HIGHWAY SAFETY PLANNING, DESIGN AND OPERATION - PROBLEMS AND POSSIBLE SOLUTIONS IN DEVELOPING COUNTRIES

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abstract: Accidents have reached an alarming rate recently in developing countries of the east Asia. Safety planning, design and operation of highways are the three aspects that are proposed to reduce accidents in this study. Because conflict road hierarchy causes competition between mobility and access, a self-contained zone is suggested for network planning to reduce trips. Geometric design standards of developing countries are found improper because roads are design at higher speeds with relatively tight pavement width and narrow radius. Road maintenance and traffic management techniques such as pavement surfaces, road signs and parking controls are recommended for the operation of safe highways.

1. INTRODUCTION

Growth in economic in the east Asian region has led to both increased traffic volume and unplanned rural/urban development. Complicated by incompatible land-uses, high levels of pedestrian/vehicle conflicts have resulted in inevitable accidents. On highway geometric design, existing standards in many developing countries are to some degree outdated (often dating to colonial times), irrelevant, and simply direct translation from overseas without appropriate modification for the particular needs of the developing country. Furthermore, the emphasis tends to focus upon the construction rather than the operation aspects. Important operational elements such as road signs or roadside features are too often left for later addition if and when time or money permits. All these factors have contributed to an alarming accident rate in the east Asia.(Turner 1993)

Whereas the situation in most industrialized countries appears to be improving in terms of actual numbers of accidents, many developing countries have, in recent years, faced a worsening situation. Figure 1 indicates that the growth of road accident deaths in developing countries increased by nearly 50%. Conversely, in the developed countries over the same period, the number of accidents actually declined by 10%.

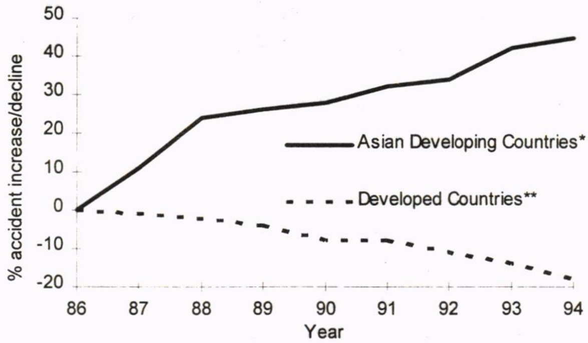


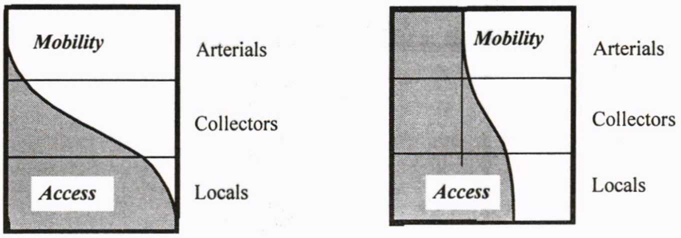
Figure 1. Percentage change in accidents between Asian developing and developed countries.

As living standard is improving, the public have started to demand government agencies to provide safe driving environment, or even forgiving highways. In order to reduce injuries and fatalities occurring on roadways, improvements should be made on planning, designing and operating highways. Yet, little research is made to quantify potential safety problems that are specific to developing countries in this region. Few considerations are given to provide insight responses to these challenges that are faced today. This paper is to present safety problems observed on the highways in east Asian developing countries, analyze facts that may cause accidents, and offer possible solutions.

2. PLANNING HIGHWAY NETWORK FOR SAFETY

Road planning can have a profound effect on the level of road safety in a country. Planning road networks in developing countries usually contains a complex interaction of land-uses and activities. It is observed in this region that a great mix of land-uses exists side-by-side, sometimes in conditions of extreme conflict. For example, a huge shopping mall is constructed along an expressway where commercial activities demand access and highways focus on mobility. Each type of land use has its own traffic characteristics and this can lead to safety problems. Commercial development grows rapidly along freeways where no access control is provided, thus pedestrians or motorcycles risk lives crossing highways. Figure 2 shows the difference between ideal and conflict highway functional classification.

Road hierarchy in highway planning is to consider the functions of local roads, collectors, and arterials in terms of accessibility and mobility. Local roads mostly provide access to land, whereas arterials mostly provide mobility for through traffic. Collectors fall functionally halfway between local roads and arterials as shown in Figure 2(a).(AASHTO 1990) In reality, because of severe competition for access and mobility at the same place and at the same time, the distinction among arterials, collectors and locals becomes vague in developing countries such as Figure 2(b).



(a) ieal road hierachy (b) conflict road hierachy

Figure 2. Proportion of roadway service

Study indicates that accident and fatality rates on highways with full control of access are half that of ones with no access control in developed countries.(Stover et al. 1982) It is believed that the accident rate in developing countries is much higher due to lack of regulation on land use and drivers discipline. Grid-iron layouts as shown in Figure 3 are generally observed in developing countries for their convenience providing quick access for all users. Because of the large number of crossroads, grid-iron networks are less safe than ones based upon principles of segregating function of access and mobility. The increase in roadside development results in an increase in at-grade intersections and in business with direct access to the highway. On all types of freeway facilities, this situation always significantly increases accidents. Study indicated that, if intersection number increases from one to ten per kilometer, the accident rate also increases ten times.(Fee et al. 1970)

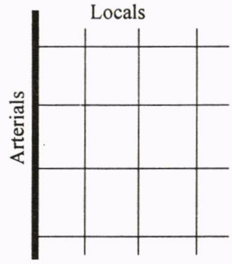


Figure 3. Grid-iron network that does not separate access and mobility functions

Designation of a hierarchy can help clarify policies concerning the highway planning decisions on properties served by the roads concerned. Furthermore, specific planning criteria could be developed and applied according to a road designation in the hierarchy. As shown in Figure 4, grid-iron networks should be closed off or restricted to self-contained zones, i.e., neighborhoods. Within these areas all non-essential traffic should be excluded. It should be possible to carry out most daily trips to shops, schools or other indispensable facilities wholly within the area. The natural barrier of main routes can, then, be used to segregate and contain incompatible uses and to reinforce local identities. It is also important to ensure that roads are assigned to the appropriate level in the hierarchy on the basis of their proposed (or desired) functions rather than their existing functions that may not be the same as those required for safe operation.

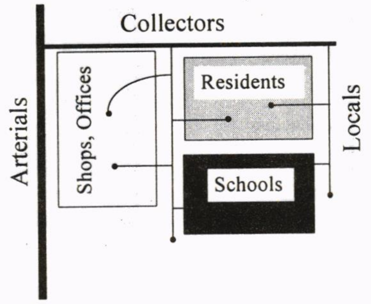


Figure 4. Self-contained zone with separate access and mobility functions

Highway network planning for safety should include following items: road hierarchy, land use and access control. The key features associated with each item are discussed as follow:

Road hierarchy

- Highway networks should be clearly categorized into those which are primarily intended for mobility and those which are originally designed for access.
- Unmistakable priority should be indicated at each intersection so that the traffic from the more important road is always given preference over that from the less important one.

Land-use

- Thoroughly scrutiny on land development proposals should be made on traffic and safety implication before approval..
- Minimizing road traffic and pedestrian conflicts should be included in land-uses.
- Locating shops and schools within the walking distance of homes helps reducing the need of travel.

Access control

- For a new arterial, a direct access should be permitted only in limited locations.
- Potentially dangerous locations such as intersection and poor visibility are not allowed to have any access.

3. DESIGNING HIGHWAY GEOMETRIC FOR SAFETY

To understand the differences on design philosophy, an international comparison is made. Guidelines and/or policies are usually the terminology used in publications for geometric design in America, Britain, and Australia. Standards and/or specifications are used in developing countries such as China and Bhutan. It is not, however, in words that these design manuals differ notably. Manuals from industralized countries pay homage to notions of liveability residential street design. Developing countries manuals call for both mobility and access at the same time in local streets.

Instead it is in deeds (that is, the specific guidelines or standards set forth) that the manuals differ. What follows is an international comparison of geometrics, sidewalk warrants, intersection treatments, network design, and traffic-calming measures. Space permits discussion only of the high points as shown in Tables 1 and 2. *Overseas Road Note 6* published by the Transport and Road Research Laboratory (TRRL) in U.K. provides the setting of geometric design standards for developing countries, which is well adopted by India, Malaysia, and Sri Lanka. Other developing countries like Philippine, Taiwan, and Thailand are accepting the design guidelines from America, Britain or Australia as standards.

3.1. Local Streets

Design speeds for developed countries are about the same, and are relatively lower compared to developing countries as shown in Table 1. Yet pavement widths and minimum curve radii in developed countries are so much greater for streets in developed countries that one suspects that design speeds, in practice, are not very similar (particularly when British and Australian traffic-calming measures are factored in). Higher design speeds associated with narrower pavement widths and tighter curve radii can cause severe safety problems in developing countries. Cars lying through local streets are very likely to hit or be hit due to limited manoeuvre spaces provided.

However, wider streets for developed countries do not appear to be the solution. These free-for-all roads result not only from wider individual lanes but also from an unobstructed traffic lane, and parking on both sides. For example, Americans assume the worst case (parked cars across from each other), which leaves Americans with very wide, high-speed cross sections for the common case. American practices may not be applicable to developing countries because drivers would be encouraged to speed and are subject to accidents with higher severity. It is more practical to allow one- and two-lane cross sections on local roads and deal with the worst case by requiring adequate off-street parking for residents, banning parking on one or both sides, and providing frequent parking bays on the narrowest streets.

As for curve radii, Americans strictly limit centerline curvature to extend sight distances. AASHTO's policy, for example, requires a minimum radius of 30 meters but recommends "as large a radius curve as feasible." British and Australians, on the other hand, use sharp curvature to slow down traffic to design speeds. Sight distances may be limited on such curves, but so are travel speeds. In cases of developing countries, higher speeds are designed on tighter curves in which sight distances may not be sufficient for a vehicle to stop ahead of hazards. Specially TRRL design guidelines do not seem to be adequate because of its high design speeds on narrow curves. It appears that TRRL guidelines tend to make use of both extremes on speed and horizontal alignment, which can be risky for road users.

Large curb radii are not pedestrian friendly because they add to crossing distances and allow motorists to negotiate turns at high speeds. Small radii help avoid any encroachment of turning vehicles into opposing lanes. It is observed in Table 1 that design guidelines of local streets from developed countries pay more attention to pedestrians needs than from developing countries. In the south east Asian region, non-motorized transportation means should be encouraged by geometric design. Particularly in local roads, access should be emphasized instead of mobility. Walking is the predominant transpiration mode in a residential area, thus should be well protected in geometric design.

Lack of information on pedestrians needs may be the reason that Bhutan and TRRL do not provide any standards/guidelines for sidewalks. China standards specify relatively wider sidewalks because of its large non-motorized population. This may not, however, be enough to accommodate the needs in high density residential areas. At the same time, sidewalks should be designed in such a way that motorized vehicles cannot intrude their safety. Practices from developed countries such as narrow curves and traffic-calming devices provide good lessons for developing countries to learn.

Table 1. Geometric Design Guideline/Standard for Local Streets

	AASHTO	British	Austalian	China	Bhutan	TRRL
Design Speed	30-45 km/h	30-40 km/h	15-40 km/h	20-50 km/h	20-50 km/h (depend on slope)	40-50 km/h
Pavement Width	6-7.3 m standard (less when ROW limited)	3.65-5.48 m	3.5-6.5 m (depend on traffic volume)	3-3.5 m (depend on speed)	3-3.5 m	2.5-3 m
Min. Curve Radius	30 m (as large as possible)	20-30 m	specify max. radius for traffic calming at design speed	20 m	15 m	15 m
Curb Radius	4.5 m (min.) 25 m (desirable)	4-6 m (depend on traffic volume)	4 m	5-40 m (depend on speed)	not available (N.A.)	N.A.
Sidewalk Width	at least one side	both sides	at least one side	both sides	N.A.	N.A.
Min. Sidewalk Width	1.2 m	1.34-2 m	1.2 m	2-3 m	N.A.	N.A.

3.2 Collectors

The differences in local streets between developed and developing countries are similar for collectors. Apparently, there is a different perception of collectors' function in the road hierarchy. They are perceived more as channels of movement instead of extensions of the residential environment in developing countries, since collectors are designed as high as 70 km/h. These design standards for collectors make them more like arterials than access streets. The Australians classify collectors as *residential streets* instead of *traffic routes,* implying an access function.

Table 2. Geometric Design Guideline/Standard for Collectors

	AASHTO	British	Austalian	China	Bhutan	TRRL
Design Speed	50 km/h or higher	60-70 km/h	50-60 km/h	40-50 km/h	30-70 km/h (depend on slope)	50-60 km/h
Pavement Width	6-13 m standard (provide two parking lanes if possible)	6.5-7.5 m (2 lanes) 12.3-14.6 m (4 lanes)	6.5-10 m (depend on median width)	3.75 m per lane	3.5 m	5-5.5 m
Min. Curve Radius	77 m (as large as possible)	60 m	no min. specified, but max. 60 m for 50 km/h	70 m	60 m	60 m
Curb Radius	7.6-9 m (where feasible)	10 m	N.A.	40 m or higher (depend on speed)	N.A.	N.A.
Sidewalk Width	both sides	both sides	both sides	both sides	N.A.	both sides
Min. Sidewalk Width	1.2 m	1.7-2 m	1.2 m	2 m	N.A.	1 m

Geometric design is the properly layout of the road in the terrain to meet the requirements of the road users. The needs of road users in developing countries are often different from those in the developed countries. In developing countries, pedestrians, animal-drawn carts and other non-motorized vehicles are often important components of the traffic mix on both minor and major roads. Trucks and buses generally occupy the largest proportion of the motorized traffic, whereas traffic composition in the developed countries is dominated by passenger cars. There may be less need for high-speed roads in developing countries compared to developed countries. Traffic volumes on most rural roads in developing countries are also relatively low. Thus, providing a road with high geometric standards may not be economic, since transport cost savings may not offset construction costs. The requirements for wide roadways, flat gradients and full passing sight distance may therefore be inappropriate. In some cases, high geometric standards encourage speeding and cause severe accidents because of drivers reckless behaviours.(Vijayalakshmi 1997)

Consequently, mobility should not be overemphasized in developing countries. Also, in countries with relatively weak economics, design levels of comfort used in industrialized countries may be a luxury that cannot be afforded.

4. OPERATING HIGHWAY FOR SAFETY

Apart from the planning and design of roads, transportation engineers need to better operate accident reduction countermeasures. Through effective use of maintenance and management techniques, engineers can create safer, less congested and more efficient road networks.

4.1 Road Maintenance

Developing countries in east Asia have rapidly extended their road networks in recent years due to economic growth, but few have maintained highways in a reasonable condition. The costs of rehabilitation have become very substantial because of lagging repairs in an adequate time. Badly maintained roads contribute to the growing road safety problems of developing countries. Significantly greater resources (manpower, equipment, and funds) need to be applied in this area to ensure that the safety-related elements of the roads are kept properly maintained. The key areas of particular concern and which require maintenance for road safety purposes are road structure, drainage, shoulders, slopes, bridges and traffic control devices.

- Road surface - Potholes which could damage vehicles cause them to turn away suddenly. Surface texture and skid resistance need also be maintained. Surface and ground water should be able to drain away from the road or under the road.

- Drainage - Ditches must remain free of obstructions and retain their intended cross sections and grades. If needed, guiderails should be provided to shield rigid headwalls.

- Shoulder - Shoulders provide adequate side support for pavements, and traffic can use the shoulder at speed without danger.

- Slopes - Ensure that side slopes retain their shape and stability so that a vehicle can safely transverse or stop at that designed slope.

- Bridges - Cheek that bridges are in sound structural condition and safe for traffic. At bridges over water, the water must flow unimpeded at all flood levels without damaging the bridge or the waterway.

- Traffic control devices - These include signs, reflectors, guideposts, kilometre posts guiderails and pavement markings. Cheek that traffic control devices are in a good and useable condition. Ensure they remain correctly located, properly mounted, fixed, stable and visible at all times. Where necessary vegetation should be cut back.

4.2. Traffic Management

Congestion and road safety problems in the cities of developing countries can be attributed to inefficient use of road space, poor enforcement, uncontrolled conflicts and the poor design of traffic and pedestrian facilities. Experience in the developed countries has demonstrated that some traffic management techniques can be a highly cost-effective way of alleviating congestion problems and can play a vital role in improving road safety. The main traffic management options are described below.

- Parking: At least at peak times and near pedestrian crossings, parking and loading controls can relieve congestion problems and improve safety on main traffic routes. Visibility for and of pedestrians is significantly increased so road crossing is safer. Alternative sites for parking should also be provided nearby.

- Singalization: Optimal traffic control measures seek to minimise conflicts. The range of measures is wide and they are usually applied on a comprehensive basis along a route corridor or in a specific area of the city.

- Re-routing: Traffic circulation measures include bans on certain conflicting movements, road closures and re-routing schemes. They can be used to prevent non-essential, through or undesirable traffic from entering specified areas (e.g., congested central areas, residential areas etc.). One-way systems can result in a reduction of conflicts and should improve safety but care must be taken to ensure that resultant increased speeds do not erode the safety benefits.

- Segregation: Separating pedestrians conflicts from moving traffic by special crossing facilities or guiderails enhances road safety.

It must be emphasised that maintenance and enforcement are extremely important for the success of many of the above measures. These are often major problems in developing countries. Consequently, efforts should be made to design such schemes to be as maintenance free and as self-enforcing as possible. It is also important that the use and operation of the existing roads can be optimised without recourse to major reconstruction. Such an approach is particularly relevant to the needs and financial resources of developing countries.

5. CONCLUSIONS AND RECOMMENDATIONS

Improper road safety planning, design and operation strategies used in developing countries at different stages of highway network development have lead to an increase on accidents. Road hierarchy in developing countries is in conflict with mobility and access. The competition for right-of-way between motorized and non-motorized vehicles has a profound effect on the level of road safety and can have a major impact upon pedestrian accidents in particular. Self-contained zones proposed in this study can ensure that (1) through traffic is re-routed to more suitable roads, and that (2) the right sort of environment is created for the road users likely to use each type of road. Geometric design standards used in developing countries are found to be inadequate because roads designed at higher speeds are provided with narrow pavement width and tight radius. Compromises are inevitable to achieve an acceptable solution and not all objectives can be fully met; however, it is possible to improve road safety characteristics markedly at little or no extra cost, provided the road safety implications of design features are considered at the design stage. Operation approaches are proposed in this study to tackle the problems of road safety and congestion on existing road networks. It is further recommended that hazardous areas be located, safety effectiveness of each countermeasure be analysed, and safety research be conducted systematically to reduce accidents.

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