THE APPROPRIATE ENGINEERING SOLUTIONS FOR IMPROVING TRAFFIC SAFETY IN DEVELOPING COUNTRIES

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Abstract

The application of traffic accident reduction and prevention has some problems in developing countries. The scarce resources of governmental budget should be efficiently distributed among the road infrastructure projects. Optimization and reduction of the road faciiities in some cases should be considered in order to increase the number of road projects and road length. Obviously, traffic safety is not taken into account or considered as "do minimum" in the design process. On the other hand, the number of accident fatalities increases as the road traffic demand increases. In Indonesia, for example, according the government figures, the number of fatalities was around 10,000 in the year 1994. This paper deals with the appropriate engineering solutions for improving traffic safety based on research at the Department of Civil Engineering of the University of Indonesia. Two treatments were suggested: First the single sites treatment to improve blackspot areas and; Second, the corridor based treatment. This improvement should be based on traffic accident data. Through investigation of data on the type of accidents and types of vehicles involved in the accidents, the appropriate geometric solution can be decided.

I. INTRODUCTION

1.1 The Background

The application of traffic accident reduction and prevention has some problems in developing countries. The scarce resources of governmental budget should be efficiently distributed among the road infrastructure projects. Optimization and reduction of the road facilities in some cases should be considered in order to increase the number of road projects and road length. Obviously, traffic safety is not taken into account or considered as "do minimum" in the design process. On the other hand, the number of accident fatalities increases as the road traffic demand increases.

The attitude to face with the financial problems, perhaps should be in the way of the OECD meeting conclusion in 1976 (TRRL, 1990): "In view of the long service life expected from road investment, geometric road design standards should not be compromised by short term adverse economic condition. This, however, does not mean that effort aimed at improving standards from an economic point of view should be neglected". The developing countries should not merely adopt standards employed by the developed countries, but should develop and adopt standards which are appropriate to their own circumstances. The nature of traffic and driver behavior in the traffic safety point of view, clearly should be understood. For example, in Indonesia the composition of motor cycles and paratransit are very high compared to the developed countries.

1.2 The Magnitude of Traffic Accidents in Indonesia

According to government figures, the number of fatalities was around 10,000 in the year 1994. Traffic safety has become one of the main issues of public concern as can be seen in the new 1992 road traffic act. The new road traffic act is more concerned with traffic safety matters than the previous road traffic act. Table 1 shows the characteristics of traffic accidents in Indonesia based on the Indonesian Police report. The number of accidents does not give a clear picture due to the possibility that serious injury accidents and slight injury accidents seem to be under reported. This evidence can be seen in the study case of Margonda Raya Street in municipality city of Depok. The fatal accidents, heavy injuries and slight injuries as can be seen in Table 4 have an unusual ratio that the number of heavy injuries is higher than the number of slight injuries; and the number of heavy injuries is only fourth times greater than the number of fatal accidents.

Table 1. Traffic Accident Characteristic 1989-1992 in Indonesia

	1989	1990	1991	1992
No. of traffic accidents	28,984	25,741	22,587	19,920
Road length (kilometer)	227,946	250,314	274,094	300,133
No of vehicles	8,243,982	8,850,739	9,230,741	9,892,737
No of fatalities	10,726	10,887	10,621	9,819
fatality rate *	13	12	12	10

* Fatality rate = No of fatalities /10,000 vehicles

1.3 The role of Highway and Traffic Engineers

There are three major contributory factors in any traffic accident, namely: the road users, the vehicles and the road environment. It has been be found, that the major contributory factor in traffic accidents is human error. However, it is rare for a traffic accident to be caused by a single factor. Traffic accidents occur as a result of multiple factors and the contribution of the road environment should be considered in the traffic accident prevention and reduction programs. It is likely that in about one-quarter of accidents, some aspect of highway design, layout, surface characteristic or traffic control is a major contributory factor (IHT, 1990). The role of engineers, therefore is very important, the immediate programs of traffic safety should be based on improving the road environment and the traffic operation.

2 THE APPROPRIATE ENGINEERING DESIGN

2.1 Accident Prevention Through Highway Design

Some aspects of geometric design that should be considered to prevent traffic accidents are as follows (TRRL, 1990).

a) Road cross-section
It has been found in developed countries that for single carriageway, the accident rate progressively declines with increasing lane or pavement width, but there is little saving beyond the lane widths of about 3.40 meter or pavement widths of about 6.80 meter. The most recent evidence in the United Kingdom (UK) indicates that significantly lower accidents rate are achieved on the 10 meter single carriageway width roads standard compared to the 7.30 meter width roads. However as can be seen in the case study in this paper, wider roads (beyond the 7.30 meter width roads) in Indonesia tend to have a higher traffic accident rate especially the head-head on collision and pedestrian cross accident as we can not insure that the central marking is available. This type of accident can be reduced with physical road separator (concrete curb). Wider roads also make passing sight distance more difficult for drivers to judge correctly.

b) Horizontal Alignment and Vertical Alignment.
A sharp curve at the end of a long straight section of road is considered particularly hazardous. The combination of sharp horizontal curvature on crest or in sag is also considered a hazardous location.

c) visibility
Good visibility particularly on junctions is associated with lower accident rates.

d) Skid resistance
High skid resistance materials are considered to improve traffic safety on high speed roads. It is also used for some potential accident locations such as the immediate approaches to junctions and pedestrian crossings, where there is a high level of vehicles braking.

e) junction design
Almost all accidents in urban areas occur at or near the junctions. The use of appropriate traffic lights and channelizations can improve traffic safety. Painted

channelization has very little impact to improve vehicle safety since most drivers do not obey this painted road marking.

2.2 Technical Procedures and Data Requirements

Accident prevention and reduction programs rely on the existence of reliable data. However, it is very difficult to find reliable traffic accident data. In Indonesia there are two main problems. First, not all traffic accidents are reported to the police. Second, the database system is still maintained manually. Not all of the local police stations, database systems have been computerized yet. Other problems with the traffic accident database included the fact that the quality of the data was not in general suitable for traffic engineering purposes, the manual analysis of accident records was slow, error prone and fraught with inconsistencies (Lundebye and Tumewu, 1990).

In view of the above, the Indonesian Institute for Road Engineers has developed a "Traffic Accident Recording Form (TARF)" based on a model developed by Transport and Road Research Laboratory (TRRL)-UK: A Microcomputer Accident Analysis Package (Hills and Elliott, 1986).

Based on these data, then the accident can be investigated and analyzed and the general results, (particularly the type of accident collision and traffic behavior) can provide useful input to development of geometric design standards. These standard should be considered in the development of new roads and road improvement projects.

'The interim manual on Accident Investigation Procedures and the development of low cost engineering schemes" (TRL,1993) introduces 12 steps on the accident analysis and prevention program. It is intended for use by traffic engineers in local government Basically, it can be divided into 4 stages as shown in Fig. 1.

2.3 Implementation Strategy

The choice of the appropriate engineering solution is the crucial issue for engineers. A particular problem may have one or several remedial measures. The basis for a strategic approach to the development of accident reduction programs is based on a framework within which priorities can be set for implementation. IHT (1990) suggested 4 investigatory techniques as follows:

1. Single sites.
   These are specific sites where cluster of accidents have occurred within a specific period of time. The location may be a single junction, a small area of 200 - 400 meter in diameter, or a short length of road of 300 - 500 meter.

POLICE	Recording the accidents and data entry into computer	
STAGE 1	IDENTIFICATION	
	Step 1	Finding sites with high number of accidents
	Step 2	Weight sites for severity and exposure
	Step 3	Initial accident investigation and site visit
	Step 4	Rank sites for in-depth investigation
STAGE 2	DIAGNOSIS	
	Step 5	Collection of further data from the accident forms and site studies
	Step 6	Analysis of the data
	Step 7	Further site visit to investigate the human factors
STAGE 3	SELECTION	
	Step 8	Select and check package of potential measures
	Step 9	Rank sites for treatment
WORKS	Implementation: detail design and construction	
STAGE 4	EVALUATION	
	Step 10	Monitor behavior during first days and months
	Step 11	Evaluate the effect on accidents
	Step 12	Cost-benefit analysis

Fig. 1 The Twelve Steps of Accident Investigation (TRL 1993)

2. <u>Mass Action Plans</u>.
   Accident data for the whole or a selected part of an area is searched for locations having a particular type of accident for which there is a well tried engineering remedy, e.g. wet road accident by anti-skidding surfacing remedy program.

3. <u>Route Action Plans</u>.
   Accident data on all routes of a particular type for a given period is determined.

4. <u>Area Action Plans</u>.
   Areas for priority treatment can be identified by examining the distribution of accidents through all urban areas.

3. THE CASE STUDY

3.1 The Study Area Description

Margonda Raya street is located in the Municipality of Depok, just on the southern border of Jakarta. This road is part of the main corridor that connects the city of Depok to Jakarta with a length of 5.20 km and a width of 9.00 meter of two lanes single carriageway. The road has a right of way of 30 meter and it is able to make road widening in the future.

The typical cross section of this road is illustrated in Fig. 2. The features related to traffic safety of this road are as follows: No pedestrian sidewalk or pedestrian crossing are available in this road. There is also no traffic marking available and traffic signing is inadequate. Street lighting is only available at one side but is too far from the carriageway. The land use type along this road is mixed: school and university campus, student accommodation, shop-houses, restaurants, garages and bus terminal. The average daily traffic of this road was 21,870 for both directions in 1991 and 24,680 for both directions in 1993. The volume per capacity ratio during the peak hour as determined by the Indonesian Highway Capacity Manual (IHCM, 1993) in 1993 was 0.74 and the average speed was 42 km per hour based on 1993 data (Tjahjono and Agah, 1994).

Based on traffic accident data from the nearest police office, the number of road deaths were 5 in 1991, increased to 7 in 1992 and 10 in 1993 . The fatal and severe injury (KSI) figures were 40 in 1991, reduced to 38 in 1992 and 31 in 1993. The number of accidents based on the police record were 58 in 1991, increased to 60 in 1992 and reduced to 42 in 1993. The KSI figure and the number of accident do not give a clear picture due to the possibility that serious injury accidents and slight injury accidents seem to be under reported. Obviously, it is clear that the magnitude of traffic accidents is very high. The fatality rates were 0.12 per million km-vehicles in 1991, increased to 0.21 per million km-vehicles in 1992 and 0.26 per million km-vehicles in 1993.

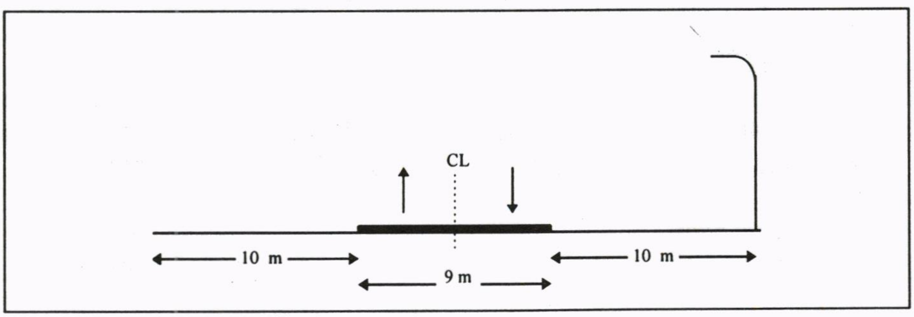

Fig. 2 The Typical Cross Sectional of Margonda Raya Street

3.2 The Route Action Plans

The type of accidents, based on those three years traffic accident data can be seen in Table 2. It can be seen from this table, that the highest accident type involved the pedestrian. Accidents involving hitting pedestrians crossing the road account for around 38 %. Total accidents involving pedestrians account for around 44 %. It is clear that pedestrians are vulnerable road users and it is likely that high rate of accidents at this location is due to the absence of any pedestrian facilities such as pedestrian sidewalk and pedestrian crossing. The next accident type that should be considered is head-head collision accidents account for around 26 %. When head-side collision accidents are added, the figure rises to around 40 %. These accidents are obviously caused by the absence of traffic markings and the ambiguous road width of 9.00 meter. The road width is too wide for a two lane highway but it is not wide enough for four lanes. The idea of 9.00 meter width in the design is clearly for a 7.00 meter carriageway and 1 meter shoulder for both sides of the road. However, because of the absence of road markings and the use of the same materials in construction of both carriageway and shoulder, it is difficult to distinguish between them.

Table 2. Type of Accident on Margonda Raya Street

No	Collision Type	No. of Accident				Percentage
		1991	1992	1993	Total	(%)
1	head-head collision	4	8	9	21	25.93
2	head-side collision	6	3	3	12	14.81
3	head-rear collision	0	1	0	1	1.23
4	side-side collision	1	3	2	6	7.41
5	hit pedestrian crossing the road	12	9	10	31	38.27
6	hit pedestrian on side of the road	3	1	1	5	6.17
7	passenger fell from bus	2	0	0	2	2.47
8	single vehicle accident	1	2	0	3	3.71
	Total	29	27	25	81	100.00

The type of vehicles involved in the accidents can be seen in Table 3. The highest percentage is passenger car (37.69 %). However, the majority traffic composition is also passenger car (57 %). The next type of vehicle is motor cycle (36.15 %) which comprises 33 % of total traffic flow. In this case, motor cycles can also be considered vulnerable road users. Buses, which comprise only 3 % of total traffic flow have a high accident rate of 23.08 %. The probability that a bus is involved in the accidents, obviously is the highest.

Table 3. Type of Vehicles Involved in Accident on Margonda Raya Street

No	Collision Type	No. of Accident				Percentage
		1991	1992	1993	Total	(%)
1	trucks	0	1	1	2	1.54
2	buses / public transport	9	17	6	30	23.08
3	passenger cars	16	15	18	49	37.69
4	motor cycles	16	13	18	47	36.15
5	others	0	2	0	2	1.54
	Total	41	48	43	130	100.00

The type of accident injuries can be seen in Table 4. Looking at the fatal accident figures here the vulnerability of motorcycles and pedestrian is obvious. Further investigations showed that almost all motorcycles accidents (80 %) involved head-head or head-side collisions.

Table 4 The Type of Injuries by The Road Users

No	Road Users	Type of Injury					
		fatal		heavy		slight	
1	trucks						
2	buses / public transports	3	14 %	16	18 %	25	48 %
3	passenger cars	1	5 %	24	28 %	5	10 %
4	motor cycles	12	54 %	22	25 %	10	20 %
5	pedestrians	6	27 %	25	29 %	11	22 %
	Total	22	100 %	87	100 %	51	100 %

Therefore, some aspects should be considered to improve this corridor, namely:

1. The pedestrian facilities should be the first priority. Pedestrian sidewalks and pedestrian crossings should be not omitted in the design of urban roads specially in major corridors. The zebra crossing is not a suitable type of pedestrian crossing for a heavy flow corridor such as Margonda Raya Street. For at grade pedestrian crossing on wider roads, pedestrian refuges in the middle of the road should be required in order to improve the safety.

2. An wider roads e.g. four lanes single carriageway there should be at least a road separator in the median to prevent head-head and head-side collisions especially to motor cycles and buses. The ambiguity of wider roads (between 7.30 meter and 12.50 meter) such as Margonda Raya suggests then should not be a recommended geometric design.

3.3 The Single Site (Blackspot)

Single sites are identified by the extent to which accidents have clustered. To be able to identify which locations are blackspot areas, the study area corridor was divided into 400 meter segments. The distribution of traffic accidents on these segments can be seen on Fig. 3.

The number of accidents per 400 meter segment are randomly distributed distributed and the distribution is hypothesized to follow the Poisson distribution. A test on how a good fit exists between the frequencies of occurrence of accidents and the expected frequencies from the hypothesized distribution was carried out employing the chi-square test at the 5 % level of significance. The results infer that the locations (400 meter segments) having 10 number of accidents or more rejected the test and determined as the hazardous area. These hazardous locations are segment 2 (sta. 0+400-sta. 0+800), segment

4 (sta. 1+200-sta. 1+600) and segment 11 (sta. 4+000-sta. 4+400). Then in a similar way to the corridor based procedure, the type of accidents in these particular location are identified as can be seen in Table 5.

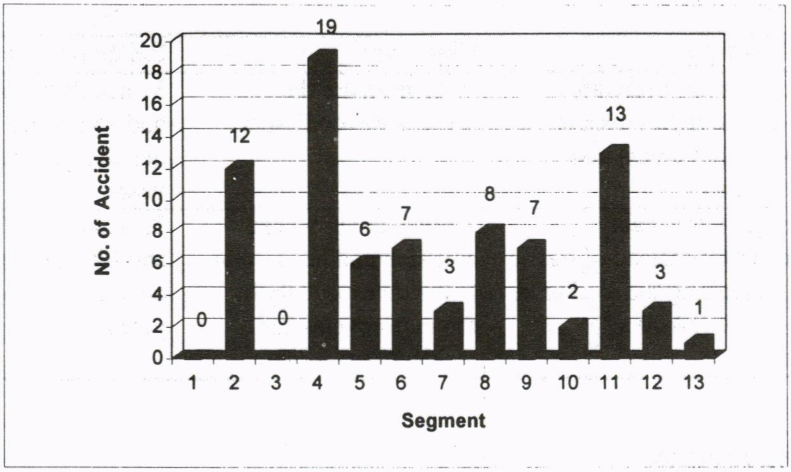

Fig 3 Traffic Accident Distribution by Road Segments

3.4 Remedial Measures suggested

The suggested remedial measures are based on two types of accident that have the highest fatality rates. First, accidents involving pedestrians, and; Second, head-head and head-side collision accidents specially by buses and motor cycles.

Table 5 Accident Identification for Single Sites Improvement

No	Collision Type	Segment 2 sta. 0+400 - sta. 0+800		Segment 4 sta. 1+200 - sta. 1+600		Segment 11 sta. 4+000 - sta. 4+400	
1	head-head collision	4	34 %	5	27 %	4	30 %
2	head-side collision	1	8 %	3	16 %	1	8 %
3	head-rear collision	0	0 %	0	0 %	1	8 %
4	side-side collision	1	8 %	1	5 %	1	8 %
5	hit pedestrian crossing the road	6	50 %	8	42 %	6	46 %
6	hit pedestrian on side of the road	0	0 %	0	0 %	0	0 %
7	passenger fell from bus	0	0 %	1	5 %	0	0 %
8	single vehicle accident	0	0 %	1	5 %	0	0 %
	Total	12	100 %	19	100 %	13	100 %

The appropriate objectives of these two suggestions are to reduce accident fatalities involving pedestrians and motorcycles as can be seen in Table 6.

Table 6 The Remedial Measurements on Margonda Raya Street

Remedial Measures	Objectives	Relation to the Analysis
Pedestrian crossing (preferably pedestrian traffic light crossing on the three blackspot areas) and pedestrian sidewalk	Pedestrian are the vulnerable road users	31 accidents, 6 deaths and 25 serious injuries occurred during the three years
Road separator (preferably concrete separator instead of traffic marking). Widening the road to be four lanes single (14.00 m) carriageway.	To reduce head-head collision and head - rear collision especially by the motorcycles and reckless bus drivers.	33 accident, 16 deaths and 62 serious injuries occurred during the three years.

4. CONCLUSION

Appropriate engineering solutions for improving traffic safety should be based on traffic accident data. However, reliable and accurate traffic data is a major problem in developing countries. Computerization of the accident database should be introduced in order to address this problem. In Indonesia, the Traffic Accident Recording Form (TARF) is becoming the standard system used by the Indonesian police.

It is necessary to understand the appropriate countermeasures and their potential to influence the particular problems. The appropriate countermeasures should be based on traffic accident characteristics..

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