety information, such as radio and television.

Besides these technical measures, road safety can be improved indirectly by institutional measures, for example, by giving clear authority and responsibility to the different agencies involved in road safety, creating an entity responsible for the coordination of the various safety activities, educating and training staff responsible for safety activities, and by allocating sufficient public resources for safety related actions. It should also be noted that most safety measures have to be based on results from research and development.
III. THE ROAD SAFETY PROCESS

The complexity of factors influencing road safety, the wide array of available countermeasures to road accidents, and the coordination required among the many parties involved call for a systematic approach to the road safety process. A simplified framework for such an approach is shown in Figure 2.

The initial step in the safety process is setting goals and objectives based on the present accident situation and the resources and opportunities available for improving safety.

The next step is the planning of safety measures. This step, based on the goals and the resources available, includes collecting and analyzing data, identifying suitable safety measures, setting priorities, and designing and organizing safety programs. This step includes financial arrangements for road safety activities.

Planning is followed by implementation of safety measures, which affect the road users, the vehicles, and the road infrastructure, directly or indirectly. This, in turn, influences accidents and their consequences and has a bearing on other variables, such as accessibility and transport costs, as well as costs for implementing and maintaining the measures. Progress of implementation, its initial effects and attendant costs need careful monitoring.

After a safety program, or a single countermeasure, has been implemented, an evaluation should be carried out in order to study the effects and the costs.

The safety measures implemented will lead to new conditions; among other things, a different accident situation. This, together with the results of the evaluation, will form a basis for a continuing safety process.

The approach described above is intended to improve safety in the broadest sense. It is assumed that it will contribute to improved road safety, because it:

* provides a more comprehensive view of the accident problem and suitable countermeasures;
* provides a more systematic and uniform way of tackling the problem;
* provides incentives to better organizational coordination of safety activities and measures;
* makes it easier to determine the most suitable level of resources for safety interventions;
* makes it easier to find the most efficient safety measures; and
Figure 2. A systematic approach to the road safety process
• in the long run, increases the general interest in, and knowledge of, road safety.

The proposed approach requires: **methods and knowledge**, by which the different safety activities can be adequately carried out and evaluated; **information systems**, which can supply the information and data needed; and **safety research and development**, by which methods and knowledge can be improved.

The road safety process involves a number of **influencing factors**, such as the cultural, social, economic, technological and educational environment of the country, and **preconditions**, such as the interest in, and knowledge of, road safety, and the capabilities of road safety organization and its staff.

The factors which influence the road safety process also have a direct bearing on the attitudes and will of the public, the administrators, and the politicians to improve safety, as well as the opportunities available to them.

Factors directly related to the road transport system are:

• the road accident situation;
• awareness, knowledge, and understanding of road safety; and
• the road safety organization.

Other indirect but important factors are:

• the cultural, religious, and social background;
• other competing social and economic needs;
• the economic situation; and
• the educational and technological level.

Road safety is likely to receive greater attention if the accident situation is perceived to be serious, in view of high and steadily increasing death and injury rates, especially in relation to other countries and other causes of injury and mortality. In developing countries the accident problem is generally underestimated because of inadequate accident reporting systems and lack of public awareness.

**Awareness and knowledge** of road safety problems and countermeasures are essential prerequisites for carrying out efficient safety work. In many developing countries, the general public is not used to motorized road traffic and does not have a realistic perception of its dangers. Both road authorities and road users are therefore reluctant to support safety efforts.

The opportunities to improve safety depend to a great extent on the management and the organization of road transport and road safety. It is clear, for instance, that the importance of safety work will be adequately emphasized only through political commitment at a high level. There is normally also a need for a special agency to coordinate safety work among different governmental departments, public authorities, and private groups. The safety process otherwise slows down because of institutional inertia.
The cultural, religious and social background can affect the importance and priority given to road safety improvements. For example, in some cultural and religious settings, accidents can be regarded as acts of God over which man has little control. In other settings, people are so inured to hardship, pain, and suffering that they consider road accidents just another hardship to be endured. The social background also affects the public's attitudes towards laws and their enforcement, leading to difficulties in enforcing traffic safety regulations, such as the prohibition to drive against red lights or the compulsory use of seat belts.

Improving road safety depends to a large extent upon the magnitude and nature of other urgent problems and competing social and economic needs. In developing countries there are often critical needs calling for attention and resources, such as disease, illiteracy, and natural disasters. In many cases, other sectors of the economy -- agriculture, industry, housing, health, education, and employment -- may have higher claims on public resources than transport and road safety. Even within the road transport sector there can be several competing needs, such as provision of vehicles, spare parts, new roads, and better road maintenance. In many developing countries, improved accessibility and mobility may be considered superior objectives to improved safety.

The general economic situation in a country certainly affects the prospects for carrying out safety measures. In developing countries, persistent resource constraints can delay road safety improvements.

The educational level in a country can affect public perception of road safety problems and potential remedies, and public receptivity to information campaigns. Effective road safety work furthermore depends on the availability of appropriate technical skills in a country.
IV. A FRAMEWORK FOR ROAD SAFETY ACTIVITIES

Setting of Goals

Safety goals are statements spelling out future safety improvements of the road transport system. Goals are established in safety work to enhance road safety in an expeditious and efficient manner. Setting goals can be useful in establishing and managing coordinated safety programs, when several different agencies with different responsibilities, are involved. Goal setting thus provides an opportunity to bring together various parties concerned with safety issues and to focus on one common and important task (ref. 28).

There are different types, or levels, of goals, such as:

- general policy objectives, which for instance, may aim to reduce the number of road accident fatalities; and
- target values, which often are derived from the policy objectives but are more specific; for example, the number of road accident fatalities to be reduced by a certain percentage in a given number of years.

In general, goal setting has the following advantages:

- it increases the motivation to carry out and integrate safety work;
- it provides direction and establishes the scope of safety work, and helps in determining priorities;
- it shows commitment of responsible authorities to safety work; and
- it focuses public attention on this commitment.

The process of goal setting has a drawback in that it constrains freedom and limits flexibility. This disadvantage, however, can be reduced to a certain degree by periodically reassessing goals.

The use of target values has the following advantages and drawbacks:

Advantages:

- it facilitates management and control, because numerical values are simple to use in the evaluation of goal attainment; and
- it makes the public understand that a certain risk level has to be tolerated.

Disadvantages:

- it tends to exaggerate the importance of areas for which goals can be established;
- unless target values are set with due regard to other effects and the costs of goal attainment, it may lead to sub-optimal allocation of resources; and

- it causes difficulties in decision-making, because target values can give different results than those obtained by ordinary appraisal methods.

It should be mentioned that politicians are often reluctant to set definite target values, possibly because such values can be linked to funding requests; thus making funding appropriations more difficult to justify when planned targets are not achieved.

There are many different policy objectives and target values for road safety. Below are some examples:

<table>
<thead>
<tr>
<th>Policy Objective/Variable</th>
<th>Target Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>reduce number of accidents/fatalities/injuries/property damage only accidents;</td>
<td>reduce by XZ in Y years;</td>
</tr>
<tr>
<td>reduce risk of accidents/fatalities/injuries/property damage only accidents;</td>
<td>reduce by XZ in Y years, or by XZ of the difference between the actual and a target value in Y years;</td>
</tr>
<tr>
<td>reduce total accident costs or severity value;</td>
<td>reduce by XZ in Y years;</td>
</tr>
<tr>
<td>reduce special casualties, e.g., those involving children more than others;</td>
<td>reduce by XZ in Y years;</td>
</tr>
<tr>
<td>reduce total accident costs in the most efficient way;</td>
<td>reduce down to a level where the marginal economic rate of return is ZZ;</td>
</tr>
<tr>
<td>increase use of seat belts (safety-proxy);</td>
<td>increase to XX in Y years.</td>
</tr>
</tbody>
</table>

In summary, setting of goals provides an opportunity to bring together various parties concerned to focus on one common and important task, and that goals are useful in directing and evaluating programs. Target values, however, should be used only after careful examination, in which their appropriateness has been tested, for instance, by applying potential safety measures, estimating their safety effects, other effects and costs, appraising their benefits and costs, and comparing the resulting safety effects with preliminary target values and estimated costs. It is advantageous to formulate goals in such a way so as to disaggregate them into target values suitable for different participating agencies, fields, and levels. It is also important that, if warranted, goals be periodically modified to meet changing conditions.
Financing

Funding for road safety comes from both public and private sources as well as from private individuals. The public sector is normally responsible for road infrastructure, vehicle inspection centers, road user education and training, and regulations, and their enforcement, while private groups and individuals pay for their vehicles, including statutory and voluntary safety equipment.

In order to obtain sufficient public funds for road safety, one of the first steps is usually to impress on decision-makers the magnitude of the accident problem and the need for action. This could be done by showing the discrepancy between the annual costs of road accidents (a real loss to society), and the budget appropriations for safety-related activities.

The primary responsibility for the allocation of appropriate public funds lies with the national government. It is, however, often suitable and also equitable that those who benefit from improved safety, carry their share of financing. Public funds could come from: (i) income taxes; (ii) special levies and fees from private groups and individuals; and (iii) voluntary contributions from companies, organizations, and individuals. Special levies and fees could include fees for driving license testing and examination, annual fees from driving license holders, vehicle registration and inspection fees, vehicle and gasoline taxes, fines for traffic violations, and special levies from auto insurance companies, vehicle and tire manufacturers, and other related industries. Voluntary contributions could come from donations by private individuals and companies.

Financing for road safety work in developing countries could also be obtained from (ref. 40) bilateral and international sources. Bilateral sources, which can provide loans or grants in aid, are important as they can also provide direct assistance, on a country-to-country basis, in the form of experts, equipment, and materials. Such assistance is normally backed by specialized institutions in the donor country, which can also assist in planning and executing the programs, and in setting up and supporting newly established national institutions. International agencies which mainly provide loans and credits also have an important role in supporting safety efforts. In the last decade, international lending agencies, including the Bank, have increased their lending for road safety. The mechanism for obtaining Bank loans or credits for safety programs is usually the same as for other components of the transport sector, such as road construction or maintenance programs.

Planning

In planning for road safety the main objective is to determine what problems should be remedied and what measures should be adopted, including their prioritization and timing. As these questions are interrelated, the correct procedure is to consider all these questions simultaneously. For practical reasons, however, a more realistic approach is to determine first the problems and relevant measures, and then their priority and timing.
Planning for road safety, therefore, consists mainly of the following activities:

- data collection and analysis,
- identification of safety measures,
- setting of priorities, and
- design of safety programs.

Data Collection and Analysis

Data collection and analysis are needed to assess the magnitude and nature of the safety problem, and to identify areas where specific problems occur. This knowledge is essential in order to focus safety activities on the most serious problems and on problems that can be resolved within the given resource constraints. There are many important questions to be answered, such as what categories of road users are involved in accidents, what maneuvers and behavior patterns lead to accidents, and under what conditions (vehicle type, time of the day and season, locations, operational conditions) accidents occur. It is also important to monitor the overall road safety situation and its evolution, and to make comparisons with other countries.

The accident analysis could, among other things, comprise a study of:

- the number of accidents/fatalities/injuries/property damage only accidents;
- the number and severity of different accident types; and
- the risk of accidents/fatalities/injuries/property damage only accidents.

The analysis in addition could include: road user categories and characteristics; vehicle types and characteristics; road locations, types and characteristics; traffic conditions; time of the day and the year; and other influencing variables, such as lighting and weather conditions.

In order to analyze road accident problems in detail, it may be also necessary to study safety-proxies, for example, incidence of traffic conflicts; road user characteristics, such as driving speed, use of safety equipment, and drunken driving; road user behavior and attitudes; and physical characteristics of vehicles and roads, such as brakes and surface friction, respectively.

A special and frequently-used method of accident analysis is to identify 'black-spots', that is, road sections or intersections that are especially prone to accidents. The analysis is normally carried out by determining the accident risks and the numbers of accidents along the roads and at intersections, and by comparing the values obtained with normal or threshold values. Sites where the actual values are much larger than the normal or threshold values are 'black-spots', which should be the subject of further studies and possibly treatment. Another way of identifying the sites is to inquire from professional road and traffic engineers, police officers, or the public where the most hazardous locations are to be found. It is possible that the most comprehensive list of 'black-spots' is obtained if the results of these two methods are combined.
When accident data and other statistics are lacking, the accident problem may be analyzed by studying present conditions, procedures and activities regarding road safety-related areas. Such an analysis attempts to identify deficiencies by using knowledge and experience from other fields and regions, for example, countries with good safety records. Studies of this type may cover a variety of topics: urban and transport planning; road design and maintenance; vehicle design, equipment and inspection; road user education and training; traffic legislation, regulations, and enforcement; medical care and rescue systems; and organization and management of safety activities.

Identification of Safety Measures

This step aims to find the most suitable countermeasures to solve or reduce the accident problems identified by the accident analyses, or to find efficient safety measures in general.

This activity normally includes the following:

(a) more in-depth analysis of plausible contributing factors to the accident problems;
(b) preliminary choice and design of a number of potential counter-measures assessed to contribute to the solution or reduction of the accident problems;
(c) estimation of safety and other effects and costs of the measures outlined in (b);
(d) appraisal of all benefits and costs and estimation of benefit/cost-ratios for the potential measures studied in (c);
(e) preliminary choice of the most suitable measure based on efficiency;
(f) comparisons between present safety conditions, goals, and estimated future safety conditions under the most suitable measure selected in (e); and
(g) possible corrections and final choice of countermeasures.

In activity (a), the aim is to find plausible contributing factors to the accident problems and thus to provide a basis for selecting countermeasures. This step can include, besides accident analysis: conflict studies, crash studies, behavioral studies, and on-the-spot inspections.

In activity (b) choices are made and preliminary designs prepared for alternative remedial measures. If, for instance, there have been several accidents with crossing travel paths at an intersection, then construction of an interchange or a round-about, or installation of traffic signals, yield or stop signs would appear to be suitable alternative solutions to be tested.

Activity (c) aims at estimating safety and other effects and costs of the potential measures based on the relationships between measures and their future effects under varying conditions. The relationships could be based on results from evaluations of already implemented measures, as well as research and development.
Activity (d) aims at appraising potential safety alternatives in order to identify the most suitable solution. To be able to do this, appraisal methods, values (e.g., time and accident values), parameters (e.g., life of measures and discount rate) and criteria (e.g., minimum acceptable benefit/cost ratio) are needed.

When cost-benefit analysis is used, it is customary to start by estimating the benefits and the costs of the cheapest investment option and then to estimate the marginal benefits and costs for progressively more expensive measures. The most suitable option will be identified when the minimum acceptable marginal benefit/cost-ratio has been reached, as illustrated in Figure 3. This methodology will maximize the total net present value (the difference between the discounted values of all benefits and costs) for all measures within the budget limits. It should be observed that the measure yielding the highest net present value is not necessarily the most suitable one.

In activity (e) the most efficient measure is chosen for further assessments, while in (f), an assessment is made if the preliminary measure chosen solves the problem adequately and if it fulfills current goals, for example, reducing accident risks to an acceptable level. Finally, in activity (g), possible adjustments are made in order to ensure that the measure selected is truly the most appropriate and can be accepted by the public.

This problem-oriented approach must be supplemented with a more measure-oriented approach, which aims at finding efficient, practical and economic solutions. There are, indeed, effective and inexpensive measures, such as road markings and road-side delineators, that can be used more widely, beyond the areas identified as particularly hazardous.

Another way of selecting countermeasures, which has to be used if accident data is lacking and knowledge of the effects of the potential measures is inadequate, is to use subjective judgement. It must be noted, however, that such judgements should preferably be based on extensive experience from similar measures and programs elsewhere.

Setting of Priorities

The purpose of this step is to prioritize the chosen, optimal countermeasures for each problem in the most suitable manner.

If cost-benefit analysis has been used in selecting the optimal measures, then the measures should be prioritized by the order of magnitude of their respective benefit/cost or net present value/cost ratios, as indicated in Figure 4.

If cost-effectiveness analysis has been used, then the measures should be prioritized by the order of magnitude of their respective effectiveness-cost ratios.

If no formal analysis has been, or can be, used, then the measures have to be set in order of priority by educated good sense and experience, taking into account safety effects, non-safety effects, and costs.
Figure 3. Principle for selecting an economically-optimal safety countermeasure
Figure 4. Different countermeasures arranged in order of economic priority
In all prioritization methods, due consideration must be given to budget constraints in relation to the goals and target values concerning the level and distribution of safety improvements (e.g., geographically and by different road user groups), and their public acceptance. In coordinated safety programs, special attention has to be paid to how different countermeasures interact, reinforcing or weakening each other.

Design of Safety Programs

Road safety programs are sets of more or less coordinated actions aimed at reducing road accidents. The general purpose of such programs is to improve the safety situation faster and more efficiently than would have been the case if all actions had been taken separately without coordination. Over the years, different types of safety programs have been designed and implemented. Three different types can be distinguished, even though they have some common features:

- problem-oriented programs;
- measure-oriented programs; and
- component- or sector-oriented programs.

Problem-oriented programs aim at reducing identified accident problems by using different types of actions. For example, programs aimed at reducing nighttime accidents may include appropriate education and training; better testing of drivers' vision; use of retroreflectors by pedestrians; improved lighting and reflectors on vehicles; and more frequent use of road markings, road-side delineators, and road lighting.

Measure-oriented programs aim at reducing accidents by applying specific safety measures on a wider basis. Programs designed to increase the use of seat belts by a variety of means, such as information campaigns, and seat belt laws and enforcement, are illustrative of this approach.

Component- or sector-oriented programs strive to improve different components of the road transport system -- road users, vehicles or roads. Examples of vehicle-related programs are improved crash avoidance, occupant protection and vehicle inspection, while examples of road-related programs include improvements in planning models; design, maintenance and operation standards, and 'black-spot' elimination programs.

Over the last decade, it has become increasingly clear that the accident problem has many dimensions and that its solution involves a truly multidisciplinary approach. More cooperation and coordination is therefore needed among the various disciplines and skills involved in road safety. It is now believed, at least in some industrial countries, that the more restrictive safety programs used in the past -- particularly the component/sector type -- can easily become inefficient, and, in fact, may reach a point of diminishing returns. It is therefore generally recognized that future safety programs should have wider applicability and be more integrated; they should be based on a systems-approach, incorporating in principle all elements contributing to accidents, all possible countermeasures, and including organization and management of the safety work, staff education and training, and safety research and development.
The Organization for Economic Cooperation and Development (OECD) (ref. 28) defines an integrated road safety program as "a set of coordinated activities to be carried out by a variety of agents of different nature (governmental or private organizations and acting at different levels) with the aim of solving a number of well-defined safety problems." The implementation of such programs aims at adjusting the various measures to each other so that the total effect of the package is larger than the sum of the effects of the separate measures. Such a reinforced effect can be attributed either to a suitable synergetic mix and timing of different measures in various areas, or to massive actions that lead to increased interest in safety and to more responsive attitudes towards safety improvements.

Besides technical measures, safety programs could include institutional measures, such as improved organization and coordination of the safety work, and education and training of staff. They could also contain research and development programs focused on road safety.

In order to successfully design and implement integrated safety programs, specialists in many disciplines should be involved, such as behavioral and social scientists, engineers (vehicle, road, and traffic), statisticians, economists, project and program managers, and senior executives. It is also important that the work of all the involved agencies be coordinated, preferably by a special unit, with the ability and authority to cut across established bureaucratic channels.

At the end of the safety program design phase, overall goal attainment should be checked. If a suggested program does not attain the stated goals, then either the goals, the resources allocated, the safety program or a combination of these elements should be changed, until the program attains the desired results.

The decision on what measures should be taken and in what order must be based on technical, economical and political considerations. To the extent possible, the selection of safety measures and setting of priorities should be based on objectively estimated benefits and costs, using accepted appraisal methods. It should be remembered, however, that deficiencies in benefit and cost data can limit the use of the cost-benefit or cost-effectiveness analyses. In such cases, decision makers could, for instance, use a multi-disciplinary team, comprising researchers, program managers, and senior executives, to subjectively assess various measures from the standpoint of different disciplines.

It is important to note that the success or failure of a safety program depends to a very great extent on the commitment of those involved, and on the acceptance of the program by the road users.

A general approach, which could be used for the design of safety programs in developing countries, where data and expertise are often lacking, might incorporate a limited number of key technical improvements, while simultaneously introducing basic institutional improvements (ref. 31, 32 and 33).
The technical improvements should include measures which are likely to improve safety or are necessary for efficient safety work in the future, such as:

- 'black-spot' elimination;
- vehicle safety regulations, for example, concerning seat belts;
- road user education, for instance, in school curricula;
- police enforcement, for example, speed and alcohol controls; and
- information systems concerning accident statistics.

The institutional improvements could include:

- definition of authority and responsibility for different agencies involved in safety activities;
- creation of a road safety coordinating unit;
- education and training of staff working with safety problems; and
- establishment or reinforcement of safety research and development.

A road safety program should include the following elements: background information and data (including present safety situation and goals); descriptions of program components (including estimated safety and non-safety effects, and costs); an action program (including time-schedules, responsible agencies, organization, staff, and equipment, and monitoring arrangements); financing and procurement arrangements; and an evaluation program. A safety program should also include a description of the appraisal methods used and the results obtained.

In summary, the road accident problem is very complex, has many dimensions, and consequently a truly multi-disciplinary approach is needed to reach sensible solutions. In order to be efficient, safety programs should be well integrated and based on a systems approach, including an assessment of contributory factors and countermeasures. Consideration should also be given to organization and management of the safety work, to staff education and training, and to research and development.

Implementation and Monitoring

The implementation of a safety program should include monitoring besides the normal implementation activities. Monitoring is intended to help program management to assess progress and to take appropriate action in order to complete or adjust the program in the best possible way.

The implementation of a road safety program consists of several activities:

- creation of a road safety agency and appointment of a manager responsible for the coordination of the safety program;
- assignment of authority and responsibility, as well as resources to the safety agency;
- design of an action plan including details of implementation of various projects;
- execution of various projects according to the action plan; and
- monitoring of the component projects and the program as a whole.
The design of the action plan includes structuring of the program into suitable projects and activities, appointing managers for the various projects, designing detailed implementation plans for various projects and activities (including starting and finishing times, coordination of activities, etc.), and assigning authority, responsibility, and resources (e.g., funds, staff, equipment and materials) for the safety program.

Monitoring entails the collection and use of information to enable program/project management to assess implementation of the program and to take appropriate decisions about future actions, in order to complete the program in the most effective way (ref. 34). Monitoring should be included in the planning phase and should normally be integrated into the management structure. The cost of monitoring should be related to the likely returns in improved implementation and in spin-off benefits for similar future programs.

Monitoring normally includes the study of the following elements in relation to the original program and the action plan:

- progress of program/plan, including amount and quality of work;
- provision and use of resources: funds, staff, equipment and materials;
- initial effects on accidents and safety related proxy-variables; and
- other factors important to the program, for example, public reactions.

The indicators to be measured should preferably be fixed at an early stage. It is advantageous if there are specific goals for the program/projects, preferably in the form of operational target values.

In designing safety programs, certain assumptions and estimates are usually made regarding the likely effects of the safety measures, often based on evaluations of previous projects. These assumptions and estimates commonly pertain to reductions of accidents and their severity and changes in road user behavior. In assessing the initial effects, monitoring can reveal previously overlooked problems and lead to corrective actions. A detailed study and analysis of the effects, however, should be carried out during the evaluation phase of the program.

Evaluation

Evaluation aims to present an analysis of the results of safety programs/projects and to provide an assessment of how the programs have been implemented. The results of safety measures in terms of direct outputs, effects, and costs, and, to the extent possible, the causal links and long-term impacts (ref. 29 and 34) are assessed. The purpose of this analysis is to:

- determine to what extent the goals have been attained and if the initial targets were realistic; and
- contribute to the general knowledge of safety measures and their effects and costs.
Besides checking goals and targets, program evaluation serves as a basis for decisions on further actions directly connected to the actual program, as well as the design of future safety programs.

Evaluation should be an integral part of a safety program and should be considered in both the planning and implementation phases of the program. In the planning phase, a detailed plan for the subsequent evaluation has to be established. In implementation (especially the monitoring phase) problems and results can emerge which might require detailed investigation during evaluation.

While monitoring is mainly a tool of program management, evaluation is a mechanism to be used by the responsible road safety authority, and other government agencies for planning future programs. In order to be unbiased, evaluation should normally be performed by staff outside program management and with limited participation from project management personnel.

The cost of evaluation, which as a general principle (ref. 35) should normally not exceed 10-25% of the project cost, cannot be solely justified by the knowledge gained from the results of the ongoing program. The major benefit comes from the application of that knowledge to other, future programs. This benefit will be greater if past experience with safety programs is limited and if the safety measures in question are costly and are to be used on a large scale in future projects. In some cases the possibilities of obtaining reliable results are so slim because of inadequate or unreliable data, that evaluation may merely be a waste of resources.

There are three different types of evaluation (ref. 34 and 35):

- administrative evaluation;
- effectiveness evaluation;¹ and
- efficiency evaluation.²

Administrative evaluation is carried out to assess how program implementation has been performed. It could include assessments of how closely the plan has been followed (amount and quality of work, timeliness, costs, etc.) and how the resources (funds, staff, equipment and materials) have been used. Administrative evaluation could also include assessment of the monitoring process.

Effectiveness evaluation is carried out to assess the direct effects of safety countermeasures on incidence of road accidents and on 'non-safety' factors. This evaluation could also include assessments of the causal links between safety measures and effects, and the resulting impact. The task of assessing all relevant effects and causal links can be time consuming and complex and is therefore seldom performed.

¹/ "Impact" evaluation according to ref. 35.
²/ "Clinical" evaluation according to ref. 35.
Efficiency evaluation is undertaken to assess the overall efficiency of safety measures. It could include assessments of the long-term impact, comparisons with other sources of information, and estimates of the resulting benefit-cost ratios. As the evaluation of all effects and impacts can be a very complex task, this type of evaluation is seldom performed in full. Efficiency, as well as effectiveness, evaluation of a program will normally take a long time (several years) before yielding even tentative conclusions.

One critical task that must be carried out at an early stage is to select the most suitable indicators to be used for evaluation. Such indicators, sometimes called Measures of Effectiveness (MOE), should show the specific effects of the measures. If, for example, a certain measure is expected to reduce left-turn accidents at intersections, then the MOEs should include the number of left turn accidents over a specified period, or the risk of such accidents. The total number of accidents or the total accident risk are aggregate measures and can hardly be used to detect a specific effect. In many cases it is difficult to assess the effects by using number of accidents as a MOE. In such cases, it is advisable to use proxy-variables, such as traffic conflicts and other indicators of road user behavior and attitudes.

Besides recording the number of accidents and related proxy-variables, it is often necessary to control, and in some cases record, other accident-contributing factors, such as road and vehicle characteristics, general road user behavior, traffic volumes, and environmental factors.

There are several general problems involved in the evaluation of safety effects -- accidents are normally under-reported and the reporting can be inaccurate; there are normally time trends in the data besides random variations; accidents and casualties are relatively rare and the validity of proxy-variables can be doubtful; and other accident-contributing factors are difficult to control.

Despite these limitations, evaluation is an important element of the road safety process because it provides guidance for the design of future programs. In order for the evaluation process to be effective, it is important that the evaluation team includes experts from different fields, and that the team is given sufficient resources and time to fulfill its mandate.
V. ROAD SAFETY APPRAISAL AND EVALUATION METHODS

Analytical techniques for road safety programs pertain to:

- road safety indices;
- appraisal methods;
- effects of safety improvements;
- evaluation methods; and
- monetary valuation of accidents.

Road Safety Indices

There are several indices that may be used as scalar measures of road safety:

- number of accidents differentiated by degree of severity;
- number of fatalities, injuries, and property damage accidents;
- risk of accidents differentiated by degree of severity;
- risk of fatalities, injuries, and property damage;
- accident cost, (number of accidents multiplied by their monetary values);
- severity value (number of accidents weighted in proportion to their severity); and
- ratios related to risk and incidence of accidents, for example, number of casualties per accident.

The term risk can be defined as the number of unwanted events, for instance, road accidents, in relation to the number of possible events, risk exposure. Some frequently used measures of exposure are: number of inhabitants; number of vehicles; number of trips; time in traffic (e.g., person hours or vehicle hours); and road length travelled (e.g., person kilometers or vehicle kilometers).

It is not always clear what measure of exposure should be used for a given purpose. If the aim is to indicate the size of the health problem associated with road accidents, then the exposure should be expressed in number of inhabitants. If, on the other hand, the aim is to estimate how safe the road transport system is, then the exposure should be expressed in some measure related to the amount of traffic, for example, the number of vehicles, vehicle-kilometers or passenger-kilometers.

Numbers of accidents/fatalities/injuries are not in themselves adequate indicators of road safety conditions. For example, a smaller number of accidents for a specific condition does not necessarily mean that it is a safer condition than one with higher numbers. To decide which one is the safest, the number of accidents have to be related to the risk exposure. On motorways, for instance, it is quite normal to expect a higher number of accidents per km. This does not
mean that motorways are unsafe, but that with higher traffic flow more accidents occur, even if the motorways are equipped with the necessary safety features.

Commonly used measures of risk are:

- for road sections: the number of accidents per vehicle-kilometer; and
- for road intersections: the number of accidents per incoming vehicle.

These risk measures are often called accident rates and can be refined by using number of accidents with different degrees of severity in the numerator, such as fatal accidents, injury accidents, or property damage accidents.

Using accident costs as a measure of safety requires that accident costs for different degrees of severity have been determined. If index values for different degrees of severity have been established, safety can be measured by severity value instead of monetary value.

One way to illustrate the relations between some of these measures is given in Figure 5 (ref. 56). The horizontal axes represent the exposure (E) and the accident consequences (casualties per accident, C/A) respectively; the vertical axis indicates the accident risk (accidents per exposure, A/E). The area in the A/E-E-plane is then proportional to the number of accidents, the area in the A/E-C/A plane proportional to the casualty risk (C/E) and the volume to the number of casualties (C).

It can be seen from this figure that the number of casualties can be reduced in three ways: by reducing the exposure; by reducing the accident risk; and by reducing the accident consequences. Assuming the goal is to reduce the number of casualties in a situation with increasing exposure, then the accident risk and/or the accident consequences must be reduced to such an extent that the decrease compensates for the increase in exposure.

There are some general problems with using accident and casualty data, namely:

- accidents and casualties are normally under-reported;
- there are random variations; and
- accidents and casualties are relatively rare.

Although in most countries it is compulsory to report to the police all accidents involving injuries, the number of accidents and casualties are generally under-reported. It has been found in some developed countries that less than 50% of all injury accidents are reported. Another serious problem is that the proportion of accidents reported can vary in time and space; accidents are reported less at night than in daytime, and less in rural than in urban areas. To overcome these problems other data sources are used, such as insurance and medical care statistics, but these sources also have inaccuracies, for example, concerning the location of the accidents.
Figure 5. Relations between some measures of safety

Accident Risk (A/E)

Volume: Number of Casualties

Area: Number of Accidents

Accident Consequence (C/A)

Exposure (E)
Most accidents can be seen as the outcome of a large number of probable events and are therefore subject to random variation. The number of accidents in a certain region, or on a certain road section can, consequently, vary from time to time, even if the circumstances seem to be identical. This has to be taken into account in safety work, especially in the evaluation.

Road accidents and casualties are relatively rare, thus the number of accidents occurring in a limited area in a limited period of time is usually rather small. This together with the random variation, creates problems in comparing accidents both by time and by location.

The measures of exposure are also subject to uncertainty, particularly the amount of time spent in traffic and the vehicle-kilometers travelled. Accident risk is therefore even more uncertain than the number of accidents.

To minimize some of these problems, it is possible to use other, less direct, measures of safety, the so called safety-proxies, such as the number and risk of conflicts, the distribution of vehicle speeds and lateral positions, other measures of road user performance and behavior (e.g., seat belt use), and road user attitudes.

The main advantage of these indicators is that they can be measured in a short period of time. The main disadvantage is that they may not be strongly correlated to accidents and casualties.

**Appraisal Methods**

In order to determine what safety actions should be selected, methods are needed for the appraisal of safety measures. A road safety program can contain many different types of measures affecting safety as well as non-safety variables. Appraisal methods used in safety work, therefore, should make it possible to compare the safety effects with other advantages and disadvantages of the safety measures. Such appraisal methods should preferably be applicable not only to measures funded by public agencies, such as road improvements, but also to measures partially or fully paid by individuals, such as vehicle safety devices. It should be noted that appraisal methods provide guidance in the decision process and do not replace the political decision-making process.

There are several appraisal methods for evaluating road safety measures (ref. 29):

- educated good sense;
- safety standards;
- target values;
- cost-benefit analysis;
- cost-effectiveness analysis; and
- multi-criteria analysis.

An appraisal based on educated good sense and experience consists of an informal comparison of estimated safety benefits and other effects with the costs of proposed safety measures. This method, which probably can produce good
results in some areas, can lead to inconsistencies in the assessments produced by different analysts and, by the same analyst for different projects.

**Appraisals using safety standards** (incorporated in guidelines and manuals) compare pre-determined service standards and qualifications with existing or future conditions of land use, roads, drivers and vehicles. Another variation of this method is to compare estimated safety conditions with **target values**. If the safety standards and the target values used do not take into account total effects and costs, both these methods can lead to inconsistencies and inefficiency.

**Cost-benefit analysis** includes all estimated effects of safety improvements, whether positive or negative, in monetary terms. All the effects, **inter alia**, the reduction of accident and casualty risks, must therefore be defined in monetary values. The best safety measure will produce the highest benefit/cost ratio. This technique has the following advantages and disadvantages:

**Advantages**

- the weighting unit is money, which makes it possible to compare benefits and costs with other public and private investments;
- it is uniform for different planners and different projects;
- the values can easily be presented and discussed publicly;
- it is possible to discount future benefits and costs; and
- it is widely used in transport and road planning.

**Disadvantages**

- it presents difficult valuation problems, for instance, for accidents with different degrees of severity; and
- it does not normally address the question of distribution of welfare, that is, who bears the costs and who reaps the benefits.

The criteria normally used in cost-benefit analysis to determine the suitability of different road safety alternatives are: the net present value; the benefit-cost ratio; and the internal rate of return. The benefit-cost ratio (B/C), that is, the ratio between the discounted values of all benefits and the costs of a safety alternative, is usually regarded as the most appropriate criterion for selecting the optimal safety alternative. If B/C is greater than one, or the ratio between the net present value (i.e., the difference between the discounted values of all benefit and cost streams) and the cost (NPV/C) is greater than zero, the alternative is considered economically justified and beneficial. In ranking alternatives, the safety improvements should be arranged in the order of magnitude of their B/C (or NPV/C) values.

In **cost/effectiveness analysis**, investment and maintenance costs of the measures are expressed in monetary terms, while the effects are expressed either in numerical values of an effect-variable or goal indicator, for example, the reduction in number of accidents, or by a value on an effectiveness index scale. The best measure is one giving the best goal attainment, or total effectiveness.
value, in relation to the costs. This method has the following advantages and disadvantages:

**Advantages**

- it circumvents the problem of assigning monetary values to intangibles;
- it is suitable for ranking safety projects in order of priority within a specified safety budget, provided there are no other relevant extraneous effects; and
- it forces the decision-maker to consider the balance between advantages and disadvantages (including intangible effects) instead of a fairly simple monetary balance between benefits and costs.

**Disadvantages**

- it does not give any indication of the appropriate size of the road safety budget;
- it precludes uniform comparisons with other types of improvement projects within and outside the road transport system, even if it permits cross-sectoral "safety versus cost" comparisons;
- it is oriented to the attitudes of the analyst and the decision-maker rather than to social preferences in general; and
- if there is more than one "effect-variable", a special weighting scale has to be established.

Multi-criteria analysis combines a range of methods in which all positive and negative effects (including costs) are represented by indices. These indices could include the preferences of the decision-maker and some established ranking of various objectives. The best measure is one showing the highest overall index value. This method has some of the advantages of cost-effectiveness analysis and most of its drawbacks. Additionally, the method entails establishing preference indicators and weighting the effect-variables.

In conclusion, the selection of appraisal technique should be related to the objective of the analysis. If the overall objective is the efficient use of scarce economic resources, then cost-benefit analysis is most suitable. If the objective is the effective use of resources under a specified safety budget, then cost-effectiveness analysis may be used. In most cases, however, when all effects have to be taken into account and when there is no specific safety budget, cost-benefit analysis, combined with a multi-criteria-analysis for intangibles, is probably the most suitable appraisal method. If data on safety effects and other benefits and costs are lacking, then "educated good sense and experience" remain the only practical technique.

**Effects of Safety Improvements**

Appraisals of safety improvements require estimates of the effects and the costs of alternative measures. As their selection and priority for implementation depend to a great extent on the results of such appraisals, it
is important that the estimates are correct. The efficiency of safety improvements will otherwise be jeopardized.

The effects of safety improvements can be divided into:

- safety effects; and
- non-safety effects.

The safety effects comprise all relevant safety variables expressed in suitable scalar measures, for example, risk of accidents and fatalities, accident costs, and safety-proxies. The non-safety effects comprise all other relevant effect-variables, for example, travel speeds, vehicle operating costs, noise, air pollution, compliance with traffic regulations and so on.

Reliable estimates of the effects of potential safety improvements require detailed and careful analysis. In order to facilitate such analysis it is necessary to collect and compile information about the effects of similar safety actions used in the past and data available from safety research and development.

The costs of safety improvements and actions whether paid by public or private agencies, or individuals, can be divided into investment, maintenance, and operating costs. As costs are normally easier to calculate than benefits and are more easily available, the need for detailed compilations of costs is less than that for effects.

Information about the effects, where possible, and associated costs should preferably be presented in special handbooks. The safety and non-safety effects can be given both in terms of absolute effect-variable values (for example, what accident rates and travel speeds can be expected on roads of different characteristics), and in terms of changes due to defined safety improvements or actions (for example, what reductions in accident rates and speeds can be expected from increased law enforcement).

Values given in such special handbooks, however, can only be best estimates; they can never be expected to give completely correct estimates for each specific case. They still provide reasonably reliable estimates of the average values of the effects for a number of similar cases. In order for the estimates to become progressively more accurate over time, it is important to evaluate projects that affect safety and to up-date the handbook when new results are available. Handbooks of this type should include: summaries of results from different sources, explanations of variations in the results, identification of the most important factors influencing the safety effects, identification of special circumstances in the countries for which the handbook is intended, and differences in the effects to be expected under such circumstances.

Compiling such a handbook, especially for developing countries, presents several difficulties:

- evaluations take a long time;
- results vary due to random variations and real differences in circumstances;
- there are relatively few good studies; some of the early
before-and-after studies tend to overestimate the effects; and

- most studies have been carried out in developed countries, and it is difficult to assess what effects the same measures would have in countries with different cultural, social, economic, and educational conditions.

The main techniques to obtain information on the effects of safety improvements are:

- own observations and evaluations from full-scale implementations, pilot implementations, and simulations; and
- compilations of results from other sources, for example, literature surveys.

In order to begin the process of producing information on the effects of different safety measures, it would be of great value if a wide-scale compilation of present knowledge could be made. The results of such a study could provide the basis for more detailed studies for the specific circumstances in developing countries. Annex B presents examples of such a compilation.

Evaluation Methods

A number of statistical methods are available to analyze the effectiveness of safety measures (ref. 29 and 35):

- statistical experiments;
- before-and-after studies; and
- regression and correlation studies.

In statistical experiments a representative sample of a population is selected (for example, road sites with certain characteristics) and each subject in the sample is randomly assigned to one of two groups, the experimental group -- treated with a safety measure -- and the control group -- left untreated. This method aims to duplicate conditions between the two groups in all respects except for the treatment. Comparisons between the results from the two groups gives a good assessment of the effect of the treatment. There are also some refinements to this randomized design, one being the randomized block design, in which in its simplest form, there are two identical subjects in each block and one is chosen randomly for treatment.

Statistical experiments are considered to be the best analytical method because it is most unlikely that the responses measured result from factors other than the treatment. This is the reason why it is sometimes recommended that "all projects selected for effectiveness evaluations should be designed as experiments and should follow general scientific rules of experimental design" (ref. 29). In most cases, it is, however, very difficult to use this method in road safety work because it is normally not possible, or reasonable, to choose subjects randomly.

In before-and-after studies, a commonly-used evaluation technique, accidents or other effect variables are compared for a time period before the treatment to a similar period after the treatment and the difference is
attributed to the treatment. Before-and-after studies can be problematic. In order to minimize the influence of extraneous variables and long-term trends, before-and-after results are often controlled by results from similar comparison groups. If there are no such controls available, it is normally advisable to carry out time series analysis.

Regression to the mean is a problem connected with before-and-after studies of black-spot improvement programs. Accidents at any site are subject to random variations, and locations showing a high incidence of accidents during a given period of time may either represent a genuine accident problem, a normal statistical variation, or a combination of both. If a safety treatment is implemented and the number of accidents decreases during a corresponding period of time after implementation, it is tempting to describe this reduction in accidents to the treatment. It is, however, quite possible that the accidents would have gone down anyway, without any treatment at all, if the high incidence of accidents observed before the treatment was merely due to random statistical variation.

Migration is another problem associated with before-and-after studies and becomes evident when the experimental group and the comparison group are located close to each other. In such cases it is possible for traffic patterns to change, and the modified traffic behavior due to the treatment can also affect the control group sites.

Regression and correlation studies cannot from a purely scientific point of view be used to estimate the effects of a specific safety improvement. These statistical techniques are appropriate to assess the variation in accidents or other related variables as a function of changes in a physical parameter, e.g., variation in accident risks for different road widths. Hence careful selection and control of the investigated parameters is essential to obtain unbiased results.

Monetary Valuation of Accidents

The use of cost-benefit analysis requires explicit monetary costs of accidents and monetary values of accident prevention or risk reduction. There are several approaches to determine such costs and values based on (ref. 21):

- gross-output;
- net output;
- life-insurance;
- court awards;
- implicit public sector valuation; and
- willingness-to-pay.

In the gross-output approach, the cost is estimated as the sum of real resource costs (such as property damage, medical, police, law court and insurance administration costs), and the discounted present value of the victim's future output. The value of the prevention of an accident is defined as the avoided cost. In some variants of this approach, a significant amount is added to reflect a value for the fear, pain, and grief suffered by the victims and those who care for them. Estimates of gross output costs and values are usually based
on average output or earnings data. The net output method differs from the gross output method, only in that the present value of the victim's future consumption is subtracted from the gross output figure. An individual's net output may be regarded as a measure of society's economic interest in his continued survival.

In the life insurance approach, the cost of an accident, or the value of accident-prevention, is directly related to the sums for which typical individuals are willing to insure their own lives (or limbs). In the court-award approach, the sums awarded by courts to the surviving dependents of victims of crime or negligence are treated as indicative of the cost that society associated with the accident or the value related to its prevention.

In implicit public sector valuation, an attempt is made to determine the costs and values that are implicitly placed on accident-prevention in safety legislation or in public sector decisions taken either in favor of, or against, investment programs that affect safety. The willingness to pay approach is based on the fundamental premise that decision-making in the public sector should reflect the interests and wishes of those individuals who will be affected by those decisions. Accordingly, the value of safety improvement is defined as the amount that people are willing to pay for it, and the cost of a decrease in safety is defined as the amount people would require in compensation for the increased risk.

Hills and Jones-Lee (ref. 21) have shown that different methods can give very different numerical estimates. They have further shown that different values can have a marked effect on net present values and on project rankings. This conclusion is shared by other experts (ref. 30). It is therefore important that appropriate methods for determining accident costs and values of accident prevention are used.

Hills and Jones-Lee have concluded that for "developing countries whose economic and social policies tie more closely to output objectives" (e.g., GNP), "the definition and estimation of accident costs and values...will involve variants of the standard gross output measures," and if "a developing country wishes to take the rather wider, 'warm-blooded' view of road safety policy...then the willingness-to-pay definition...would seem to be appropriate."

The willingness-to-pay approach, however, is problematic because of lack of relevant data, especially in developing countries. As an interim or compromise solution for those countries that wish to take a social-welfare view of road safety, they suggest that gross output measures of accident costs and values could be used as a lower-bound limit, as long as relevant data are lacking. It is reasonable, however, to add an amount to the gross output figure to account for the value of human life. To exclude such an amount would lower the value of preventing accidents involving elderly people since most of their productive years are past, a view generally not shared by society.
VI. INSTITUTIONAL ASPECTS OF ROAD SAFETY

Organization and Staffing

Road safety work is a complex process involving different sectors of the economy and various elements of the society. The responsibility for carrying it out is usually shared by many governmental departments and public and private agencies at the national, regional and local level. There could, for instance, be a separate department for each of the following functions directly or indirectly related to road safety: land use, roads, health, education, and traffic legislation, regulations and enforcement. Among the many private groups involved are vehicle manufacturers, repair shops, and organizations partly or fully concerned with safety information and campaigns. There could also be civic associations working on safety issues, particularly at the local level.

The diversity of entities involved in road safety makes it necessary to assign clear authority and responsibility to the various entities involved, in order to ensure that all important functions are covered and there are no redundant activities. Coordination between the various entities and activities must also be established to ensure that resources are used in the most efficient way. There are several management structures that may be used to achieve coordination in road safety work (ref. 28 and 38).

- coordination by a high-level unit;
- coordination by a lead government department;
- coordination by a special government agency; and
- coordination by various forms of coordinating/advisory committees and councils.

High-level coordination implies that coordination is effected by a government unit ranking higher than operational governmental departments, such as a unit in the Prime Minister's Office. This structure has several advantages -- high priority is automatically given to safety; there is less risk of bias towards one sector; and there is a clear responsibility for the total program, even if subordinate units are responsible for implementing their respective parts. A possible drawback is the long span between planning and implementation. To improve understanding of road safety and better coordinate its activities, such a coordination unit could be assisted by an advisory safety committee or council.

Lead department coordination entails charging one governmental department, for example, the Department of Transportation, with responsibility for overall coordination of road safety programs. This structure has the advantage of reducing the span between planning and implementation. Drawbacks involve a risk of bias towards one sector, possible lack of full cooperation from other departments, lack of complete responsibility for the overall safety program, since one-line department cannot hold another accountable. As in the case of
high-level coordination, there could be an advisory committee to assist the lead department responsible for coordination.

Special governmental agency coordination implies coordination by a special agency charged with overall responsibility for road safety programs. This agency is normally subordinate to a department, such as the Department of Transportation, but it could possibly report directly to the Prime Minister's Office. The agency could be more powerful and efficient if it is managed by a board, or advised by a council, composed of representatives of different parties involved in road safety work. The agency could have executive responsibility for some parts of the safety program, for instance, safety information and campaigns.

The last structure implies that there are various types of coordinating and advisory committees and/or councils assisting different government units in their safety work. Normally these entities can be multi-disciplinary and thus have the advantage to cut across departmental areas of responsibilities. Their weakness, however, is that they have no direct access to resources and no accountability for results.

Besides a suitable organizational and management structure it is essential to have competent, multi-disciplinary staff responsible for safety work, especially for planning and coordination. It is essential that road safety personnel, commonly assigned to several entities, include staff with basic education in most safety related subjects, such as behavioral science, statistics, urban and transport planning, road, traffic and vehicle engineering, law, public relations, and advertising. It is also important that adequately trained staff are available for specialized tasks such as methods and techniques of accident analysis.

In developing countries, where skilled human resources are often scarce, it is essential that knowledgeable and experienced staff contribute to the safety process from its inception, and that steps are taken to gradually improve their competence, for instance, by incorporating a safety course in university curricula. In the interim, staff could be sent abroad to acquire specialist training in road safety.

Information Systems

In order to carry out safety work efficiently, it is necessary to have access to reliable information on accidents, traffic, and factors influencing road accidents. Appropriate information systems (normally computerized) may be used for the collection, storage, processing, analysis and presentation of this information.

An information system for road safety should make it possible to:

- describe the general accident situation for different road users in time and space and provide a basis for setting goals and for comparisons of accident rates with other modes of transport and other countries;
• identify and analyze accident problems and influencing factors in order to find suitable countermeasures;
• monitor and evaluate the effects and costs of implemented safety measures; and
• carry out safety research and development work.

To meet these requirements, a safety information system should normally contain information on: accidents/casualties; traffic exposure; roads; vehicles; road users, especially drivers; and other influencing factors, as illustrated in Figure 6 (ref. 36, 37).

Accident/casualty data from the police should include the following information: place, date and time, type of accident, number of killed and injured persons, road and traffic conditions, vehicles involved, road users involved, nature and extent of property damage, light and weather conditions, maneuvers, and a sketch of the accident site. Accident information could also be obtained from medical care statistics, in which case the information should also include data on the type of injury, treatment, rehabilitation and possible permanent disabilities. Additional information could be obtained from insurance statistics.

Figure 6. The structure of an information system for road safety
Traffic exposure data should include information on vehicular traffic, preferably separated into categories such as cars, trucks, buses, etc., and other types of traffic, for example, pedestrians and cyclists. It is advantageous to make estimates of traffic volume for different time periods, for instance, vehicle-kilometers travelled in darkness on a specific road section. Traffic information can be obtained from traffic counts and related surveys.

Road data should contain administrative information, such as region, municipality, and technical information on road geometry (e.g., cross-section, alignment, intersection type), road surface conditions (e.g., type of surfacing, roughness, skid resistance), road appurtenances (e.g., lighting, pedestrian crossings, guard rails) and traffic regulations (such as speed limits, stop and yield regulations). These types of data are normally stored in road data banks.

Vehicle data should include information about the owner, type of vehicle, make and model, model year and certain other characteristics, such as motor power, weight, and front/rear wheel drive. This information is normally available from vehicle registers.

Road user data should include information on holders of driver licenses and, when possible, on other road users. The driver license registers should include information such as the year when the license was issued, and the age, gender, and disabilities (if any) of the license holder. Information about other road users (age and gender, etc.) could be obtained from civic registers.

Data on other factors may include information on climate/weather and light conditions and information about police enforcement.

In order to specify the physical location of information on accidents, traffic, and roads, etc., it is necessary to have a geographical reference system which makes it possible to identify and locate any point or section on the road network.

It is also important to record when and where different safety actions were taken, for example, when a new intersection was constructed or when new seat belt laws were introduced. This makes it possible to make general evaluations of the effectiveness of safety work.

By combining the different types of data it is possible to obtain information on different types of accident risks. By combining accident data and traffic exposure data, accident risks can be estimated. If road data is added, it is possible to find out accident risks for various road sections and road characteristics. By combining accident and vehicle data the numbers of accidents per vehicle for different types of vehicles can be estimated. If exposure data is added, accident risks for different types of vehicles can be calculated. And, by combining accident, driver and exposure data, accident risks for different categories of drivers can be estimated.

Maintaining information systems presents several problems. Information systems have to satisfy various requirements from very general and common ones to very special and unusual ones. There are many types of data needed, and for
each type several variables. In trying to cope with these requirements, it is advisable not to develop large, all embracing systems. It is better to use modular systems, developed in stages, for coordinated information processing. The information system should mainly satisfy general, basic needs for several users; specific information for special analyses may have to be collected separately. Other important considerations in setting up road safety information systems are features of the administrative organization such as the degree of centralization and the need to periodically update the data.

One of the first steps in planning an information system should be to find out:

- what information is needed, what data have to be included, and what combinations of different types of data are needed;
- what information is possible to obtain within reasonable costs;
- what databases/registers should be established and how should they be coordinated; and
- what responsibilities should be assigned to different organizations concerned for data collection and updating.

Even in the case of a simple accident reporting system there are several issues to be resolved: what type of accidents should be included (e.g., should accidents with property damage only be included); what data sources should be used (e.g., police reports, medical care statistics, and/or insurance statistics) and how should they be coordinated; how should the problems of under-reporting and biased reporting be handled; what definitions should be used (e.g., concerning fatalities and injuries); and which organization should be responsible for collecting and processing the information (i.e., the Police Department, the Road Administration, the Road Safety Agency, the Central Bureau of Statistics or the Ministry of Transport).

Information systems are a basic requirement for efficient road safety work. Initially, the systems could be rather simple and contain information mainly about accidents and casualties. In the subsequent stages, the systems should be developed into more complete sources of road safety information, incorporating information on traffic, roads, vehicles, road users, and various factors affecting safety.

Research and Development

Research and Development (R&D) can be divided into two broad categories: basic and applied. Basic research is the search for new knowledge without any specific application in mind, while applied research is the search for new knowledge for intended application. Development is the use of present knowledge for a certain application. Road safety R&D in general aims to improve knowledge about factors contributing to accidents, the effects of different countermeasures, and the development of new and more effective safety measures.

R&D is an important part of safety work and should be incorporated into integrated safety programs. In order to be effective, safety R&D should be interdisciplinary and involve, among other experts, statisticians, behavioral and social scientists, engineers, and economists.
Considerable safety R&D has been carried out during the last decades, mainly in the developed countries (ref. 23, 25, 26, 27 and 39). Much work, however, remains to be done, particularly in the following fields:

- road safety indices relevant to developing countries;
- accident analysis and problem identification;
- relationships between road user, vehicle, and road environment characteristics and safety;
- models for road user information acquisition and decision-making;
- the causal chains leading to accidents, that is, accident models;
- relationships between safety measures and their effects on accidents, safety-proxies, and non-safety variables;
- relationships between safety-proxies and accidents;
- appraisal methods and input parameters such as monetary values for accident prevention;
- new or improved safety measures for road users, vehicles, and roads;
- methods for monitoring and evaluation;
- information systems for safety work;
- design and evaluation of integrated safety programs; and
- organization and management of safety work and programs.

As the extent and scope of safety R&D work is fairly limited in developing countries, they will have to draw on the results of R&D work in developed countries. It is likely that most of the research approaches, methods, and techniques used in developed countries could also be applied in developing countries. The research findings, however, may not be completely transferable to developing countries and before being applied, may have to be tailored to specific conditions in developing countries.

Even if most of the results from R&D from the developed countries were applicable to developing countries, it would still be important for the latter to build up their own R&D resources. In fact, the applicability of foreign research results can always be questioned, particularly in such a complicated field as road safety, and domestic R&D is essential to understand and develop local interest in road safety. In some cases it might even be suitable to establish a special Road Transport Research Institute responsible, inter alia, for safety R&D.

It is clear that intensified R&D efforts in the field of road safety are urgently needed both in developed and developing countries. In order to be efficient, such R&D has to be properly organized and staffed with sufficient and competent personnel, facilities and funds.
VII. RECOMMENDATIONS

Background and Needs

Road accidents constitute a grave and growing problem in developing countries. It is, therefore, important from both social and economic considerations that decisive action be taken now to avoid further aggravation of the problem.

The road accident problem has been of considerable concern to the developed countries with rapidly increasing rates of motorization. International organizations, such as the United Nations (UN) and the World Health Organization (WHO), have carried out several seminars and workshops to stress the seriousness of the problem and the urgency of action (ref. 42, 43 and 44). Donor agencies in the industrialized countries have contributed by publishing reports on road safety, and, in some cases, giving grants in aid for safety interventions (ref. 32, 33 and 55). Some R&D institutions in industrialized countries have helped by specifically analyzing the accident problem in the developing countries and by developing suitable means of assistance and safety measures (ref. 45 and 55). Safety consultants have also contributed by offering their skills and experience to developing countries (ref. 31).

The World Bank has been concerned with the problems of road safety for a long time. In 1982 informal guidelines for safety components in Bank projects were issued. These guidelines state that the Bank would be prepared not only to assist authorities in the developing countries, but also to initiate required action if attention to road safety is insufficient. The guidelines further indicate that the Bank would review the safety situation in transport sector studies, give explicit consideration to safety in studies for road projects, and encourage safety programs. It is also pointed out that financial support up to 5 - 10% of the Bank loan/credit amount for highway and urban transport projects (but not more than US$5 million) may be considered without ex-ante benefit-cost justification, provided that the major safety items are evaluated. In the guidelines are also discussed other important questions, such as accident data, staff competence, contents of intervention programs, and measures to improve the Bank's expertise in road safety. In the last decade the Bank has commissioned studies on the valuation of accident prevention, the efficacy of safety interventions, and monitoring and evaluation.

A recent review of some 90 Bank-supported highway projects shows that the total Bank lending for identified road safety components in highway projects amounted to about 1% of the total lending for such projects. To this should be added a large sum for implicit road safety components in both urban development and rural road projects. The review of a sample of Bank appraisal reports for highway projects showed that the road accident problem is seldom discussed beyond a superficial treatment of the problem. Furthermore, safety effects are rarely estimated and included in the economic appraisals. It could possibly be argued that most of these projects would improve safety all the same, and that the
economic rate of return -- even with safety benefits excluded -- is large enough to justify the project. There is, however, a great risk that such an approach would result in missed opportunities to introduce efficient road safety practices, and in continued low interest in road safety. Because of a lack of discussion of safety effects in Bank project appraisal reports, it is almost impossible to assess if the safety considerations are well-balanced or not. In most of the projects, for example, the geometric standards are described, but there are usually no descriptions of standards concerning other important safety features such as: road markings, roadside features, access control, intersections, and traffic regulations (e.g., speed limits).

In developing countries, lack of sufficient interest and concern about road safety has been partly due to other, more urgent problems and partly to attitudes and lack of knowledge. In the last 5 to 10 years, the interest in, and attitudes towards road safety have improved substantially. In most countries there is an increasing concern about reducing accidents and their severity. Efficient safety work, however, requires information about the accident situation, as well as a suitable organization, competent staff, and funds. In most of these areas there are still many serious deficiencies in developing countries.

Despite the growing interest and concern for road safety in developing countries, there has been some lack of decisiveness and perseverance on part of international organizations and bilateral aid donors in introducing road safety improvements through sufficient levels of lending, suitable means of assistance, and, eventually, by efficient safety actions. There also appears a lack of cooperation and coordination on road safety matters between the international and national parties concerned. Many of the developing countries have started to take action to tackle the accident problem, but there is still a long way to go before road safety work can become truly efficient.

Proposals for Further Work

Given the deficiencies in road safety work in developing countries, the following tasks are proposed to sharpen focus on road safety activities:

(i) to clearly articulate a World Bank policy on road safety in developing countries;
(ii) to provide suitable means of assistance for safety work in developing countries; and
(iii) to establish better cooperation and coordination between the international and national organizations concerned with road safety in developing countries.

The main aim of task (i) is to further vitalize Bank efforts to improve road safety in developing countries. This task would require preparation of well-focused studies:

* to increase the awareness of the problem and the need for action;
* to provide a general overview of potential safety measures and their effects;
to establish a Bank policy on road safety in terms of providing advice as well as granting loans and credits for interventions, assistance, and education;

to provide technical guidelines on how the Bank should handle safety questions in different situations (e.g., in staff appraisal reports and the need for \textit{ex-post} evaluation); and

to outline an action plan for the Bank to further contribute to improved road safety in developing countries.

The main aim of task (ii) is to provide various means of assistance, partly in the form of studies, handbooks, and guidelines on appraisal and evaluation techniques, information systems, organization and staff, and partly in the form of educational material, seminars, and courses. The following subjects described in Annex C, are considered to be the most important:

- information systems for road safety;
- effects of road safety measures;
- methods for determining monetary values of accident prevention;
- methods for monitoring and evaluation;
- road safety organization, management and staff;
- review of models, guidelines and standards concerning urban planning and land use, traffic management, road design, equipment and maintenance, vehicle equipment and inspection, and road user information (including education in schools and driver education and training); and
- road safety research and development.

The main aim of task (iii) is to improve the efficiency of the safety efforts through a coordinated, long-term program. It is suggested that the World Bank take the responsibility for establishing the necessary cooperation and coordination among concerned international organizations, bilateral aid donors, and national groups. This commitment is justified by the Bank's long-standing support for road infrastructure projects and its close association with developing countries, and its close ties with international and national organizations as well as with the academic community.

The task of establishing this cooperation and coordination could consist of the following activities:

- to spell out the needs for cooperation and coordination, in the context of a long-term program, including the organization, management and financing of the program;
- to arrange a meeting with representatives of concerned agencies (e.g., international organizations, national aid development agencies, R&D institutions and client countries) to discuss the proposals for cooperation and coordination;
- to implement the long-term program by drawing up terms of reference for different tasks, assigning tasks to suitable organizations (R&D institutes and universities, etc.), and transferring the knowledge to developing countries; and
- to establish an advisory council of road safety experts to develop and monitor the program.
ANNEX A

THE ROAD ACCIDENT PROBLEM IN DEVELOPING COUNTRIES

The magnitude and the nature of the road safety problem varies between countries as well as the different road and street environments within a country. A description of the road safety situation in a country should include the following parameters:

(a) number of accidents, fatalities, and injuries: relative to the size of the population and the vehicle fleet;

(b) measures of risk: Risk is defined as the number of negative events (fatalities, injuries, accidents) divided by some relevant measure of risk exposure (e.g., vehicle km or person km). Risk is the quantification of the probability that an accident, fatality or an injury will occur per unit of exposure;

(c) cost of accidents: The cost of accidents is a measure of the amount of resources wasted in a country due to accidents. To illustrate its magnitude, it is common to compare accident costs with GNP. It may be even more relevant to compare the cost of accidents with the vehicle operating cost since accidents are an unavoidable component of the cost of transportation; and

(d) statistics in (a), (b) and (c) above should be classified by: road user categories, vehicle types, road and street environments, months in the year, days of the week, hours of the day, road and weather conditions, etc.

The lack of reliable data is a serious problem in most of the developing countries. Road statistics published by the International Road Federation (IRF) include data on the number of fatalities, the number of injured and the number of accidents with personal injury for about one-half of the developing countries. These data, however, are not reliable. This is particularly true of statistics related to the number injured and the number of accidents with personal injury. It is quite reasonable to assume that the incidence of accidents is much larger than actually reported so that any description based on available statistics underestimates the real road accident problem.

Based on the available statistics, the road safety situation in developing countries has been analyzed by various researchers. The Overseas Unit of the Transport and Road Research Laboratory (TRRL) in the UK has carried out considerable research in this field and has also undertaken specific and more detailed investigations in some countries.
The Total Numbers

The total numbers of fatalities, injuries and accidents in relation to population are normally lower in the developing countries than in the developed world. The reason for the lower figure in the developing world is the relatively small number of motor vehicles per inhabitant.

A generalized relationship between road transport fatalities and increasing levels of motorization based on data from developed countries is shown in Figure A.1.

In many developing countries the rate of motorization has reached a level (50-100 motor vehicles per 1000 inhabitants) where road traffic accidents are emerging as a major cause of deaths and injuries (ref.4).

The Risks

Measures of risk describe the road safety situation in a country and permit comparisons between countries. The magnitude of the risk provides an indication of the seriousness of the road safety problem.

The most relevant risk measures in road transport are the number of accidents per vehicle-km or the number of fatalities and injuries per person-km. These measures directly relate accidents to the consumption of transport services compared to other effects of road transport. Unfortunately, data on vehicle kilometers and person kilometers are not normally available in developing countries. The measures of risk exposure commonly used are the number of motor vehicles of different types, and population.

If the fatality risk is defined as the number of fatalities per 1,000 motor vehicles per year, several investigations show that the risk is 2-20 for developing (low-motorized) countries, compared to 0.2 - 0.5 for developed (high-motorized) countries. Expressed differently, there is one death per year for every 50-500 vehicles in the low-motorized countries, whereas in the high-motorized countries there is one death for each 2,000-5,000 motor vehicles.

Smeed noted in 1949 (ref.5) in his comparison of road accidents in different (mostly European) countries for the year 1938, that there exists a close relationship between the fatality risk (annual fatalities per motor vehicle) and the level of motorization (motor vehicles per inhabitant).

Analyses of this kind have been made on data from different countries and for different years (see ref. 6-14). The following relationship:

\[
\frac{F}{V} = \frac{a V^b}{F}
\]

(A1)

where \( F \) = number of fatalities per year
\( V \) = number of motor vehicles
\( P \) = population
\( a \) and \( b \) = regression constants
Figure A.1. Typical relationship between fatalities per inhabitant and motor vehicles per 1,000 inhabitants.
normally explains about 80% of the observed variation between the countries even if the constants ‘a’ and ‘b’ vary significantly between the various analyses.

Jacobs et al. at the TRRL studied this relationship for developing countries for the period 1965-78 (ref. 15). They also reexamined the same developed countries analyzed by Smeed for 1938, for the years 1950, 1960 and 1970 (ref. 7). Their conclusions suggest that while the relationship for European countries has remained relatively stable over time, the fatality rates per motor vehicle in developing countries increased during the period 1965-78, for the same level of motorization. Had the fatality rates per motor vehicle not increased in developing countries, the number of fatalities in 1978 would have been about a third less than the actual incidence.

To test the validity of this trend after 1978 and to compare developing and developed countries, 34 countries were analyzed for the period 1979-83 using the most recent data from IRF (ref. 16).

In Figure A.2 the mean values of fatalities per year per thousand motor vehicles $\ell$ are plotted against the number of motor vehicles per thousand inhabitants $V_p$ for the period 1979-83. The regression relationships for all 34 countries, from low-motorized ($V_p < 200$) to high motorized ($V_p > 200$) countries are shown in the figure.

Among the countries surveyed Togo had the highest fatality risk (40 fatalities per 1000 vehicles each year) and Sweden the lowest (0.23). A large proportion (about 90% of this variance is explained by the level of motorization, i.e. the number of motor vehicles per inhabitant.

If the regression line for the low-motorized countries is extrapolated to higher levels of motorization, it lies 50 to 70% higher than the line for the high motorized countries.

It is interesting to compare the relationship for the years 1979-83 with Smeed’s 1938 relationship for the developed countries. Figure A.3 shows that Smeed’s relationship is quite close to the regression line for low-motorized countries (1), whereas the fatality rate per motor vehicle is 15-30% lower for high-motorized countries, than predicted by Smeed’s formula. These results compared to the previously mentioned analyses by Jacobs, which showed minor deviations from Smeeds relationship for the developed countries during the 1938-70) suggest that reductions in fatality rates in developed countries have mostly occurred during the 1970’s. The fatality rates in developing countries seem to be fairly close to those in developed countries before the 1970’s, after accounting for the level of motorization.

---

1/ The most common definition of a fatality is that the victim is dead within 30 days. For countries with other definitions the number of fatalities have been adjusted according to ref. 8.
Figure A.2.

MEAN VALUES FOR 34 COUNTRIES 1979-83

Equations:

1. \( \frac{F}{V} = 42 \left( \frac{V}{P} \right)^{-0.75} \) for \( 1 < \frac{V}{P} < 1000 \) \( n=34 \) \( r^2=0.92 \)

2. \( \frac{F}{V} = 32 \left( \frac{V}{P} \right)^{-0.65} \) for \( 1 < \frac{V}{P} < 200 \) \( n=20 \) \( r^2=0.87 \)

3. \( \frac{F}{V} = 50 \left( \frac{V}{P} \right)^{-0.79} \) for \( 200 \leq \frac{V}{P} < 1000 \) \( n=14 \) \( r^2=0.42 \)
Figure A.3.

COMPARISON BETWEEN 34 COUNTRIES 1979-83 & SMEED'S FORMULA FOR "DEVELOPED" COUNTRIES 1938

Equations:

(1) \( \frac{F}{V} = 32 \left( \frac{V}{P} \right)^{-0.65} \) for \( 1 < \frac{V}{P} < 200 \), \( n=20, r^2=0.87 \)

(2) \( \frac{F}{V} = 50 \left( \frac{V}{P} \right)^{-0.79} \) for \( 200 \leq \frac{V}{P} < 1000 \), \( n=14, r^2=0.42 \)

(3) \( \frac{F}{V} = 31 \left( \frac{V}{P} \right)^{-0.67} \) SMEED'S FORMULA

- F: Fatalities
- V: Year, \( 10^3 \) Motor Vehicles
- P: \( 10^3 \) Inhabitants
Figure A.4 shows a comparison between the relationships evaluated by Jacobs for developing countries for 1965 and 1978 and the relationship for low-motorized countries for 1979-83. In Jacobs' analysis the relationship for 1965 lies well below the graph for 1978 which, in turn, lies a bit higher than the relationship for 1979-83. The 'worsening' traffic safety situation in developing countries during the period 1965-78 has perhaps been followed by an improvement during recent years. It may be questioned whether Jacobs' results show a real worsening situation between 1965 and 1978 given the narrow influence space of his 1965 relationship. A reasonable explanation of the difference between 1965 and 1978 may be that many developing countries were building up their accident reporting systems during this period; hence, the increase in the fatality rates may be partly a function of improved accident reporting. An annual, more detailed study of the trend for the period 1979-83 has been carried out separately and the results are shown in Figure A.5 for the 34 countries, segregated by low- and high-levels of motorization.

There is a continuous overall trend during the period 1979-83 towards a lower fatality rate per motor vehicle for a given level of motorization. Had the relationship for 1979 been the same for 1983, i.e., same fatality rate for the same level of motorization, the fatality rate per motor vehicle would have been 10-50% higher in both low and high-motorized countries than the actual figures. The number of fatalities in low-motorized countries increased by about 12% during the four years instead of 20% if the relationship had not changed.

Another way to explain the development of road accident fatality rates in low-motorized countries during the period 1979 to 1983 is shown in Figure A.6. The arrows in this figure show the direction of the fatality rate in each country between 1979 and 1983 together with the average fatality rate for these years. In 12 of the countries the reduction in the fatality rate per motor vehicle was greater than can be expected from the average line; in six countries it remained almost the same. In one country it was smaller than expected and in one country the fatality rate per motor vehicle increased.

The previously mentioned cross-sectional analyses compared fatality rates in different countries for a defined period of time. If the relationship between the fatality rate per motor vehicle and motor vehicles per inhabitant is time stable, different countries should follow almost the same relationship as their motorization increases. In reference 17 road accident fatality trends are shown for 46 countries (28 developed and 18 developing) from their early stage of motorization until the beginning of the 1970s and compared to Smeed's curve. Most of the countries show a decrease in fatality risk in accordance with Smeed's curve and there are no noticeable differences between developed and developing countries.

If the fatality risk is mostly a function of the level of motorization then how should Smeed's relationship be interpreted and used in road safety work in developing countries? It would appear that road transport authorities and road safety agencies should respond to the total number of fatalities and not to the risks. If the total number of fatalities is high, or perhaps even more important, if it is increasing rapidly, there is a strong motivation for action.
Figure A.4.


Equations:

1. $F = 9.7 \left( \frac{V}{P} \right)^{0.43}$  
   Jacobs, Developing Countries 1965

2. $F = 41 \left( \frac{V}{P} \right)^{-0.7}$  
   Jacobs, Developing Countries 1978

3. $F = 32 \left( \frac{V}{P} \right)^{-0.66}$  
   Developing Countries 1979-83  $n=20$  $R^2=0.87$

V Year, $10^3$ Motor Vehicles
F Fatalities

Countries included in the comparison:
Figure A.5.

THE TREND FOR 20 DEVELOPING & 14 DEVELOPED COUNTRIES 1979—83

Equations:

$1 < \frac{V}{P} < 200$

$F = 37 \left( \frac{V}{P} \right)^{0.66}, r^2 = 0.88$

$F = 110 \left( \frac{V}{P} \right)^{0.92}, r^2 = 0.49$

$200 \leq \frac{V}{P} < 1000$

$F = 36 \left( \frac{V}{P} \right)^{0.67}, r^2 = 0.87$

$F = 48 \left( \frac{V}{P} \right)^{0.78}, r^2 = 0.39$

$F = 32 \left( \frac{V}{P} \right)^{0.85}, r^2 = 0.33$

$F = 49 \left( \frac{V}{P} \right)^{0.80}, r^2 = 0.37$

$F = 31 \left( \frac{V}{P} \right)^{0.86}, r^2 = 0.86$

$F = 38 \left( \frac{V}{P} \right)^{0.76}, r^2 = 0.40$
Figure A.6.

THE TREND FOR 20 DEVELOPING COUNTRIES

Equation \( F = 32 \left( \frac{V}{P} \right)^{0.65} \), \( r^2 = 0.87 \)

(Based on Averages 1979-83)

[Graph showing the trend for 20 developing countries with data points for various countries and the equation F = 32(\( \frac{V}{P} \))^0.65, r^2 = 0.87.]
As a result of the safety measures adopted, the risks in the transport system are reduced. The differences in the totality risk between countries at the same level of motorization thus depends mainly on the efficiency of the safety measures that have been introduced. Preston (ref. 8) has compared some European countries, with especially good or bad accident records (assessed in terms of deviations from Smeed's formula) and found that countries with fewer road deaths than expected have lower speed limits and stricter laws to prevent drunk driving.

Smeed's formula seems to be a practical tool for presenting an overall picture of the road safety situation in a country or a region. It also permits comparisons with other countries. In Table 1 the differences between the number of fatalities estimated by the relationship for all the countries:

\[
\frac{F}{V} = 42 \left(\frac{V}{P}\right)^{-0.75}
\]  

and the actual number of fatalities is shown for 34 countries in order of magnitude of percentage differences. Such a comparison can be useful in formulating realistic objectives for the overall impact of safety programs in a country.

If a country, for example, has a fatality risk 25% above the average value at a given level of motorization it would be desirable to bring down the risk to the average level within five years. What then will be the number of fatalities after five years if there is an annual 10% increase in the number of motor vehicles and a 3% increase in the population? Using the relationship for low-motorized countries:

\[
\frac{F}{V} = 32 \left(\frac{V}{P}\right)^{-0.65}
\]

it is estimated that there will be about 4% more fatalities after five years.

If instead the objective is to keep the number of fatalities constant, the relationship can be used to assess if the requisite reduction in fatality risk appears feasible. In the example above the fatality risk must be reduced from 25% above to 4% below the average or by 38% within the five years to prevent any increase in fatalities over the five years.

Finally, the above relationship for low-motorized countries may be used to estimate the change in the number of fatalities in developing countries by year 2000 under the following assumptions:

(a) the accident risk relationship will not change;
(b) the number of motor vehicles will increase by 10% annually; and,
(c) the population will grow by 3% annually.
Table A.1. A comparison between predicted and actual number of road accident fatalities per annum for the period 1979-83.

<table>
<thead>
<tr>
<th>Country</th>
<th>Predicted</th>
<th>Actual</th>
<th>Deviation from predicted in Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>1,585</td>
<td>819</td>
<td>-48</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>1,789</td>
<td>988</td>
<td>-45</td>
</tr>
<tr>
<td>Japan</td>
<td>22,816</td>
<td>13,362</td>
<td>-41</td>
</tr>
<tr>
<td>Great Britain</td>
<td>9,945</td>
<td>5,906</td>
<td>-41</td>
</tr>
<tr>
<td>Pakistan</td>
<td>5,492</td>
<td>3,828</td>
<td>-30</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>604</td>
<td>427</td>
<td>-29</td>
</tr>
<tr>
<td>Ivory Coast</td>
<td>846</td>
<td>603</td>
<td>-29</td>
</tr>
<tr>
<td>Indonesia</td>
<td>15,025</td>
<td>11,017</td>
<td>-27</td>
</tr>
<tr>
<td>Spain</td>
<td>6,513</td>
<td>4,878</td>
<td>-25</td>
</tr>
<tr>
<td>Yemen</td>
<td>798</td>
<td>600</td>
<td>-25</td>
</tr>
<tr>
<td>Italy</td>
<td>10,840</td>
<td>8,870</td>
<td>-18</td>
</tr>
<tr>
<td>USA</td>
<td>50,171</td>
<td>47,655</td>
<td>-5</td>
</tr>
<tr>
<td>New Zealand</td>
<td>648</td>
<td>628</td>
<td>-3</td>
</tr>
<tr>
<td>Mauritius</td>
<td>116</td>
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<td>-2</td>
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<td>Hungary</td>
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<td>Venezuela</td>
<td>2,232</td>
<td>4,899</td>
<td>+119</td>
</tr>
</tbody>
</table>

Note: The figures for developing countries (e.g. Ethiopia, Pakistan, Indonesia) may be underestimated because of the unreliable collection and reporting of data on road accident fatalities and vehicle registrations.
This analysis indicates that the number of fatalities in developing countries will increase by about 100% by the year 2000 under the foregoing assumptions. But if the increase in the number of vehicles is 5% per annum and the population growth rate is 2% per annum, the number of fatalities will increase by about 50%.

In order to improve the road safety situation by the turn of the century over the present projection of 50-100% increase in fatalities, it would be necessary for the developing countries to achieve a more rapid decrease in the fatality risk than the developed countries have achieved during their corresponding phase of motorization.

The most common measure of risk in road transport is the number of accidents per $10^6$ vehicle-km. The main advantage in the use of this index is that it directly relates accidents to the volume of transport. For purposes of this review the number of accidents per million vehicle kilometers will be called the accident risk.

There are very few investigations of accident risk in developing countries because information on vehicle kilometers is not readily available. Jacobs et. al. (ref. 15) made specific surveys of rural roads in Kenya and Jamaica and compared the result with developed countries. Their results show that the accident risk (personal injury accidents only) in Kenya is about five times and in Jamaica about seven times greater than the accident risk in developed countries.

Jacobs et. al. also estimated the accident risk (personal injury accidents) for different regions in Kenya (ref. 15 and 18). Compared to Sweden, the accident risk was estimated to be about six times greater.

The Indian Road User Cost Study (ref. 19) made comparisons between accident risks (personal injury accidents) on some Indian roads and the above-mentioned results from Kenya. The study noted that the accident risk on Indian roads surveyed was much lower than for similar roads in Kenya. In fact, it is only about 20% greater than the accident risk in developed countries for the same type of road. The accident risk on Indian roads appears low when compared with the fatality rate of 6.6 per 1000 motor vehicles (1979), a fairly normal value at India's level of motorization. This apparent discrepancy is possibly explained by the more intensive fleet utilization (km per annum) in India as compared to Kenya.

It is, however, important to understand the relationship between the fatality rate per vehicle and the accident risk (accidents per vehicle-km). This relationship can be expressed (for a given time period) as follows:

\[
\text{Fatalities} = \frac{\text{Accidents}}{\text{Vehicle-km}} \times \frac{\text{Fatalities}}{\text{No. of Vehicles}} \times \frac{\text{Vehicle-km}}{\text{Accidents}} \times \frac{\text{No. of Vehicles}}{}
\]

Consequently, if two countries have the same accident risk (accidents/vehicle-km) they have the same fatality rate per vehicle per year only if the product of the fatalities per accident and the kilometers driven per year per vehicle is the same.
The fatalities/accident ratio can be developed further and then the expression can be written as:

\[
\text{Fatalities} = \frac{\text{Accidents} \times \text{Casualties} \times \text{Fatalities} \times \text{Vehicle-km}}{\text{No. of Vehicles} \times \text{Vehicle-km} \times \text{Accidents} \times \text{Casualties} \times \text{No. of Vehicles}} \quad (A5)
\]

It is interesting to assess the relationship of the factors in Equation A5 with different types of safety countermeasures.

* Accidents/Vehicle-km can be reduced, for example, by improving the road and street environment, road user behavior, and some vehicle characteristics.

* Casualties/Accident can be reduced, for example, by safety belts, vehicle construction, and reducing the number of occupants in the vehicles. It must be noted that reducing the number of occupants per vehicle will reduce the capacity of transport or increase the number of vehicles.

* Fatalities/Casualty can, for example, be reduced by an improved medical emergency care system.

* Veh-km/vehicle may be reduced, for example, by reducing the frequency or length of work-related trips or by controlling urban sprawl.

There are other safety countermeasures which influence several of the above-mentioned factors. The most striking example is enforcement of reduced speed limits which tends to reduce accidents/vehicle-km, casualties/accident, and fatalities/casualty.

A comparison of these factors (equations) for India and Sweden is summarized below (refs. 19 & 20):

<table>
<thead>
<tr>
<th>Factor</th>
<th>India</th>
<th>Sweden</th>
<th>Ratio: ( \frac{\text{India}}{\text{Sweden}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents/Vehicle-km</td>
<td>0.49(x10^{-6})</td>
<td>0.33(x10^{-6})</td>
<td>1.5</td>
</tr>
<tr>
<td>Casualties/Accident</td>
<td>2.2</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Fatalities/Casualty</td>
<td>0.18</td>
<td>0.048</td>
<td>3.8</td>
</tr>
<tr>
<td>Vehicle-km/vehicle</td>
<td>34,000</td>
<td>15,000</td>
<td>2.3</td>
</tr>
</tbody>
</table>

| Annual Fatalities/Vehicle | 6.6\(x10^{-3}\) | 0.33\(x10^{-3}\) | 22                                    |

This analysis reveals an interesting picture. The accident risk in India seems to be only 50\% greater than Sweden. The casualties per accident are 50\% higher, which seems reasonable due to the higher vehicle occupancy rates and
population densities in India. The largest difference appears in fatalities per casualty -- 3.8 times greater in India as compared to Sweden. This indicates that improvements in emergency medical care and rescue system would be very beneficial for traffic safety in India. The difference in vehicle utilization (2.3 times greater in India) is of course not a safety problem. The product of these ratios gives a road accident fatality rate (fatalities/vehicle) that is 22 times higher for India as compared to Sweden.

The main purpose of this comparison is to show a method for using data on accidents, fatalities, injuries, and vehicle-kilometers travelled to give a simplified measure-oriented picture of the risk situation in the road transport system of a country.

The Cost of Accidents

The cost associated with road accidents is quite controversial mainly because it is very difficult to agree on the value of human life. In developed countries, accident cost analysis is a well established facet of road project investment appraisal. Cost estimates, however, vary greatly among countries, depending essentially upon the different principles used. The importance of using explicit accident values is stressed as the best way to obtain consistency in different measures concerning safety and to optimize the use of the resources available. Following the suggestion by Hills and Jones-Lee (ref. 21), the gross output approach is recommended, preferably supplemented by an additional amount to account for the cost of human pain and suffering. Fouracre and Jacobs (ref. 22) have compared and discussed seven cost analyses from various developing or semi-developed countries. The results vary substantially but the order of magnitude suggests the cost of road accidents to be about 1% of the GNP.

It seems relevant to compare road accident costs with other costs generated by road traffic, e.g., vehicle operating cost, travel time cost, maintenance cost, and the cost of road investments. In Sweden in 1985, the cost for a seven-meter paved rural road with ADT=3,000 vehicles (12% lorries and buses) was (ref. 23):

<table>
<thead>
<tr>
<th></th>
<th>US cents per vehicle km</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>2.1</td>
<td>8</td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.6</td>
<td>2</td>
</tr>
<tr>
<td>Accidents</td>
<td>3.6</td>
<td>14</td>
</tr>
<tr>
<td>Travel time</td>
<td>9.5</td>
<td>36</td>
</tr>
<tr>
<td>Vehicle operation</td>
<td>10.6</td>
<td>40</td>
</tr>
</tbody>
</table>

The accident cost is a substantial part (14%) of the total road transport cost and represents an important loss in transport efficiency. It must be noted that a very high monetary value is associated with accident costs in Sweden. About 60% of road accident cost is human cost to compensate for pain and suffering of the accident victims and those who care for them. Even if this human cost is excluded, the accident cost is about 6% of the total road transport cost. The accident costs are likely to be considerably higher proportion of road transport costs in developing countries because the number of accidents,
fatalities and casualties per vehicle kilometer are much higher than in Sweden. An assessment of the road accident problem in a country should include an estimate of the accident costs and these costs should be compared to the total costs of the road transports.

Road Accident Characteristics

Analyses of road accident patterns are essential in order to understand the nature of the problem and to choose proper countermeasures. Important questions are:

(a) Where and when do the accidents occur?
(b) How serious are the accidents?
(c) Which are the accidents types? and
(d) Which road user categories are involved?

The analyses of road accidents generally relate to conditions in developed countries and the recommended countermeasures relate to these conditions. A few investigations suggest that accident patterns can be quite different in developing countries.

To answer the question, "Where and when do accidents occur?" some investigations show there are more accidents in urban than in rural areas (ref. 24) in spite of the fact that a large majority of the population lives in rural areas. The explanation of this can be:

(a) under-reporting of accidents in rural areas;
(b) higher accident risks in urban areas; and
(c) a large proportion of motor vehicles are based and driven in the urban areas.

A study of fatal accidents in New Delhi, India (ref. 9), shows that a majority of the accidents take place on urban streets between intersections and not at intersections. The reverse is true in the cities of developed countries.

Many studies from developed countries have shown that high-standard rural roads are safer than low-standard roads. Studies in Kenya, Jamaica and India (ref. 15, 18 and 19) show that this appears to be equally valid for developing countries.

All investigations comparing the consequences of accidents in developing and developed countries have shown that accidents in developing countries are much more serious than in developed countries. There are many plausible explanations:

(a) there are more occupants per vehicle, and vehicles are often overloaded in developing countries;
(b) the occupants are less protected (no seat belts, no helmets, riders on truck platforms, etc.);
(c) there are more unprotected road users (pedestrians, cyclists, two wheel-drivers, etc.).
(d) there is a mix of fast, heavy motor vehicles and slow, light often non-motorized vehicles, a situation that does not exist in developed countries; and  
(e) under-reporting of less serious accidents is greater in developing countries.

The proportion of accidents involving pedestrians is much higher in developing than in developed countries -- 40-80% pedestrian casualties in cities in developing countries compared to 15-30% in developed countries (ref. 24). The larger proportion of pedestrians killed or injured in cities in developing countries is due to the fact that each motor vehicle interacts with more pedestrians per kilometer driven in developing countries than in developed countries. Other important causes can be attributed to inappropriate behavior both on the part of drivers and pedestrians and poor visibility due to the lack of street lighting and non-functioning vehicle lights.

There are large differences between developing and developed countries in the categories of vehicles involved in accidents (ref. 8, 9 and 24):

(a) the proportion of accidents involving commercial and public service vehicles (e.g., trucks and buses) is higher and the proportion of cars lower in developing countries;
(b) the proportion of accidents with two-wheeled vehicles varies greatly between different developing countries, but it is on average higher than in developed countries; and
(c) there are accidents involving vehicles which do not exist in developed countries (e.g., rickshaws, different types of carts, etc.).

The more heterogeneous traffic in some developing countries produces higher accidents risks and more serious consequences than in developing countries. A greater variety of safety measures are therefore required in developing countries.
ANNEX B

ROAD SAFETY MEASURES AND THEIR EFFECTS - TWO EXAMPLES

A. Cross-section of Rural Two-lane Roads

General

The cross-section of a road is an important geometric design element. It is made up of the travelled way, the shoulders, and the roadsides. The travelled way and the shoulders constitute the roadway.

The travelled way is the portion of a roadway which is intended for the normal movement of vehicles. The shoulders are the portion between the travelled way and the roadside, and are mainly intended as space for stopped and disabled vehicles, slow moving vehicles, pedestrians and bicyclists, recovery of run-off vehicles, and for passing turning vehicles, which are blocking the travelled way. The roadside is the area adjoining the outer edge of the roadway, including side slopes and ditches.

The width of the roadway affects the driver’s possibilities to maneuver and to overcome potentially dangerous situations. Narrow lanes and travelled way imply small lateral clearances between overtaking and meeting vehicles, and narrow shoulders means less space for stopped vehicles and less margin to regain vehicle control and to avoid encroachments into the roadsides. It is quite probable that increased lane, shoulder and roadway width will reduce accidents, unless this results in higher speeds or less attentive driving habits.

On steep upgrades, where overtaking is hazardous due to restricted sight distances, slow-moving trucks will cause considerable delay to passenger cars and other fast vehicles. This situation is often perceived as irritating by the drivers and can lead to dangerous overtakings and accidents. It is therefore plausible that the installation of special climbing lanes could reduce accidents at such locations.

Flat cross slopes on horizontal road sections will cause water to accumulate on the road surface during heavy rains and can thereby contribute to hydroplaning accidents. Severe unevenness in the lateral direction, such as rutting, can have similar effects. Sufficient cross slopes and even surfaces are therefore likely to reduce accidents of this type.

The characteristics of the roadsides affect the ability to regain control of vehicles which have run off the roadway, and the severity of accidents off the roadway. Flat side slopes and clear zones, free from hard, fixed objects, will therefore reduce the number of related accidents and their severity.
Lane Width/Travelled Way

There are a number of statistical studies of the relationships between the width of lanes/travelled way and safety, mainly from developed countries. Most research results show that accident rates decrease with an increase in width (ref. 57, 58). Some results are shown in Figure B.1. These results indicate a rather steep decrease in accident rates with increases in width of travelled way from 4m to 7m. As an example, an increase in lane width from 2.7m to 3.4m can be expected to reduce accident rate by 30% (ref. 60). Some results indicate that accident rates decrease as lane width increases up to 3.4m and that little additional benefit is gained by widening lanes beyond this value (ref. 57, 60).

Shoulder Width

There are several studies of the safety effects of shoulder widths, mainly from developed countries. The results differ substantially. Some early studies in the USA indicated that accidents increase with increasing shoulder width (ref. 57, 58, 60). More recent studies, however, show that accident rates are reduced as shoulders are widened. Some of the results are shown in Figure B.2. These results show a fairly steep decrease in accidents with increases in width from 0m to 2m. As an example, an increase in shoulder width from 0.6m to 2.4m can be expected to reduce accident rate by 20% (ref. 60). Most results indicate that little additional benefit is obtained by widening shoulders above 2.7m (ref. 58, 60).

It should be observed that the surface and the level of the shoulders are very important. Roads with paved shoulders at the same level as the travelled way have lower accident rates than similar roads with unpaved shoulders of the same width (ref. 57, 58, 61).

Roadway Width

There are a number of studies of the relationships between the width of the roadway and safety. The results generally indicate that accident rates decrease when roadway widths increase. Some results are illustrated in Figure B.3. It should be noted that some recent studies from developed countries have shown less difference between roads of different widths than previous studies. In some cases, it has not been possible to show any clear correlation between roadway width and accidents (ref. 27, 66).

The results presented in the figure differ considerably, particularly for roadway widths less than 7m. It should be observed that the relationships (1) and (4) concern roads with 70 km/h speed limits and that (7) originates from a multiple regression analysis based on a fairly limited number of accidents and a narrow range of road widths.
Figure B.1. Relationships between width of travelled way and accident rate, expressed as an index with the base at 7m.
Figure B.2. Relationships between width of shoulders and accident rate, expressed as an index with the base at 3m.
Figure B.3. Relationships between width of roadway and accident rate, expressed as an index with the base at 7m (fitted curve also at 13m).
It should be noted that in many studies it has not been possible to fully eliminate the effects of other variables affecting safety, such as alignment, sight distance, density of intersections and access roads, and surface and roadside characteristics. These design elements often are of higher standard for wide roads than for narrow roads. It is therefore possible that some of the results overestimate the effect of roadway width. It is also likely that deliberate efforts to reduce speeds on narrow roads, for example, by lower speed limits, will result in flatter relationships.

In Figure B.3 the two bold curves with base values at widths of 7m and 13m illustrate the changes in accident rates on road sections that can be expected on the average by changes in roadway width for normal or average road and traffic conditions in developing countries. Based on the curve with a base value of 13m, average accident reduction factors for various increases in width are summarized in Table B.1.

For roads with bad alignment and short sight distances, high traffic flows, and a mix of fast and slow moving traffic (heavy and wide trucks, pedestrians, bicyclists, animal drawn carts, etc.), it is possible that the influence of roadway width, especially for smaller widths, is stronger than is indicated by the fitted curve and the table values. For roads with good alignment and sight distances, as well as low traffic flows, and a low proportion of slow moving traffic, it is likely that the given relationship overestimates the effect of the roadway width. In such cases the curve and the reduction factors should be corrected accordingly. It is estimated that the reduction factors (in Table B.1) in the case of adverse road and traffic conditions should be multiplied by a

**Table B.1.** Average accident reduction factors for various increases in roadway width (proportion of the original accident rate).

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
<td>0.10</td>
<td>0.19</td>
<td>0.27</td>
<td>0.32</td>
<td>0.36</td>
<td>0.40</td>
<td>0.42</td>
<td>0.44</td>
</tr>
<tr>
<td>6</td>
<td>0.10</td>
<td></td>
<td>0.24</td>
<td>0.29</td>
<td>0.32</td>
<td>0.35</td>
<td>0.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>0.09</td>
<td>0.16</td>
<td>0.21</td>
<td>0.25</td>
<td>0.28</td>
<td>0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>-</td>
<td>0.08</td>
<td>0.13</td>
<td>0.18</td>
<td>0.21</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.06</td>
<td>0.11</td>
<td>0.14</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.06</td>
<td>0.11</td>
<td>0.14</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.05</td>
<td>0.09</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.04</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.03</td>
</tr>
</tbody>
</table>
factor of 1.2 to 1.4, and in the case of favorable conditions should be multiplied by a factor of 0.5 to 0.7.

The foregoing results are based on normal combinations of lane and shoulder widths and traffic composition. The balance between the two widths has been studied in some research projects. One study shows that, for any total roadway width, within the studied range of variation (travelled way 5.5m to 7.9m, shoulders 0.6m to 3.0m), it is better to use wide lanes and narrow shoulders than narrow lanes and wide shoulders (ref. 63). Another study shows stronger effects of shoulder widths and weaker of lane width (ref. 57). An appropriate safety balance is obtained if the widths of travelled way and shoulders are within the following ranges relative to the total roadway width (Table B.2):

Table B.2. Suitable balance between the widths of travelled way and shoulders.

<table>
<thead>
<tr>
<th>Roadway (m)</th>
<th>Travelled way (m)</th>
<th>Shoulder (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>6.0 - 6.5</td>
<td>0.25 - 0.5</td>
</tr>
<tr>
<td>8</td>
<td>6.5 - 7.0</td>
<td>0.5 - 0.75</td>
</tr>
<tr>
<td>10</td>
<td>7.0 - 7.4</td>
<td>1.3 - 1.5</td>
</tr>
<tr>
<td>13</td>
<td>7.2 - 7.6</td>
<td>2.7 - 2.9</td>
</tr>
</tbody>
</table>

A wide travelled way is generally required when the alignment is curved, sight distances are short, the number of wide, heavy vehicles is high, and speeds are high. Wide shoulders are required when the numbers of slow moving vehicles, as well as pedestrians, bicyclists and carts etc., are high. The selection of the best combination, therefore, has to be based on the actual circumstances for the road in question.

Climbing Lanes

Climbing lanes have often been installed for traffic flow reasons. Limited attention has been given to the safety effects, and there are therefore very few studies of the relationships between climbing lanes and safety (ref. 23, 57, 67, 68, 69, 70).

One study indicates that the installation of climbing lanes on rural two-lane roads will reduce the total accident rate, for the section in question, by on the average 25%, that is, 10 to 20% on moderate upgrades (3 to 4%) and 20 to 35% on steeper grades (ref. 23, 69). It was also observed that additional accident reduction can be obtained within a distance of about 1 km beyond the climbing lane.
In another study it was recommended that climbing lanes should be installed when the combination of length and grade is such that the speed of trucks is reduced to 15 to 20 km/h below the speed of the rest of the traffic stream (ref. 57, 70). The recommendation is based on the fact that accident involvement rate is often increased substantially when the speed difference exceeds 15 to 20 km/h.

Based on the limited research results available, it is estimated that the installation of climbing lanes on roads in developing countries will reduce accident rates by 20 to 30% on the average for the road sections in question. The reduction will be less (15-25%) on moderate and short upgrades and more (25-35%) on very steep and long upgrades. It is also plausible that additional accident reductions will be obtained on a section of about 1 km beyond the climbing lane. On mountainous sections, with high percentages of heavily loaded trucks (in relation to their engine power), it is likely that the accident reduction will be even higher when climbing lanes are used.

Cross Slope and Lateral Unevenness

There are very few studies of the effects of the cross slope on safety. In one study, however, it has been shown that road sections with relatively flat cross slopes, in areas with heavy rainfalls, show higher accident rates than similar sections with steeper slopes (ref. 58, 62). The results indicate that accident rates were about 30% higher on sections with a slope of 0% than on sections with slopes of 2.5%. Based on related results, a minimum cross slope of 2 to 2.5% on paved roads has been recommended (ref. 58, 71).

There are also very few studies of the safety effects of lateral unevenness, such as rutting. One study assumes that an increased number of hydroplaning accidents due to rutting will increase the total accident rate on sections with severe rutting by 5% (ref. 72). In a yet unpublished Nordic study, however, it is indicated that, although hydroplaning accidents on wet surfaces increase due to rutting, the number of other accidents may go down, resulting in unchanged or even possibly lower total accident rates. Plausible reasons for this could be lower speeds on uneven roads and more alert and careful drivers.

Because of the limited research results available, it is difficult to estimate the effects of cross slopes and lateral unevenness on safety. It is reasonable to believe, however, that increasing the cross slope on horizontal road sections from 0% to normally recommended values of 2 to 2.5%, in areas with very heavy rainfalls, could reduce accident rates by up to 10 or possibly even 15%. There is not yet sufficient data to give any estimates of the safety effects of rutting. In areas with heavy rainfalls severe rutting should be avoided, because of the risk of hydroplaning and loss of vehicle control.

Roadsides

Studies in some developed countries have shown that 30 to 40% of all police-reported accidents are run-off-the-road accidents and that the severity of these accidents is high (ref. 58, 73, 74, 75). Since run-off accidents are mainly single vehicle accidents, and as such not reported to the same extent as
other accidents, it is likely that the problem in reality is more serious than it appears from general accident statistics (ref. 73).

When a vehicle unintentionally leaves the roadway and encroaches into the roadside, the following can happen:

(a) the driver is able to regain control and return the vehicle to the roadway without any injuries or damages, that is, no real accident occurs;
(b) the vehicle rolls over, often with serious consequences;
(c) the vehicle collides with roadside objects (including side slopes), the consequences depending on the characteristics of the object;
(d) combinations of (b) and (c); or
(e) the vehicle stops off the roadway, without any rollover or collision.

Since roadside accidents account for a considerable portion of all accidents and injuries, it is important to reduce their number and severity. Roads should be designed and equipped so as to: (i) reduce the number of run-off accidents, for example, by suitable alignment, width and markings; (ii) give the drivers of errant vehicles a good chance to recover and return to the roadway, for instance, by flat roadides and clear zones free from hazardous objects; and (iii) reduce the severity of the accidents, for example, by flat roadsides, clear zones, yielding roadside objects, and by shielding hazardous objects. In other words, the road should be 'forgiving'.

The rate of run-off accidents depends mainly on (ref. 73, 74, 76, 77) road alignment, roadway width, road surface friction, road markings and delineation, lighting and visibility conditions, and recovery areas, that is, the roadside design.

According to several studies the accident rate of run-off accidents increases with decreasing horizontal radius (ref. 58, 76, 78). One study shows that the rate rises sharply with radii less than 600 m for roads with 90 km/h speed limit, and that the rate for a 400 m radius curve is three times that of a tangent. With a speed limit of 70 km/h the rate rises when the radius falls below 400 m, while for roads with 50 km/h, the accident rate is not affected (ref. 76). In general, encroachments off the road are more frequent to the right than to the left (for right-hand traffic), on left curves than on right curves; and at the outer side of the curve than at the inner side (ref. 58, 78).

The rate of run-off accidents increases with steeper grades (ref. 58, 76, 78). One study shows that an increase in grade from 0 to 5% is followed by a run-off accident increase of 60 to 70% (ref. 76). Another study indicates that downgrades, and especially in combination with left curves, are particularly hazardous (ref. 58, 78).

Several studies show that the risk of running off decreases with increased roadway width and that the type of shoulder (paved or not) is important (ref.
As an example, an increase from 7 to 13 m paved roadway can be expected to reduce run-off accidents by 40 to 50% (ref. 74, 75).

It has also been shown that accident rates increase with decreases in road surface friction, that the rate is higher in bad lighting and visibility conditions than in good conditions, that accidents decrease with good road markings and delineation, and that the chance of avoiding a real accident, by regaining control and returning to the road, increases with flatter slopes and wider clear zones (ref. 58, 73, 74, 79).

The severity of run-off accidents depends mainly on (ref. 75, 76, 77, 80):

(a) front and back slopes, ditches;
(b) lateral distance to objects, clear zones; and
(c) crash characteristics of objects.

There are few studies of the relationships between roadside design and accidents and their severity. In one study of single-vehicle run-off accidents it has been shown that accident rates increase significantly with steeper slopes and lack of clear zones (ref. 58, 81):

<table>
<thead>
<tr>
<th>Front Slope</th>
<th>Clear Zone (m)</th>
<th>Relative Accident Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:6</td>
<td>9</td>
<td>0.4</td>
</tr>
<tr>
<td>1:4</td>
<td>9</td>
<td>0.6</td>
</tr>
<tr>
<td>1:3 or 1:2</td>
<td>no special</td>
<td>1.0</td>
</tr>
</tbody>
</table>

In several other accident studies it has been shown that the severity of run-off, object collision accidents depends mainly on the gradient and the length of the slope (ref. 58, 62). One study shows that, for a constant slope length of 5 m, the severity (expressed as the ratio between the number of killed and injured drivers and the number of accidents) increases from 0.1 for flat front slopes (between 1:∞ to 1:2.7) to 0.23 for average slopes (between 1:2.6 to 1:1.7) and to 0.46 for steep slopes (between 1:1.6 to 1:1.2). It was also found that for flat slopes severity did not increase with increased slope length, as was the case for average and steep slopes (ref. 76).

Computer simulation studies have been used to evaluate the safety effects of various slope and ditch configurations (ref. 58, 75, 80, 83). The results show, among other things, that the hinge point (where the shoulder meets the front slope) produces no major problem if the front slope is flatter than 1:3,
that all corners should be well rounded, and that return maneuvers can be accomplished on smooth, firm embankments of 1:3 or flatter, even at high speeds and relatively large encroachment angles, if the friction is high (ref. 58, 83).

The results of one major study, see Figure B.4, show that slope configuration (for normal V-ditches) should be on or under the curves in the diagram to produce tolerable accelerations on car occupants (ref. 57, 58, 83). Curve A concerns "lapbelt restrained" and curve B "unrestrained" occupants. The general conclusion is that front slopes steeper than 1:4 are not desirable, partly because their use severely limits the choice of back slopes. If curve A is used, a front slope of 1:4 requires a back slope of 1:4, while a front slope of 1:6 requires a back slope of about 1:3.

In other simulation studies, it has been shown that for soil cuttings the following front/back slope combinations: (i) 1:6/1:6 and further out 1:2; and (ii) 1:4/1:4 and further out 1:2; are considerably safer, especially for vehicles departing (running off) at high speeds and large angles, than: (iii) 1:6/1:2; (iv) 1:3/1:3 and further out 1:2; and (v) 1:3/1:2 (ref. 75, 80). If the costs of average run-off accidents for combinations (i) and (ii), which showed similar results, were set at 1 (index scale), the cost of an average accident for combination (v) was estimated at about 3.5 (ref. 75).

The same studies indicate that embankment slopes of 1:6 and 1:4 are safer than 1:4 and 1:2 further out, 1:3 or 1:2. The difference between 1:4 and 1:3, however, was small (except for low banks, 2 m and less, where 1:4 was better), while the difference between 1:3 and 1:2 was substantial. Expressed in the same cost index scale as before, the accident costs for 1:4 and 1:3 were estimated at about 0.7, while the cost for 1:2 was around 1.7. Embankments with ditches at the bottom (back slope 1:2) turned out to be hazardous. It was also shown that increased height of the embankment (with slope 1:4) increases accident costs, but only to a very limited extent.

For rock cuttings it has been shown that the lateral distance from the edge of the roadway to the rock wall is of significant importance relative to severity of accidents. Front and back slopes of 1:6 and 1:6 respectively and a distance of 6m from the roadway to the wall turned out to be insufficient to prevent a rock collision for a 90 km/h and 20° departure (ref. 80). In another study 6.5m was sufficient to avoid a rock collision for 90 km/h and 12°, while 4.5m was sufficient for 90 km/h and 3°, but not for 7° (ref. 75). Expressed in the same cost index scale as before, the average accident cost for flat slopes and 2.5m distance to the wall was estimated at 5 to 6, while the costs for 4.5m and 6.5m were about 2.5 and 1 respectively (ref. 75). There should be a transition slope between the back slope and the wall, for example, in 1:2.

To consider hazardous objects in roadside design, it is necessary to know how far from the road departing vehicles will stop. Several studies have attempted to establish lateral distance between the edge of the roadway and the position where the vehicle either struck an object or stopped for other reasons
Figure B.4. Evaluation curves for different side slope combinations (V-ditches)

A = "lapbelt restrained occupants".
B = "unrestrained occupants".
(ref. 57, 73, 76, 77, 84). The results of some of these studies are illustrated in Figure B.5. The lateral distance depends on several factors, for example, the departure angle, the front slope height, and if an object is struck or not. It can be seen from Figure B.5 that about 90% of all errant vehicles stop within 10m, and that many vehicles striking objects stop within 5m. The bold curve (A) pertains to fairly large departure angles and high front slopes (no object collision). The lower bold curve (B) relates to rather small angles and low front slopes. From these curves it can be seen that a clear zone of 7 to 11 m in case (A) and 4.5 to 7m in case (B) would prevent most object collisions (80 to 90%). It must be noted that the lateral distances depend to a large extent on specific circumstances and that the curves A and B are valid only for average conditions.

Departing vehicles can strike many different types of roadside objects. The most frequent collision objects are: side slopes, trees, poles (electricity, telephone and lighting), and guardrails (ref. 58, 75, 77). On motorways, for example, there are many collisions with guardrails, while on minor roads, collisions with trees and utility poles are frequent (ref. 58).

The severity of the collisions depends on the crash characteristics of the objects and the distance between the road and the object. Collisions with trees, rocks, bridge columns, abutment ends and similar objects are normally very severe, and this is also often the case with collisions involving poles and culverts. Even guardrail collisions, in many cases, can be quite severe (ref. 58, 75, 77).

In some studies the accident costs have been estimated for collisions with different types of objects (ref. 75, 77). The results show that, expressed in the same cost index scale as before, collisions with trees, poles and guardrails are about 6 to 8, 3 to 4, and 2 to 4 respectively (the guardrails were normally of the semi-rigid, nonblocked W-beam type, often with concrete posts).

Some of the techniques to alleviate the roadside object collision problems are to (ref. 58):

(a) eliminate the hazard;
(b) relocate the hazard;
(c) make the hazard yielding or breakaway; and
(d) shield the hazard.

Method (a) can, for instance, be used for trees and sometimes guardrails and utility poles. Method (b) can be used for poles, signposts and overhead sign structures, while (c) is suitable for signposts and lighting poles. Method (d) can be used to shield highly hazardous objects, such as high and steep slopes, exposed ends of abutments and bridge columns, with traffic barriers or impact attenuators.

Traffic barriers should not be overused, because they can become major roadside hazards, especially the ends of the barriers (ref. 58, 75, 77). Barriers should either stop or redirect vehicles without strong accelerations or decelerations, overturns or penetrations. Flexible barriers provide a high
Figure B.5. Percentage of departing vehicles stopping at or above the indicated distances from the edge of the roadway.
level of protection, but rigid, concrete barriers can be suitable where space is limited, for example, in narrow medians (ref. 58, 78).

There are many types of impact attenuators: steel drums; water and sand cushions; and crushable packages of different types. In general, the safety performance of such attenuators has been good (ref. 58).

In summary, the risk of running off the roadway should be reduced by avoiding sharp horizontal curves, and by using sufficient roadway width, skid-resistant road surfaces, markings and delineation. Roadsides should be designed and equipped so as to: (i) give the drivers of departing vehicles a good chance to recover and return to the roadway; and (ii) reduce the severity of run-off accidents. This can be achieved by using flat side slopes, wide clear zones, yielding or breakaway roadside objects, and by shielding specially hazardous objects.

Based on the available research results, the following general recommendations can be given:

(a) **Soil cuttings.** Front slopes should be 1:4 or flatter. Back slopes should be 1:4 or flatter, but could further out rise to 1:2.

(b) **Embankments.** Slopes should be 1:4 or flatter; 1:3 could be used on high banks. There should be no ditches with steep back slopes at the bottom of the bank slope.

(c) **Rock cuttings.** The distance between the edge of the roadway and the rock wall should be at least 6 to 7m on high speed roads and 4 to 5m on low speed roads. The slopes between the road and the wall should be designed according to (a), and there should be a transition slope between the back slope and the wall, for example 1:2.

(d) For (a), (b) and (c) slope surfaces should be smooth with no protruding rocks, and all corners should be well rounded.

(e) **Clear zones.** There should be a clear zone, free from hazardous objects, of 7-9m width on high speed roads and 4.5-6m width on low speed roads.

(f) **Hazardous objects.** Fixed objects, such as trees, poles and structures, should preferably be eliminated or located outside the clear zone. If this is not possible, the objects should be made yielding or breakaway, or be shielded.

(g) **Traffic barriers and impact attenuators.** Barriers should only be used when the total accident consequences are less severe with a barrier than without. Impact attenuators could be used to shield specially hazardous objects.

It is recommended that the design of the roadsides should be based on a benefit-cost or a cost effectiveness analysis of different alternatives. It is possible that lower safety standards than the ones suggested above may have to be accepted on roads with low traffic volumes or where construction and maintenance costs are high.
B. Speed Control

The Influence of Speeds on Road Safety

High vehicular speeds result in increased reaction and braking distances and more severe impact on collision. Higher vehicular speeds normally are associated with increased speed variations in the traffic stream because of the variability in vehicle and driver characteristics. This is particularly true in developing countries where the vehicle mix has a greater variety ranging from modern motor vehicles to animal- and human-powered craft. Large speed variations between vehicles increases the probability of traffic tie-ups and the need for overtakings and makes it more difficult for the road users to estimate vehicular speeds, thus increasing the possibilities for accidents to occur.

The influence of traffic speed on road accidents has been documented in a large number of investigations. In almost all cases where the mean speed and/or the speed variance have decreased due to the introduction or lowering of speed limits, the number of accidents have decreased while the number of casualties and the fatalities have been reduced even more (ref. 46, 47, 48, 49 and 27). There are also several examples where an increase in speed limit has resulted in increasing traffic speeds and increasing numbers of accidents, injuries, and fatalities (ref. 46 and 47). Most of these investigations were made on rural roads and all of them in developed countries. The result from the different investigations can be summarized by the following simple models (ref. 50 and 51):

\[ \frac{A_1}{A_2} = \left( \frac{V_1}{V_2} \right)^2 \]  

(B1)

\[ \frac{I_1}{I_2} = \left( \frac{V_1}{V_2} \right)^3 \]  

(B2)

\[ \frac{F_1}{F_2} = \left( \frac{V_1}{V_2} \right)^4 \]  

(B3)

where

- \( V_1 \) = Average speed in situation 1
- \( V_2 \) = Average speed in situation 2
- \( A_1 \) = Number of accidents in situation 1
- \( A_2 \) = Number of accidents in situation 2
- \( I_1 \) = Number of injured in situation 1
- \( I_2 \) = Number of injured in situation 2
- \( F_1 \) = Number of fatalities in situation 1
- \( F_2 \) = Number of fatalities in situation 2

These models are fairly well validated and do not overestimate the effect of speeds on accidents.

In urban areas there are fewer investigations and most of them deal only with the changes in number of accidents and not speeds. The results from
available research do not, however, contradict the above-mentioned models for rural roads.

In developing countries, an homogeneous and lower speed profile is perhaps even more important to reduce accidents because:

(a) the road and street environment is poorer;
(b) the conditions of the vehicles are worse and there is a mix of slow moving and fast vehicles which does not exist in the developed countries; and
(c) driver education is worse and many road users are not accustomed to modern road traffic and its dangers.

The generalized relationships between speeds and accidents (equations B1 to B3) appear to be equally applicable in developing countries.

**Optimum Speeds**

To reduce travel time is one of the main objectives of road transport improvements. This objective often results in higher traffic speeds and conflicts with the goal to achieve safety in transport. For each type of road there is an optimum speed which gives the lowest total transport cost (construction and maintenance cost + travel time cost + vehicle operating cost + accident cost). To be able to determine this optimum speed for different types of roads it is necessary to know the relationships between speed and different components of transport cost which, among other things, implies a monetary valuation of travel time and accidents. For Swedish conditions, the optimum speeds on rural roads have been shown to vary from 60-70 km/h (for low standard two lane roads) to 90-100 km/h (for motorways) (ref. 52). There are no comparable results available for urban roads and streets.

The analysis of optimum speeds includes the costs of travel time, vehicle operation, and road accidents. If other costs of road transport are included, the optimum speed will be lower as shown in Figure B.6.

The evidence from Sweden suggests that optimum speeds are rather low and they are likely to be even lower in developing countries because of the following reasons:

(a) The difference in vehicle operating costs between developed and developing countries are much smaller than the difference in travel time costs since most of the vehicle operating cost components consist of tradable goods which can be valued at international parity prices, while the value of travel time is determined by the wages in the country. This means that the importance of vehicle operating costs will be greater compared to travel time in developing countries thus resulting in lower optimum speeds on rural roads.

(b) Average vehicle operating costs increase at a steeper rate with increase in speeds in developing countries because of a higher
proportion of heavy vehicles (trucks and buses) which compared to cars, have a larger increase in VOC when the speed is raised.

(c) In determining optimum speeds, it is difficult to assess the difference in accident cost between developed and developing countries. On one hand the unit value of a killed or injured person is lesser in developing countries due to the lower wages. On the other hand, the number of accidents per vehicle-km are higher and the consequences (the number of killed and injured persons per accident) are much more serious.

Figure B.6. Effect of different road transport cost components on optimum traffic speeds.

From an economical standpoint, taking into consideration all aspects of transport cost, it seems reasonable that average speeds (not speed limits) on rural roads in developing countries should not be higher than the values shown below.

- Two lane 5-6 m gravel road 50 km/h
- Two lane 5-7 m paved road 60 km/h
- Two lane 7-9 m paved road 70 km/h
- Two lane 9-12 m paved road 80 km/h
- Four lane motorway 90 km/h
Figure B.7. The effect of different levels of speed limit on speed distribution.

- **Case 1**
  - $V_i > V_{ss}$
  - $V$ km/h

- **Case 2**
  - $V_i = V_{ss}$
  - $V$ km/h

- **Case 3**
  - Speed-distribution after speed limit
  - Speed-distribution before speed limit
  - $V_i < V_{ss}$
  - $V$ km/h

- **Case 4**
  - $V << V_{ss}$
  - $V$ km/h
Use of Speed Limits

The most common way to control speed is to use speed limits in combination with enforcement and penalties (normally fines). Speed limits are set both according to the road and traffic conditions and according to the vehicle-types. The road-related speed limits can be either general (usually different limits for different types of roads) or local (on hazardous sections of the road). The vehicle-related speed limits are normally of a more general nature. If a vehicle with a vehicle-related limit is operated on a road with a general speed limit, the lowest of the two limits applies.

There are several investigations from developed countries showing that road-related speed limits can be effective in reducing speeds if they are introduced in a rational manner (ref. 46, 47, 49 and 53). This means that the normal or unrestricted speed of the road must be considered, the limits must be enforced, the fines for speeding must be obvious, and the drivers must be aware of the reasons for the limits.

A long-standing practice is to set the speed limit at the 85th percentile of the speed distribution curve. Investigations from Finland and Sweden (ref. 46 and 53) and some other countries show, however, that this rule seems to be a passive measure since it will not effect the actual speeds to any substantial degree. The results from Finland and Sweden concerning the effects of different speed limits on speed distribution and accidents are summarized in Figure B.7, which illustrates the four cases discussed below:

Case 1. The speed limit \( V_L \) is set above the 85th percentile of the speed-distribution curve. In this case most vehicles will be driven faster after the introduction of the limit. Only a small percentage of the faster drivers will slow down. The mean speed will increase but the variations in speeds will decrease. The number of accidents will increase and the consequences of the accidents will be worse. The percentage of drivers violating the speed limit will be very low.

Case 2. The speed limit is set at the 85th percentile. In this case the slower vehicles will be driven faster and the faster vehicles somewhat slower, after the limit is introduced. The mean speed will not change to any substantial degree, but the variations in speeds will decrease. The number of accidents will not change, but the consequences will probably be less serious. The percentage of drivers violating the speed limit will be low.

Case 3. The speed limit is set below the 85th percentile. In this case most of the vehicles will be driven slower after the introduction of the limit. The faster drivers will slow down more than the slower drivers. Both the mean speed and the variations in the speeds will decrease. The number of accidents will decrease and the accidents will be less serious. The percentage of drivers violating the speed limit will be substantial.
Case 4. The speed limit is set far below the 85th percentile. In this case all vehicles will be driven slower after the introduction of the speed limit. The effects will be the same as in case 3, but they will be greater and virtually all drivers will be violating the speed limit under free-flowing traffic conditions.

The conclusion from the above cases show that the introduction of a speed limit should be based on measurement of the actual speeds, and that the limit has to be set below the 85th percentile in the speed distribution. How far below is a question which needs to be carefully weighed since the reduction of accidents has to be balanced against the number of speed violations and the possibility and cost of efficient enforcement. To solve the violation problem recommended instead of mandatory speed limits have been tested in some countries. Unfortunately they do not seem to have any influence on speeds.

Except speed limits, different types of speed-reducing techniques such as road humps, obstacles, stop signs, and road markings have been tested and are used in urban areas.

When properly designed, the road humps have proven efficient to reduce the average speeds down to about 20-30 km/h without damaging the vehicles. They should be about 4m long and 10 cm high with a distance between them of 50-75m (ref. 27 and 54). Also different types of obstacles which narrow the driving space can be used to reduce speeds. All-way stops at intersections in residential areas are often used in the United States and they reduce speeds substantially.
ANNEX C

RECOMMENDATIONS FOR FURTHER WORK

One of the aims of this study is to develop knowledge and identify methods for efficient road safety work in developing countries. The following road safety tasks are considered to be the most important for developing countries:

1. Information systems for road safety;
2. Effects of road safety measures;
3. Methods for determining monetary values of accident prevention;
4. Methods for monitoring and evaluation;
5. Road safety organization, management and staffing;
6. Review of models, guidelines and standards concerning urban planning and land use; traffic management; road design, equipment and maintenance, vehicle equipment and inspection; and road user information (including in-school education, and driver education and training); and
7. Road safety research and development.

Brief descriptions of these tasks are given below, including task objectives, study approach, and estimated technical staff resources required:

Information Systems for Road Safety

Objectives:
- To establish the need for information systems;
- To describe what types and combinations of information (data) are needed for different purposes;
- To review different data definitions;
- To describe different types and structures of information systems;
- To discuss their advantages and disadvantages;
- To identify general problems and costs; and
- To recommend suitable information systems, organization and responsibility.

Approach:
- Survey of present systems in some developed and developing countries;
- Analysis;
- Preparation of draft report;
- Discussions within the Bank and with some safety authorities and researchers (including the UK Transport and Road Research Laboratory, TRRL and Swedish Road and Traffic Research Institute, VTI); and
- Finalization of report.

Staff Resources: 1-2 person years.
Effects of Road Safety Measures

Objectives: - To provide information about the safety effects of different safety measures and programs. The following types of measures should be included: urban planning and land use; traffic management; road design, equipment, maintenance and operation; vehicle design, equipment, maintenance and inspection; road user information (incl. driver education, training and examination); traffic laws and regulations; and police surveillance and enforcement;
- To discuss the main differences in road transport conditions between developed and developing countries and the subsequent differences in safety effects;
- To provide information about the non-safety effects of the measures and programs; and
- To discuss what measures reinforce each other and what measures work against each other.

Approach: - Survey of literature and experience from developed (e.g., USA, UK, Australia, Norway and Sweden) and developing countries;
- Analysis;
- Compilation of a draft handbook;
- Discussions within the Bank, and with some research organizations (incl. TRRL, the Norwegian Institute of Transport Economics, TOI, and the Swedish Road and Traffic Research Institute, VTI); and
- Finalization of handbook.

It is probably suitable to divide the work into several steps; for example, first to draw up a general format, and then subdivide the tasks for different groups of measures.

It is suggested that the handbook be published in a format that will be easy to revise as new knowledge becomes available.

Staff Resources: 3 - 4 person years.

Methods for Determining Monetary Values of Accident Prevention

Objectives: - To review the need for monetary values;
- To describe different methods for determination of accident costs and monetary values of accident prevention;
- To discuss their advantages and disadvantages;
- To discuss the special circumstances in developing countries;
- To recommend suitable methods for accident valuation, mainly for ex-ante cost/benefit analysis; and
- To discuss different ways to obtain necessary information.

Approach: - Survey of literature and experience;
- Analysis;
- Preparation of draft report;
Methods for Monitoring and Evaluation

Objectives:
- To discuss the importance of monitoring and evaluation;
- To describe different methods for monitoring and evaluation, as well as measures of effectiveness (incl. safety and non-safety effects);
- To discuss their advantages and disadvantages; and
- To recommend suitable techniques and provide operational guidelines for the monitoring and evaluation of different safety measures and programs.

Approach:
- Survey of literature (especially review of experience); (ref. 35)
- Analysis
- Compilation of draft report;
- Discussions within the Bank and with some safety authorities and researchers (including Haight); and
- Finalization of report.

Staff Resources: 6 - 12 person months

Road Safety Organization, Management, and Staffing

Objectives:
- To review the general characteristics of safety work and the need for cooperation and coordination;
- To identify alternative organizational structures;
- To discuss their advantages and disadvantages;
- To recommend suitable structures and review different tasks and responsibilities;
- To define the kinds of expertise needed (incl. accident analysis, road safety planning, urban planning, road and traffic engineering, vehicle engineering, safety information, driver education and training, and police surveillance and enforcement);
- To define the needs for knowledge, education, and training for different categories of expertise.

Approach:
- Survey of literature and review of experience in developed and developing countries;
- Analysis
- Preparation of draft report;
- Discussions within the Bank and with safety authorities in developed and developing countries; and
- Finalization of report.

Staff Resources: 4 - 6 person months
Review of Models, Guidelines, and Standards

Objectives: - To identify relevant areas for review (e.g., urban planning and land use; road/street design, equipment, maintenance and operation; vehicle equipment and inspection; and road user information);
- For each area describe models, guidelines and standards currently in use;
- For each area discuss on what principles the models are based, what types and variables are considered, and what standard values have been set for different variables;
- For each area discuss possible differences between developed and developing countries and suitable changes in models; and
- For each area recommend what models are suitable, and what types, variables and values should be considered.

Approach: - Survey of models, guidelines and standards in developed (incl. USA, UK and Sweden) and developing countries;
- Analysis;
- Preparation of draft report;
- Discussions within the Bank and with safety authorities in developed and developing countries; and
- Finalization of report.

Staff Resources: 3 - 6 person months per subject area

Road Safety Research and Development

Objectives: - To discuss the importance of safety R&D;
- To identify the need for safety R&D in developing countries;
- To discuss different organizational structures, such as R&D institutes and universities;
- To discuss what resources are necessary in terms of expertise, facilities, equipment, and funds; and
- To recommend suitable R&D-efforts at different levels of development.

Approach: - Survey of literature and experience from developed and developing countries;
- Analysis;
- Preparation of draft report;
- Discussions within the Bank and with some research organizations (incl. Institut National de Recherche sur les Transports et leur Securite, INRETS, TRRL and VTI); and
- Finalization of report.

Resources: 6 - 12 person months
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