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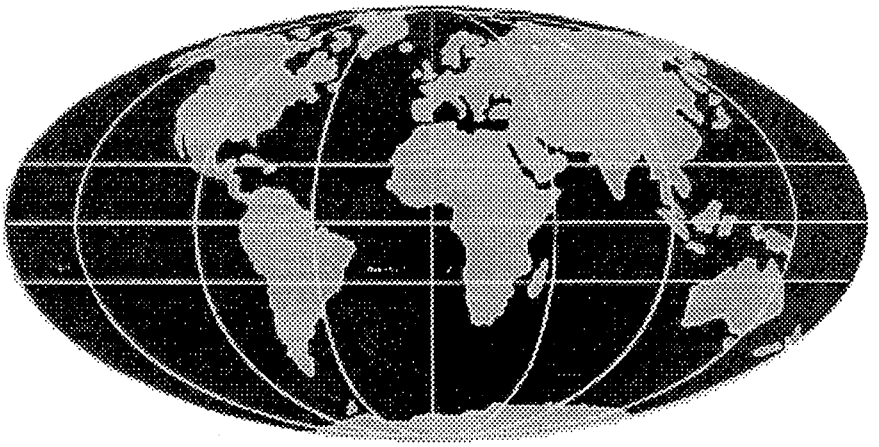
by: G D Jacobs



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Crowthorne
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United Kingdom

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The application of engineering principles to road accident reduction and prevention in developing countries

by

Godfrey D Jacobs

International Division
Transport Research Laboratory
Crowthorne, Berks, UK

THE APPLICATION OF ENGINEERING PRINCIPLES TO ROAD ACCIDENT REDUCTION AND PREVENTION IN DEVELOPING COUNTRIES

Godfrey D Jacobs
International Division,
Transport Research Laboratory
Crowthorne, Berks., UK

Abstract

A recent study by TRL has shown that there were between 750,000 and 880,000 road deaths worldwide in 1999 and, of this total, about 85 per cent occurred in developing and transitional nations. The study also identified that road deaths have continued to increase throughout Asia, Africa and Latin America over the last twenty years whilst in Western Europe, North America, Australia and Japan there have been significant decreases. This paper suggests that the application of engineering principles can do much to reduce road crashes in developing countries. Thus even if the most common factor in road crashes is road user error, problems are compounded by poor road design and planning. Many countries of Africa and Asia have outdated or innappropriate design standards and modern accident prevention and reduction methods have yet to be introduced despite their considerable potential. In order to encourge more effective approaches, TRL published a road safety Guide for planners and engineers and for some years has been engaged in a programme of evaluating low cost engineering improvements in a number of countries. This paper provides a brief outline of the key principles contained within the Guide and includes an example of an evaluation study carried out in a developing country.

1. Introduction

In recent years, major studies published by the World Health Organisation, TRL and others have identified the growing importance of road crashes as a cause of death, particularly in developing and transitional countries.

In order to provide an update of the road safety problem worldwide, a study was recently undertaken by TRL with the following objectives (Jacobs and Aeron-Thomas 2000):

- To derive an estimate of road crash fatalities worldwide and on a regional basis.
- To provide an estimate of crash costs worldwide in relation to Gross National Product (GNP).
- To obtain regional analyses of fatality trends.
- To identify current fatality rates and risk (deaths per 10,000 vehicles and per 100,000 population respectively) and also casualty trends by age, sex and road user type.

The methodology undertaken was based on official reported road fatalities, i.e. police databases, but adjusted to accommodate the following 1) countries without any published road fatality statistics, 2) updating reported road fatalities to the current year (1999), and 3) under-reporting. The latter included two different problems: under-recording, i.e. casualties reported to the police but omitted from official statistics, and non-reporting, i.e fatalities which were never reported to the police. The extent and impact of under-reporting, especially in developing countries, was highlighted with documented examples.

The study estimated that in 1999 between 750,000 and 880,000 people died from road crashes and that the majority of these deaths occurred in developing and transitional nations (85 per cent). Almost half of all estimated deaths occurred in the Asia-Pacific region. This compares with a recent estimate by the World Health Organisation of over a million deaths in 1998. Study findings also indicate that over the next ten to twenty years the number of people dying annually in road crashes may rise to 1.0 million to 1.3 million respectively.

Estimates suggest that 23-34 million people are injured worldwide in road crashes—a value almost twice that previously estimated. The problem of injury under-reporting is perceived to be even more serious with a fraction of injury road crashes being reported in many less motorised countries.

Trend data showed that the total number of people killed in road crashes in regions of the developing world continued to increase, whereas in the West there has been a steady decrease over the last fifteen years or so. For example, between 1987-1995 deaths in the Asia-Pacific rose by 40 per cent, in Africa by 26 per cent (excluding South Africa where the increase was minimal) and the Middle East/North Africa region by over 36 per cent. Road deaths doubled in a few Latin America countries and rose by 16 per cent in Brazil. Conversely road deaths in highly motorised countries fell by about 10 per cent over the same period.

A review was undertaken of those countries which have attempted to cost road crashes. It was found that as a percentage of GNP, costs ranged from as low as 0.3 per cent to over 4 per cent. In order to obtain an estimate of cost worldwide, a broad (and albeit crude) assumption was made that in developing countries the annual cost of road crashes is about 1 per cent of GNP (a value used for many years based on early research in this topic), in transitional countries about 1.5 per cent and developed countries 2 per cent. Estimates were derived of what this meant in global and regional terms and it was found that in 1998, global costs (using the above assumptions) might have been of the order of US$500 billion and in developing and transitional countries about US$60 billion.

Results show that the highest fatality rates (deaths per 10,000 motor vehicles) worldwide occur in African countries, particularly Ethiopia, Uganda and Malawi whilst fatality risk (deaths/100,000 population) is highest in a disparate group of countries including Thailand, Malaysia, South Africa and Saudi Arabia.

As might be expected, males in the most economically active age group make up the largest proportion of reported victims of road crashes. Previous studies have found

that children in developing countries tend to be more at risk than in the developed world.

It should be emphasised that vulnerable road users, i.e. pedestrians and two wheelers (motorcyclists and bicyclists), but especially pedestrians, are a particularly high-risk group throughout Africa and Asia as well as the Middle East.

2. "Towards safer roads in developing countries" design guide

In many developing countries, regional planners and engineers have, in the past, faced very real problems in acquiring the latest road safety information. This lack of advice tended to lead to low levels of awareness of the potential of engineering improvements and to design and planning errors being repeated. Therefore, to encourage countries to adopt appropriate solutions and at the same time to help them learn from other countries experiences, TRL, in association with the Ross Silcock consultancy, initiated the development of its comprehensive guide "Towards Safer Roads in Developing Countries".

The Guide was designed to be a first point of reference on road safety issues, with the following objectives:

(i) to bring safety to the forefront of the minds of planners and engineers practising in developing countries and to bring to their attention important details of design affecting road safety that they might otherwise overlook or consider insignificant;

(ii) to act as an introduction for policy-makers in developing countries and aid agencies to the wide range of issues in highway planning and design that can affect road accident rates and the mitigating actions which can be taken to reduce the number and severity of road accidents;

(iii) to bring together in a single document the joint experience of TRL and those UK consultants who have had significant developing country experience in road safety and traffic engineering, together with relevant material from standards, guidelines and design guides of developed countries to act as a first source of information for professionals in developing countries;

(iv) to act as a source of ideas for new designs and countermeasures so that hazardous locations in developing countries can be made safer; and

(v) to stimulate evaluation of and research into road safety countermeasures in developing countries so that the most effective can be identified.

The two main sections of the Guide deal separately with two distinct (and vitally important) planning/engineering mechanisms for improving safety:

1) ACCIDENT PREVENTION, resulting from good "safety conscious" standards of design and planning of new road schemes and related development; and

2) ACCIDENT REDUCTION, resulting from remedial measures applied to problems identified in the existing road network.

2.1 Accident Prevention and Planning

Examples of key planning principles are listed in Table 1. The Guide puts considerable emphasis on the need to establish the road hierarchy within a road network and discusses the function and design of each level. An example of a "safety principle" for this particular topic is:

> *"Each road should intersect only with roads in the same class or one immediately above or below it in the hierarchy."*

Planning and road safety are also considered for different land uses. The planning of residential areas has received particular attention in developed countries over the past 20 years (eg Dept of Transport, 1977).

2.2 Accident Prevention and Geometric Design

Early research by Jacobs (1976) showed that, for Jamaica, reducing road width may have had a much more severe effect on accident rates than in a typical developed country. Also Kosasih, Robinson and Snell (1987) examined geometric design research and standards around the world, and made recommendations for developing countries; these have been incorporated in the Guide. The TRL had a research programme in Papua New Guinea from 1988 to 1990 that examined the effects of certain highway design elements on accident rates, in particular the road cross-sectional profile.

It must be acknowledged, however, that much more research is required before optimum standards can be determined for all developing countries. Many developing countries have just adopted standards from developed countries or have modified such standards without evaluating the consequences; but the traffic mix and road usage is often very different in a developing country from that encountered in more industrialised countries. The Guide encourages highway engineers to incorporate the needs of all road-users into their designs. For example, in certain countries, high numbers of pedestrians on rural highways can be observed and, in other countries, there are high proportions of two-wheeled vehicles. In either case, consideration should be given to special provisions for these road-users; a good example of this is in Malaysia, where a motorcycle lane with segregated junctions has been constructed from Kuala Lumpur to Kelang; and in Papua New Guinea, some 10 km of footpath alongside the Highlands Highway are under construction using local village labour (as part of a joint PNG/TRL research programme). Also, there is usually a greater need to minimise costs; the challenge for developing countries is to achieve this whilst at the same time maintaining an acceptable level of safety.

TABLE 1
Some approaches to improving the safety of the road environment in developed countries

ACCIDENT PREVENTION: Improved planning and design of new roads and developments[1]. Basic principles include:

* Land-use should be distributed to minimise vehicle trips and pedestrian vehicle conflicts.
* Networks should be classified into a hierarchy with the emphasis on speed management.
* Layouts of roads in residential areas should be designed to keep out through traffic and keep speeds down to appropriate levels[2]
* New schemes should be checked for safety ie road safety audits[3].

ACCIDENT REDUCTION: Application of cost effective measures on existing roads.

* Low-cost engineering improvements at hazardous locations[4,5].
* Area (urban) wide schemes[6,7,8].
* Traffic calming[9].

References for Table 1:

1 = IHT, 1990 and 1991; 2 = DoE/Dtp, 1977; 3 = IHT, 1990;
4 = Dept of Transport, 1986; 5 = Helliar-Symons & Lynam, 1989; 6 = Mackie et al., 1990;
7 = OECD, 1979; 8 = OECD, 1990; 9 = Tolley, 1990

2.3 Accident Reduction

Table 1 lists some key approaches used by developed countries for accident reduction and they offer considerable potential for developing countries. In particular, it is recommended that countries with limited resources should place initial emphasis on introducing low-cost improvement schemes at hazardous locations. Such schemes have proved very effective in industrialised countries; for example, in a survey of UK schemes (Helliar-Symons and Lynam, 1989) First Year Rates of Return were estimated to range from 65 to 950 per cent. The application of this approach in a developing country (Papua New Guinea) is described elsewhere (Hills et al, 1990). The techniques of accident investigation at hazardous locations are summarised in the Guide and numerous examples of countermeasures given from both developing and developed countries.

A few developing countries have begun to introduce low-cost engineering schemes on a trial basis and TRL is currently carrying out joint research to evaluate their effectiveness in Zimbabwe, Burkina Faso, Ghana, Indonesia, Malaysia, Pakistan and Papua New Guinea (Sayer et al, 1991; Hills et al, 1991). Emphasis in the trials has been placed on testing measures that are self-enforcing and also on schemes aimed at helping the most vulnerable road-users. These trials, which have been made possible by the introduction of the TRL Microcomputer Accident Analysis Package, are still at an early stage with many sites not yet improved. However, preliminary findings indicate that countries which have relatively low levels of road-user discipline are less likely to have success with measures which are not self-enforcing such as road signs and markings. For example, a study in Pakistan of the effects of introducing stop lines and lane lines at junctions and no overtaking lines at bends indicated no improvements in driver behaviour apart from a small reduction in overtaking violations from 19 to 14 per cent (Downing, 1985). On the other hand, preliminary results from Papua New Guinea indicate that the introduction of roundabouts at uncontrolled major/minor junctions has halved the average injury accident rate (Hills et al, 1991).

2.4 The Importance of Evaluation

It is as important for developing countries as it is for developed countries to evaluate their road safety (and traffic management) schemes and in this section, this point is emphasised with the analysis of a scheme carried out in Port Moresby, Papua New Guinea.

During 1986, a 300m section of the Hubert Murray Highway in Port Moresby was upgraded from a single carriageway to a dual carriage-way. This involved associated road widening and the closure of one T-junction. The scheme was carried out more for traffic management purposes than for road safety. For the pedestrian, the median helps the crossing task but the inevitable increase in vehicle speeds will have made judgements more difficult. ('Before and After' speed measurements are not available as the scheme began before the research programme got under way).

Table 2 shows an analysis of accidents along the stretch of road for the period 1982-1989. The analysis was carried out using the TRL Microcomputer Accident Analysis Package. It can be seen that Head On, Rear End, 90 Degree and Sideswipe accidents halved after the scheme; these accidents were large in number but their severity was almost exclusively minor injury or damage only. On the other hand, 'Hit object off the road' and Pedestrian accidents show a completely opposite picture: they have doubled since the scheme was introduced, and although they are small in number, they are high in severity, with eight out of the 22 accidents being fatal or resulting in hospitalisation (six were pedestrians). The need to prevent pedestrian accidents on this section of road has thus become a high priority, despite there being a very large drop in accident numbers.

It might have been predicted that the central median would have improved pedestrian safety, but the analysis clearly shows that this was not the case. This study illustrates the value of evaluating schemes in some depth so that both benefits and disbenefits can be identified and quantified. With this information, future schemes can be modified and the optimum benefits obtained.

2.5 Checklists (Audits)

The Design Guide also contains two sections comprised of basic road safety checklists. The first section is concerned with accident prevention and contains a series of checklists that are intended to be used as a formalised system of checking that should be carried out at the planning and design stage, now commonly referred to as the "Safety Audit". Safety Audit procedures are rapidly being adopted in many industrialised countries as a simple way of ensuring that the chances of unsafe roads being constructed are reduced to a minimum. It is generally considered important that application of the checklists should be carried out by an independent team not involved in the original detailed planning and/or design.

TABLE 2

Hubert Murray Highway, Port Moresby, Papua New Guinea: The effects on accidents of constructing 300m of central reservation in 1986.

	BEFORE SCHEME				Implem-entation	AFTER SCHEME		
ACCIDENT TYPE	82	83	84	85	86	87	88	89
Head On	5	1	6	8	3	1	0	0
Rear End	24	30	22	17	17	8	8	12
90 degree	6	6	10	7	1	2	3	2
Sideswipe	7	10	11	10	7	5	3	7
SUB-TOTAL	**42**	**47**	**49**	**42**	**28**	**16**	**14**	**21**
Hit Object Off Road	0	1	0	2	0	3	1	3
Pedestrian	1	0	1	2	1	2	2	3
SUB-TOTAL	**1**	**1**	**1**	**4**	**1**	**5**	**3**	**6**
TOTAL ACCI-DENTS	**43**	**48**	**50**	**46**	**29**	**21**	**17**	**27**

The second series of checklists in the Guide is concerned with the process of accident reduction and refers to specific accident types; it provides a list of possible inadequacies in the existing road layout which might be contributory to each type and which the accident investigator should consider when analysing blackspots.

All the checklists are presented as a series of questions under various planning, design and countermeasure topics. It is inevitable that these general checklists will not cover

every safety issue in every country and thus it is recommended that users modify the lists as necessary for their local conditions.

3. Concluding remarks

The recent review by TRL shows that about 80 per cent of road deaths worldwide occur in the countries of Africa, Asia and Latin America which have, by far, the fewest numbers of licensed vehicles. The study also shows that road deaths are increasing year by year in these countries whereas in Western Europe, North America and Japan they have decreased significantly over the last twenty years.

Ten years ago, road safety professionals from the West visiting a developing country for the first time might have been surprised to find that road safety in general, and the problems of the pedestrian in particular, were not priorities in Planning and Highway Engineering departments. Regrettably, even today it is possible to see emerging nations building some of the mistakes into their road networks that countries in Europe and North America are now spending large amounts of money to correct. Undoubtedly, there are signs that engineers in developing countries are becoming more safety conscious, but greater impetus is required. It is hoped that the establishment of the recently formed Global Road Safety Partnership (GRSP), together with the application of valuable technical material such as the Asian Development Bank's Road Safety Guidelines and the TRL guide "Towards Safer Roads in Developing Countries", will accelerate the necessary change in attitudes and put safety firmly in the minds of engineers and planners at the very first stages of design.

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