The detailed accident records by LPs are kept strictly confidential because of their natures. Therefore full accident data prepared by LPs are not available for DOH. LPs will show DOH only brief accident records when requested by DOH. Appendix 3.2 shows the contents of this brief accident record form of LPs. At present, DOH has, in fact, little accident records from LPs.

3.2.3 Accident Data Compilation by DOH

The Traffic Engineering Office of DOH stores traffic accident data from HPD and DOH's sub-district offices in the mainframe computer in DOH. DOH checks carefully the accident data from the sub-district offices and HPD to eliminate duplicated accident data, since some accidents are investigated simultaneously by both parties.

In practice, the accident data in the mainframe computer of DOH are limited only to those on the roads in HPD area and accident data which occurred on the roads in the LPs area and were investigated by DOH sub-district offices.

The schematic flow of recording and reporting system of traffic accidents on DOH roads are shown in Figure 3.1.

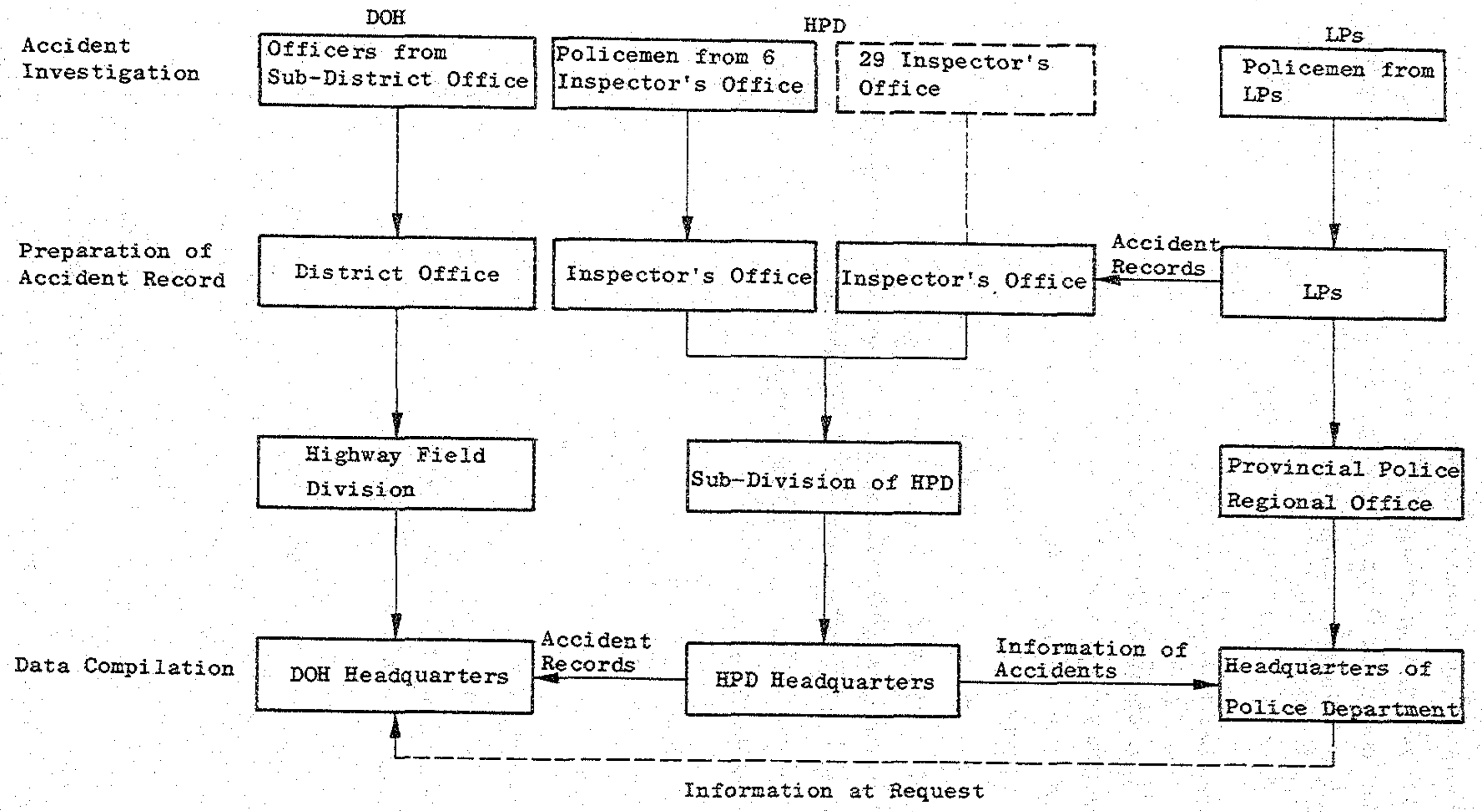

Figure 3.1 Flow of Accident Data Collection on DOH Roads

3.3 Traffic Volume Data

Since 1962, DOH has been conducting a nationwide traffic volume survey at a total of 1,834 counting stations on the national and provincial highways. There are two counting methods in the present system, that is, control count and coverage count. (see Table 3.1).

The control count is to establish both seasonal and daily characteristics of traffic volume. For the control count, traffic volumes are surveyed at 35 major counting stations on the national highways, for consecutive 17 days and for 8 hours per day (0 a.m. to 8 a.m. for 3 days, 8 a.m. to 4 p.m. for 7 days and 4 p.m. to 12 p.m. for 7 days). This control count is conducted four times per annum (January, April, July, and October).

The coverage count is conducted at 444 stations on the national highways and at 1355 stations on the provincial highways. The objective of the coverage count is to estimate average daily traffic (ADT) for each road control section which is a unit road section for the execution of road management by DOH. Traffic volumes at the coverage counting stations are surveyed for consecutive five days for 8 hours per day (8 a.m. to 4 p.m.). This coverage count is carried out twice a year (April and October for national highways, and January and July for provincial highways).

3.4 Road Data

In the past, a comprehensive road inventory had been prepared for DOH roads, but the inventory is now out of date, because no revisions were made ever since. Therefore, it is difficult to obtain road and roadside data at the headquarters of DOH. Since 1983, the Programming Section of DOH has been collecting road data for the whole DOH road network to complete the Road Data Base Scheme. The Road Data Base is supposed to provide a number of useful information for traffic accident analysis and safety planning upon its completion in a few years.

Table 3.1 Method of Traffic Counts on DOH Roads

Item	National Highway		Provincial Highway
	Control Count	Coverage Count	
Purpose	to establish seasonal and daily traffic volume characteristics	to estimate ADT on each road section	to estimate ADT on each road control section
Schedule	January, April, July and October	April and October	January and July
Count Period	Count period is for three weeks, and 17 daily 8-hour volume counts to form 24-hour volumes on Wednesday, Saturday and Sunday and 16-hour volumes count for other days of week[1)]	5 daily 8-hour volume counts from 8:00 am to 4:00 pm. on weekdays[2)]	5 daily 8-hour volume counts from 8:00 am. to 4:00 pm. on weekdays[2)]
Number of Station	35 stations in 1982	444 stations in 1982 (Including road under-construction)	1355 stations in 1982 (Including road under-construction)
Type of Vehicle	1) Passenger Car, 2) Light Bus 3) Heavy Bus 4) Light Truck or Pick up 5) 6 Wheel Truck 6) 10 Wheel Truck or Trailor 7) Bi-Tricycles 8) Motorcycles		

Note 1) Control count periods are following:

	SUN	MON	TUE	WED	THU	FRI	SAT
8:00	1st day			16			17
16:00	13	2nd	15	9	4	11	6
24:00	7	14	8	3rd	10	5	12

2) Mechanical counts at the station are used to develop conversion factor for the calculation of ADT

Source : Department of Highways

3.5 Supplemental Data Collection by the Team

As seen from the foregoing, the traffic accident data available at DOH is virtually limited to the accidents occurred in HPD area. Since there is no established arrangement for data exchange between DOH and LPs, in DOH there are few traffic accident data on roads in LPs area, except those investigated by DOH. Road data which are indispensable, in particular, for preparing traffic safety plans from engineering approaches, are not available at present from DOH, because the road data collection was commenced just last year.

To acquire minimum basic data required for the Study, the Team collected supplemental data on traffic accidents in LPs areas and road data as mentioned below.

(1) Supplemental Traffic Accident Data

After consultation with the Police Department and DOH to obtain accident data in LPs area, the Team found that the accident records kept in the headquarters of the Police Department were not readily applicable to this study, because in the records, there is no information to indicate the route number and kilometer post of a spot where accidents occurred.

The Team, therefore, decided to collect the accident data by visiting each LPs office where original accident records containing information to indicate accident location are kept. Since this collection procedure is supposed to be time consuming, about 430 Km* in the LPs area of six (6) Changwats out of seventy three (73) Changwats and a part of Bangkok Metropolitan area were chosen for the supplemental data collection.** The selected Changwats are Saraburi, Chonburi, Nakhon Ratchasima, Khon Kaen, Chiang Mai and Songkhla.

Saraburi, Nakhon Ratchasima, Chiang Mai and Bangkok were selected because these areas include the components of the Study Roads. The remaining 3 Changwats were picked up because they are located in relatively developed areas, as the HPD accident data cover mainly those in rural areas.

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* 360 Km in 6 Changwats and 70 Km in Bangkok.

** Most accidents in LPs area of 6 Changwats where DOH roads total 2,100 Km occurred on roads of 360 KM, which are located in urban area.

(2) Supplemental Road Data Collection

In order to conduct detailed analyses of traffic accidents on the Study Roads, it is necessary to collect road data, which contain conditions of roads and road facilities, and land use along roads. As mentioned above, since these data were not available from DOH, the Team collected them for the Study Roads by the site investigation as well as the observation with a video tape recorder. The items of information in road data collected by the Team are listed in Table 3.2. These road data were assorted by one kilometer section and utilized for the preparation of safety plans in the case study.

Table 3.2 Information Available from the Road Data

Information	Remarks
1. Route No.	
2. Kilometer Post	
3. No.of Intersection	Signalized, Non-Signalized (Large, Small)
4. Lane Use	High Density, Low Density, Field
5. Alignment	Striaght, Curve (< 25%, < 50%, < 75%, > 75%)
6. Number of Lanes	Two Way
7. Number of Bridges	
8. Lane Line Marking	None, Exist
9. Center Line Marking	None, Exist
10. Edge Line Marking	None, Exist
11. Median Type	None, Island, Marking, Raised Pavement Marker
12. Surface of Shoulder	Paved, Unpaved
13. Sidewalk	None, One-side, Both-side
14. Street Lighting	None, At Intersection, Full
15. Guard Rail	None, Exist (< 25%, < 50%, < 75%, > 75%)

3.6 Data Compilation for Analysis

From the information items in the accident data stored in the DOH computer, necessary information items have been selected and compiled in two forms of files, Accident Master File and Road Section File together with traffic volume data. The supplemental data collected by the Team (see section 3.2) have been also compiled in the same way.

In the Accident Master File, the selected information from the accident data, and traffic volume data have been assorted by traffic accident. In other words, the information in the file can be retrieved on the basis of each accident.

In the Road Section File, the same information in the Accident Master File has been assorted by road section so that all information can be retrieved on the basis of each road section.

Accident location maps and accident location histograms based on the original accident data have been prepared for the initial study of the safety plans for the Study Roads. Collision diagrams were also made from the original records of accidents in the sections of the safety plans.

(1) Size of Traffic Accident Data

The size of the traffic accident data which were obtained for analysis from DOH and LPs is summarized in Table 3.3.

Table 3.3 Size of the Traffic Accident Data

Data Source	Length	Year				
		1978	1979	1980	1981	1982
DOH Road	(Km)					
HPD	15,673	2,706	1,887	1,253	2,533	2,632
LPs	28,283	N.A.	N.A.	N.A.	N.A.	N.A.
(6 Chwts)*	(360)	(191)	(120)	(194)	(392)	(448)
(Bangkok)	(70)	(329)	(632)	(561)	(745)	(875)
Total	43,956	-	-	-	-	-
Study Road						
HPD	223	496	357	132	622	677
LPs	93	382	667	592	845	888
Total	316	878	1,024	725	1,467	1,555

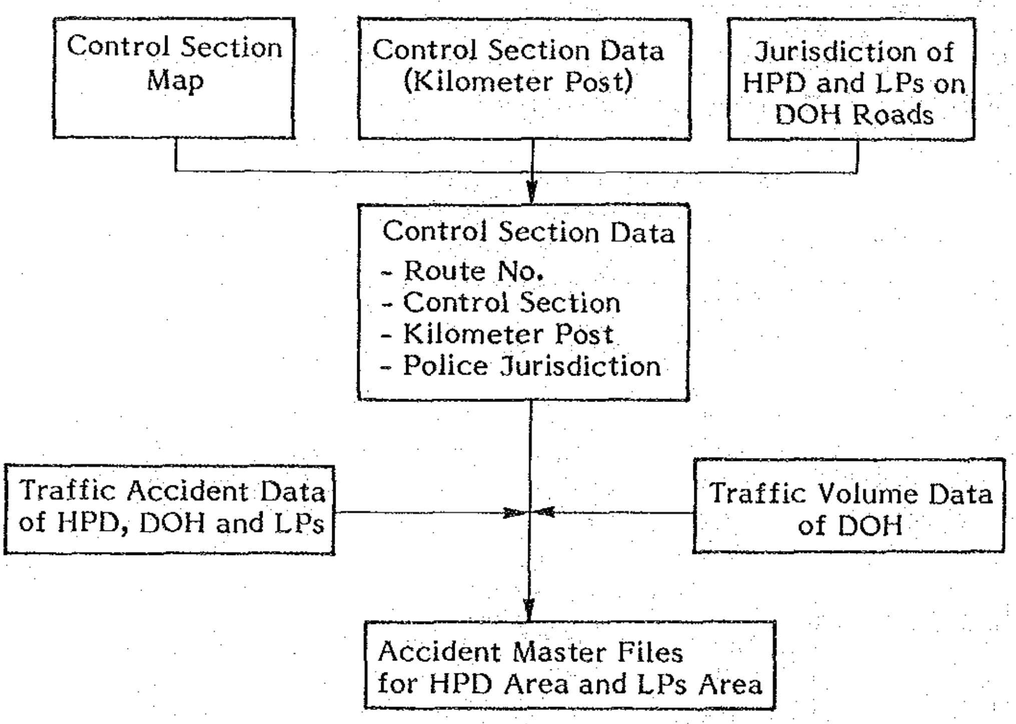
Note; * Most of accidents in LPs area of 6 Changwats occurred on roads of 360 Km, which are located in urban area.

Although the traffic accident data kept in DOH cover the period of five years from 1978 to 1982, the data in 1979 and 1980 appear to be incomplete in number, assumedly because of a problem existing in the recording and reporting system in HPD. The data for the years of 1978 (although the data for this year seem reliable, they were not used because of discontinuity of time sequence), 1979 and 1980 were excluded when compiling the following data files. It follows from this that the study hereafter has been carried out based on the traffic accident data only for the years of 1981 and 1982.

(2) Accident Master File

The procedure of the data filing of the Accident Master File, in which traffic accident data, traffic volume and road indicators (route number, control section number, kilometer post) are compiled, is illustrated in Figure 3.2.

Since the information available for the accidents in HPD area and LPs area are different, two Accident Master Files have been produced for HPD area and LPs area, respectively. The full information items in the two files are shown in Table 3.4 and Table 3.5.



Note: Two kinds of Accident Master Files have been produced for HPD area and LPs area (6 Changwats and Bangkok).

Figure 3.2 Procedure to Prepare Accident Master Files

Table 3.4 Accident Master File for HPD Area

Information	Remarks
1. District Name	
2. Route No.	
3. Control Section No.	
4. Kilometer Post	
5. Condition of Road	Maintenance Road, Construction Road
6. Date	
7. Month	
8. Year	Buddhist Era
9. Day	
10. Time	
11. Horizontal Alignment	
12. Vertical Alignment	
13. Location	Normal Roadway, Bridge, Intersection, Railway, Others
14. Road Surface	5 Categories
15. Type of Highway	2-Lane, 4-Lane, One-way, Divided Highway, Others
16. Surface Width	
17. Shoulder Width	
18. Type of Vehicle Involved	Type and number of vehicle involved
19. DOH Property Damaged	Name of Properties (8 Categories)
20. DOH Damages	Amount of Damages
21. Other Damages	Amount of Damages
22. No. of Vehicle Involved	
23. No. of Injury	
24. No. of Fatality	
25. Cause of Accident	10 Categories
26. Visibility	7 Categories
27. Type of Accident	9 Types
28. Collision Type	80 Types (See Appendix 3.1)
29. Traffic Volume	

Table 3.5 Accident Master File for LPs Area

Information	Remarks
1. Route No.	
2. Control Section No.	
3. Kilometer Post	
4. Date	
5. Month	
6. Year	Buddhist Era
7. Time	
8. Type of Accident	8 Types
9. No. of Fatality	
10. No. of Serious Injury	
11. No. of Light Injury	
12. Location	Intersection, Others
13. Collision Type	80 Types (See Appendix 3.1)
14. Traffic Volume	

(3) Road Section File

For practical purpose, it is not adequate to assess road safety on the basis of spot but section, because traffic accidents occur incidentally scattering all over the road. The Road Section File, therefore, has been prepared to assess a road by section and to develop identification methods of hazardous road locations with a section being a unit length of location.

While Figure 3.3 illustrates the procedure for compilation of the Road Section File, Table 3.6 shows full information items contained in the Road Section file. The Road Section file for intersections, with 1 km section as a unit length, has been produced separately from that of roadway as an intersection should be assessed by spot rather than by section.

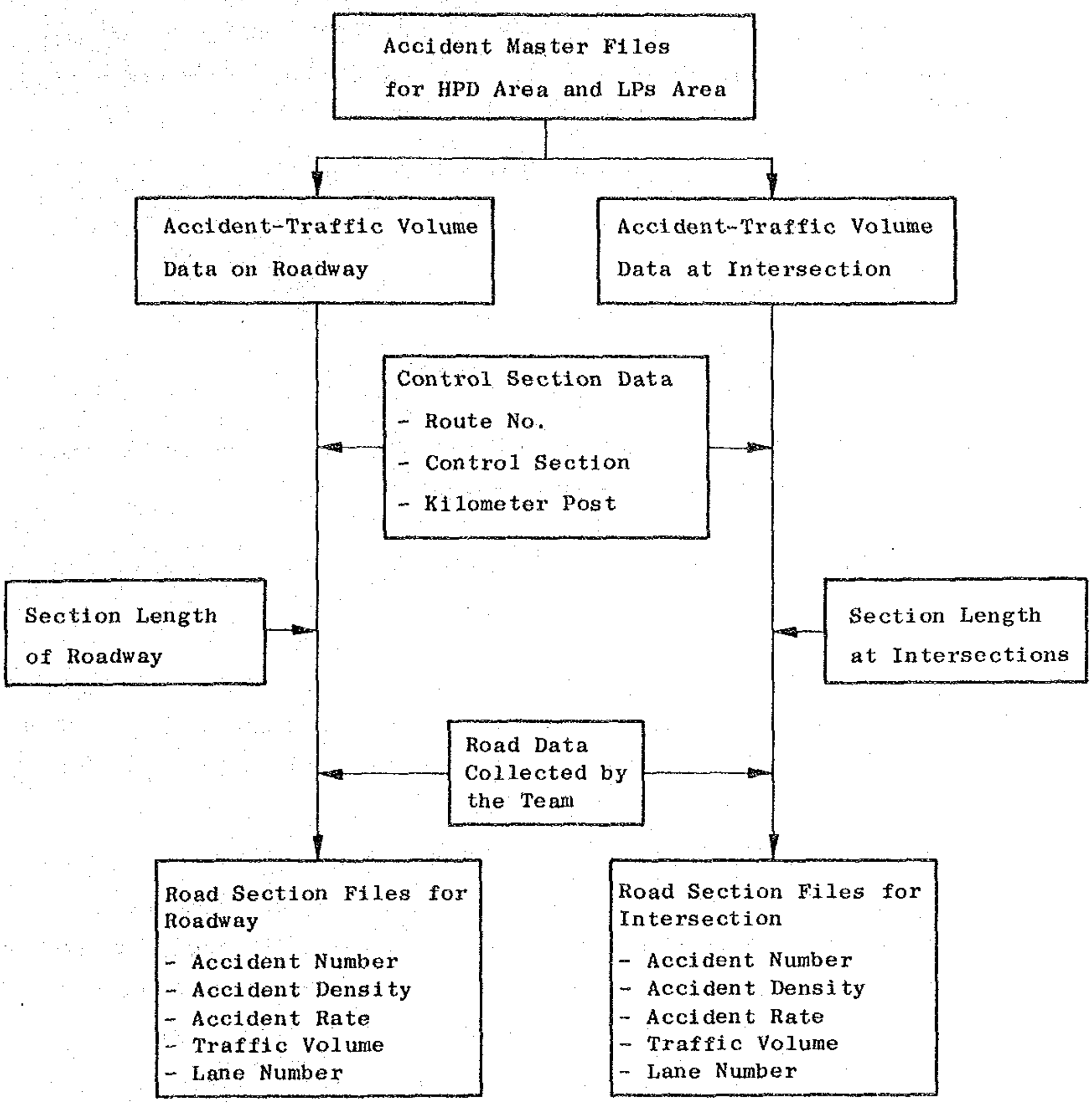
Table 3.6 Road Section File

Information	Remarks
1. Route No.	
2. Control Section No.	
3. Control Section Length (m)	
4. Section Length[1)]	
5. Beginning of Kilometer Post (KM)	
6. Ending of Kilometer Post (KM)	
7. Motorcycles (ADT)	
8. Total Traffic Volume (ADT)[2)]	
9. Number of Accidents	
10. Number of Casualties	
11. Accident Rate by Accidents	
12. Accident Rate by Casualties	
13. Accident Density by Accidents	
14. Accident Density by Casualities	
15. Region	Rural, Urban
16. Number of Lane	
17. Median[3)]	None, Exist
18. Alignment[3)]	Straight, Curve

Note 1) To divide control section length into some length based on the results of investigation of identification method

2) Excluding Motorcycles

3) For only roadway data



Note : Two kinds of Road Section Files have been produced each for roadway and intersection in HPD area and LPs area (6 Changwats and Bangkok)

Figure 3.3 Procedure to Prepare Road Section Files

3.7 Traffic Accident Analysis

To grasp general features of traffic accidents on DOH roads, traffic accident analyses have been made, by using the Accident Master Files which is comprised of accident data in HPD area and some part of LPs area (430 km) for two years of 1981 and 1982.

The analysis has been made as to the following items, i.e.:

- type of accident;
- collision pattern;
- accident location;
- property damage; and
- cause of accident.

As the accident format of HPD is different from that of LPs, the accident analyses have been conducted separately for HPD area and LPs area.

(1) Type of Accident

HPD area

In HPD area, the vehicle-vehicle type of accident is the highest (49%) in number of accident, followed by plunging into fixed object (17%), vehicle-bicycle (8%), and vehicle-pedestrian accidents (7%). (see Figure 3.4 and Appendix 3.4)

As to the number of fatalities, the vehicle-vehicle accidents account for 64 percent, followed by vehicle-bicycle (10%), and vehicle-pedestrian (8%). Accidents plunging into fixed object, which are placed at the second rank in number of accidents, share only 2% of total fatalities. In the vehicle-vehicle accidents, the fatality rate among casualties is very high.

When the accidents are counted by type of road, divided highway has a specific feature as the ratio of accidents plunging into fixed object is peculiarly high (42%), while vehicle-vehicle accident has rather a lower share (35%) compared with other road types (see Appendix 3.5).

The frequent accidents plunging into fixed objects may be attributable to the existence of median structure, which, however, caused less casualties.

LPs area

In LPs area, the vehicle-vehicle type of accident (including motorcycle) is the highest (70%) in number of accident, followed by vehicle-pedestrian (21%) and vehicle-bicycle (4%). In the accidents of vehicle-vehicle type, above one-thirds are accidents involving motorcycles. (see Figure 3.4)

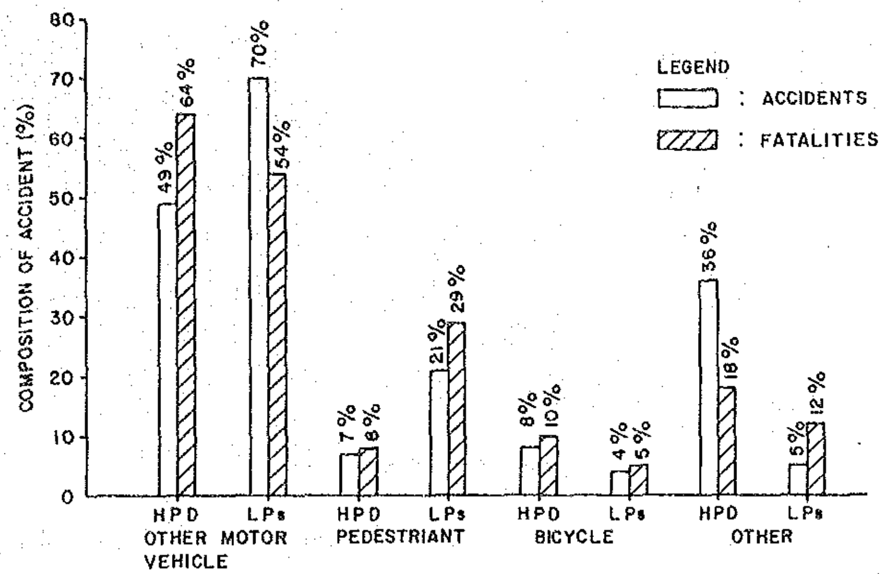


Figure 3.4 Type of Accident

As to the number of fatalities, vehicle-vehicle type is the highest (54%), followed by vehicle-pedestrian (29%), and vehicle-bicycle (5%). Half of fatalities caused by vehicle-vehicle accidents are those involving motorcycles.

On 2-lane roads, the motorcycle accidents are very high (35%) as compared with 4-lane roads (20%). This is attributed to the high composition rate of motorcycles on 2-lane roads. (see Appendix 3.5)

(2) Collision Pattern

As to the vehicle-vehicle accidents in HPD area, head-on collision is the highest (34%), followed by rear-end collision (32%). Out of these accidents, 94% are occurred on roadway. In LPs area, the highest is rear-end collision (32%), followed by head-on collision (18%) and side collision during right-turn (14%) (see Figure 3.5).

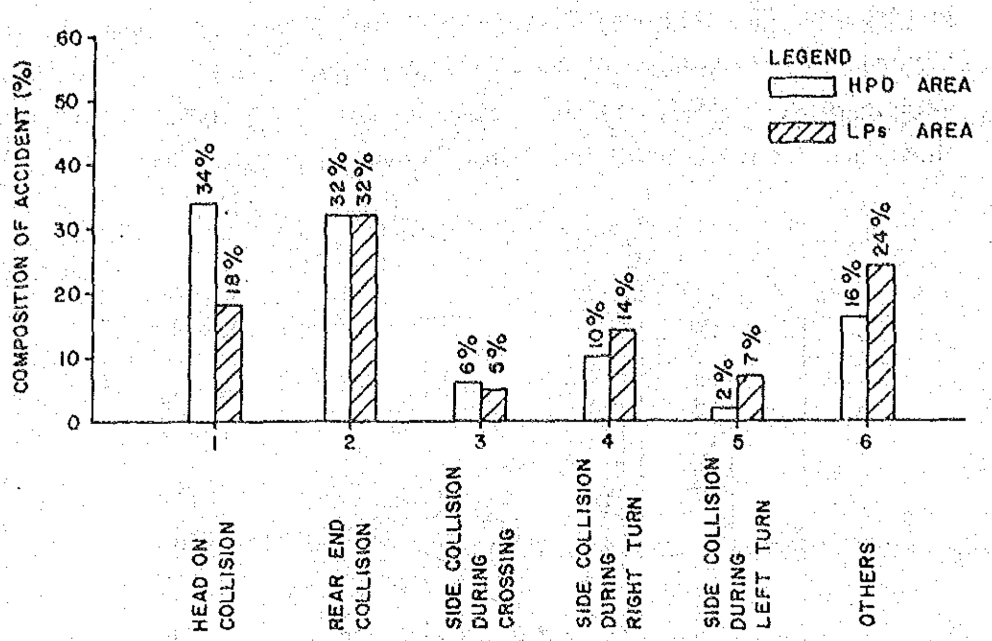


Figure 3.5 Collision Pattern

However, as far as accident at intersection is concerned, in HPD area, side collision during crossing is the highest (37%), followed by side collision during right-turn (26%), rear-end collision (15%) and head-on collision (11.5%). In LPs area the distinguished accident type is rear-end collision (36%), while head-on collision occurred quite rarely (see Appendix 3.6).

Concerning accidents involving pedestrian, most accidents (61% and 92% for HPD area and LPs area respectively) occurred when pedestrians are crossing carriageway other than crosswalk or intersection (see Appendix 3.7).

(3) Accident Location

In HPD area, eighty percent (80%) of accidents took place on roadway, followed by intersection (11%) and bridge (7%) (see Appendix 3.8).

It cannot be said, however, that intersections provide safer places, because the average accident number occurred on 1 km section including intersection (0.41 cases) is evidently higher than that of road section without intersection (0.26 cases).

(4) Property Damage

As to the kind of properties damaged by traffic accidents, highway lighting apparatus is the highest (9%), followed by guardfence (8%) and bridge (5%). Regarding the divided highways, the share of these three types of properties are raised to 37%, 15%, and 9%, respectively (see Appendixes 3.9 and 3.10).

(5) Cause of Accident

According to the accident data gathered by DOH, speeding is the most frequent cause (41%) as to the number of accidents, followed by improper passing (21%), failure to yield right of way (13%), failure to signal of way (11%), drinking (5%), and impaired ability of driving (4%) (see Appendix 3.11).

With regard to fatalities, speeding is the highest cause (29%), followed by failure to yield right of way (25%) and improper passing (18%).

3.8 Review on Data Collection System

In this section, the present data collection practices for DOH roads are reviewed mainly based on the experience gained through the execution of the Study, and some recommendations are discussed for consideration of the concerned parties.

(1) Accident Data from Police

The traffic accidents on DOH roads are investigated by HPD and LPs. The former covers HPD area with its road length of 15,700 km, while the latter covers LPs area with its road length of 28,300 km.

1) LPs Data

As primary objectives of accident investigation by LPs are to produce evidences for prosecution, brief accident records prepared by LPs are forwarded to the headquarters of the Police Department. But there is no transfer link of the accident data from LPs to DOH. Therefore, in DOH, there are virtually no accident data from LPs which is responsible for about 65% of DOH roads, and this hampers DOH from effective accident analysis and traffic safety planning.

During the implementation of the Study, the Team found that the contents of accident data at the headquarters of the Police Department are excerption from the original records investigated by LPs. These data have no information to indicate accident locations by reference to DOH route number and kilometer post. This forced the Team to visit LPs in 6 Changwats and Bangkok to get information from the original accident records for some selected roads. This data collection including the identification of accident locations, required 2 or 3 days for each LPs.

It was also found that the original accident records at LPs, which are available to DOH, do not necessarily contain sufficient information to work out adequate safety plans from engineering approaches.

Recommendation

It is desirable for DOH and LPs to establish a data transfer link as being the case with DOH and HPD, so that DOH could get the data of all accidents which occur on its roads.

The second alternative for DOH to obtain the accident data from LPs is to send officers of the DOH sub-district offices to respective LPs regularly (e.g. monthly), and to transfer the contents of accident records to the DOH's recording format.

It is also recommended for DOH to request LPs to produce accident records in the way that all information needed for traffic safety planning will be included (as to necessary information, see the paragraph of "Accident Record Format").

2) HPD Data

As aforementioned, the accident data in HPD area are reproduced in accordance with the DOH's accident format and forwarded to DOH. The information from HPD is generally sufficient for DOH to analyze accidents and plan out remedy works. A main problem with the data from HPD is an inadequate indication of accident locations. In most data, accident locations are not described precisely but in the order of kilometer posts (e.g. between km 48 and km 49). This expression is too general for traffic accident analysis.

Recommendation

It is desirable for DOH to request HPD to indicate the precise locations (at least to the level of hundred meter (100m) of kilometer post, e.g., km 48+200), when HPD prepares accident records.

3) Duplication of Accident Data

A number of accidents occurred in HPD area are investigated both by HPD and sub-district offices of DOH, and the accident data from the two sources are sent to the Traffic Engineering Office of DOH. When preparing the Accident Master Files, some data in the mainframe computer of DOH were found duplicated. The duplication of data is particularly prominent when accidents are serious ones.

In statistical analysis with number of casualties being parameters, one serious accident involving many casualties may possibly corresponds to many minor accidents. As this may mislead the analysis to a wrong conclusion, the duplication of accident data should be eliminated.

Recommendation

At present, DOH deletes one of two accident records of which all items are identical. Since two different persons are not necessarily able to produce identical records, it seems advisable for DOH to check a possibility of duplication if there are two similar accidents on a same day and at similar locations. The duplication check system developed by the Team will be of help for DOH to avoid data duplication.

4) Others

According to the experience gained through the before-and-after survey at the experimental work sites, there seems to be a gap between the real number of accidents and the number reported by police. The main reason of the gap in the number of accidents may be attributed to definition of "reportable minimum damage" in a vehicle accident, and partly shortage of manpower of police.

It may be desirable for all parties concerned with traffic accidents to discuss minimum reportable accident as well as the bottlenecks existing in the present accident investigation and reporting system.

(2) Accident Record Format

The accident record format used by DOH contains items of basic information needed for accident analysis. However, some information such as existence of safety devices, land use along road, and prevailing traffic regulation around the accident location are not available from the present record format of DOH. They are useful in many ways to prepare safety plans.

The classification of accident cause in the format seems to be insufficient to grasp the relation between the existence of safety devices and regulation, and traffic violations.

It is also noticed that style of the format can be modified introducing more multiple-choice method rather than writing method, so that a quick preparation of accident records and speedy data processing at the headquarters of DOH are expected.

Recommendation

In order to conduct a detailed analysis of traffic accidents from the traffic safety point of view, it is recommended to add following items in the present DOH format.

- Land use around the accident location
  (Urban Area, Rural Area)
- Existence of safety devices
  (Traffic Sign, Pavement Marking, Traffic Signal, Crosswalk, Lighting, Pedestrian Bridge, Others)
- Traffic regulation
  (Speed Limit, Restriction of Overtaking, Restriction of Parking, Other Restriction)

Based on the abovementioned improvement proposal including reclassification of accident causes, a newly proposed accident record format is presented in Table 3.7.

(3) Road Data

To plan out adequate and effective traffic safety plans at hazardous road locations, accurate information on physical road conditions at the location is prerequisite. As a comprehensive road data collection scheme (Road Data Base) is under way by the Programming Section of DOH, it could provide useful information needed for traffic safety planning upon its completion.

If there are any road data which should be filled in the accident record format but not covered in the Road Data Base, it is desirable to add necessary road data items in the Road Data Base scheme.

(4) Data Compilation

It is apparent that compilation of the following data files is very useful to facilitate accident analysis and planning safety devices.

1) Accident Master File

An Accident Master File which consists of traffic accident data and traffic volume is the most basic information for traffic accident analysis. The information to be stored in this file depends largely on availability of data.

Table 3.4 and Table 3.5 show the contents of the accident master files prepared by the Team and can be utilized as an example when DOH will prepare such files.

2) Road Section File

A Road Section file is, in particular, useful to identify hazardous locations. The file contains accident rates (defined as the number of accidents on a section per 100 million vehicle-kilometer travelled), accident density (defined as the number of accidents per kilometer of road), traffic volume and road section data. Table 3.6 shows the contents of the Road Section File prepared by the Team for implementation of the Study.

3) Diagrams

For hazardous routes or control sections, it is recommended to prepare the accident location histograms, (Figure 3.6), since it is easy to produce this histogram by computer program. In addition, it is also recommended to prepare the accident location maps (Figure 3.7) for hazardous routes or control sections containing problems of horizontal alignment.

On the other hand, it is recommended to prepare the collision diagrams (Figure 3.8) only for hazardous road locations for which safety plans will be prepared.

4) Control Section Number

As most data pertaining to traffic accidents are assorted in connection with the control section system of DOH, change of control section number will bring about a great confusion to accident analysis. Therefore, it is recommended to indicate the old control section number together with a new control section number in accident records, where there will be any change of control section number.

Table 3.7 Proposed Accident Record Format

Reference No.............................
To...............From...................
Reference Radio,Telegram................ Date...............

Accident Location	Date and Time	Type of Accident
1 Location______ ☐☐☐☐ Route No. 2 ☐☐☐☐ Control Section Bypass______ 3 ☐☐☐☐☐☐ Location Km	1 ☐☐ Date 2 ☐☐ Month 3 ☐ Year 4 ☐☐☐☐ Day(1.Mon,2.Tues,3.Wed,4.Thur,5.Fri,6.Sat,7.Sun)	1. ☐ Motor Vehicle vs. Motor Vehicle 2. ☐ Motor Vehicle vs. Bicycle 3. ☐ Motor Vehicle vs. Pedestrian 4 ☐ Motor Vehicle Only 5 ☐ Others (Defined)

Type of Vehicle Involved	Detail of Vehicles	Vehicle 1	Vehicle 2
☐☐☐☐☐☐☐	Type of Vehicle	----------	----------
1. Bicycle Tricycle	No. of Registration	----------	----------
2. Motorcycle	Tel.	----------	----------
3. Passenger Car	Address	----------	----------
4. Light Bus	Driver's Name	----------	----------
5. Light Truck	Age	----------	----------
6. Heavy Bus	Sex	☐ Male ☐ Female	☐ Male ☐ Female
7. Heavy Truck	Part of car damaged	----------	----------
8. Others			

Traffic Safety Devices	Traffic Regulation	Cause of Accident
1 ☐ Traffic Signal 2 ☐ Road Lighting 3 ☐ Sidewalk 4 ☐ Crosswalk 5 ☐ Flashing Signal 6 ☐ Pavement Marking 7 ☐ Traffic Island 8 ☐ Traffic Sign 9 ☐ Guardfence 10 ☐ Pedestrian Bridge 11 ☐ Others (Defined)	1 ☐ Speed Limit____Km/Hr 2 ☐ Restriction of Overtaking 3 ☐ Restriction of Parking 4 ☐ Restriction of Turning 5 ☐ Restriction of Crossing 6 ☐ Others (Defined) **Lane Use** 1 ☐ Urban Area 2 ☐ Rural Area 3 ☐ Others (Defined)	1 ☐ Over speed limit 2 ☐ Improper Overtaking at Restricted Section 3 ☐ Improper Overtaking 4 ☐ Improper Parking at Restricted Section 5 ☐ Improper Parking 6 ☐ Parking without light at night 7 ☐ Inadequate Signalling 8 ☐ Improper Turning 9 ☐ Violate Traffic Sign or Signal 10 ☐ Driving Wrong Way 11 ☐ Not Stop at Crosswalk 12 ☐ Overloading of Passengers 13 ☐ Overloading of Goods 14 ☐ Wrong Use of High Beam 15 ☐ Vehicle Defects 16 ☐ Sleeping 17 ☐ Drunkenness 18 ☐ Inexperienced Driving 19 ☐ Others (Defined)

Type of Highways	Road Surface	Location	Road Classification
1 ☐ Maintenance 2 ☐ Construction 11 ☐ Special Highway 12 ☐ National Highway 13 ☐ Provincial Highway 14 ☐ Concession Highway 15 ☐ Others (Defined)	1 ☐ Concrete 2 ☐ Asphalt Concrete 3 ☐ Bituminous 4 ☐ Unpaved 5 ☐ Others (Defined)	1 ☐ Tangent Section 2 ☐ Curve Section 3 ☐ Intersection 4 ☐ Crosswalk 5 ☐ Slope Section 6 ☐ Mountainous Section 7 ☐ Bridge 8 ☐ Railway Crossing 9 ☐ Others (Defined)	1 ☐ Two Lanes 2 ☐ Two Lanes (One Way) 3 ☐ Four Lanes (Undivided) 4 ☐ Four Lanes (Divided) 5 ☐ More Than four Lanes 6 ☐ More Than Two Lanes (One Way) 7 ☐ With Bus Lane 8 ☐ Others (Defined)

Severity	DOH Properties Damaged	Visibility	Surface Conditions
1 ☐☐ Number of Deaths at Spot 2 ☐☐ Number of Serious Injuries 3 ☐☐ Number of Slightly Injuries 4 DOH Properties Damage ☐☐☐☐☐☐☐☐ Bht 5 Properties Damage (Private) ☐☐☐☐☐☐☐☐ Bht 6 ☐ Others (Defined)	1 ☐ Road Surface 2 ☐ Bridge 3 ☐ Road Lighting 4 ☐ Traffic Signal 5 ☐ Traffic Sign 6 ☐ Guardfence,Guide Post 7 ☐ Traffic Island 8 ☐ Kilometer Post 9 ☐ Others (Defined)	1 ☐ Fine or Cloudy 2 ☐ Foggy 3 ☐ Smoke 4 ☐ Raining 5 ☐ Dark with Street Light 6 ☐ Dark with no Street Light 7 ☐ Others (Defined)	1 ☐ Wet 2 ☐ Dry 3 ☐ Rutty 4 ☐ Dirty 5 ☐ Others (Defined)

Sheet No.1 Traffic Engineering Office Sheet No.2 Maintenance Division
Sheet No.3 Distric Division Sheet No.4 Reporter Office

Sketch of Accident Location

Detail
1. Straight line shows accident highway. 2. Put the No.to each vehicle & show direction —[1]X[2]—
3. Straight line shows before accident→[1]> and dotted line shows after accident happens→[1]>

Report the Detail of Accident Case

Signature..................Reporter Signature.............Chief of Office
Position...................... Position...............
Dating.......Month.......Year....... Dating.......Month.......Year........

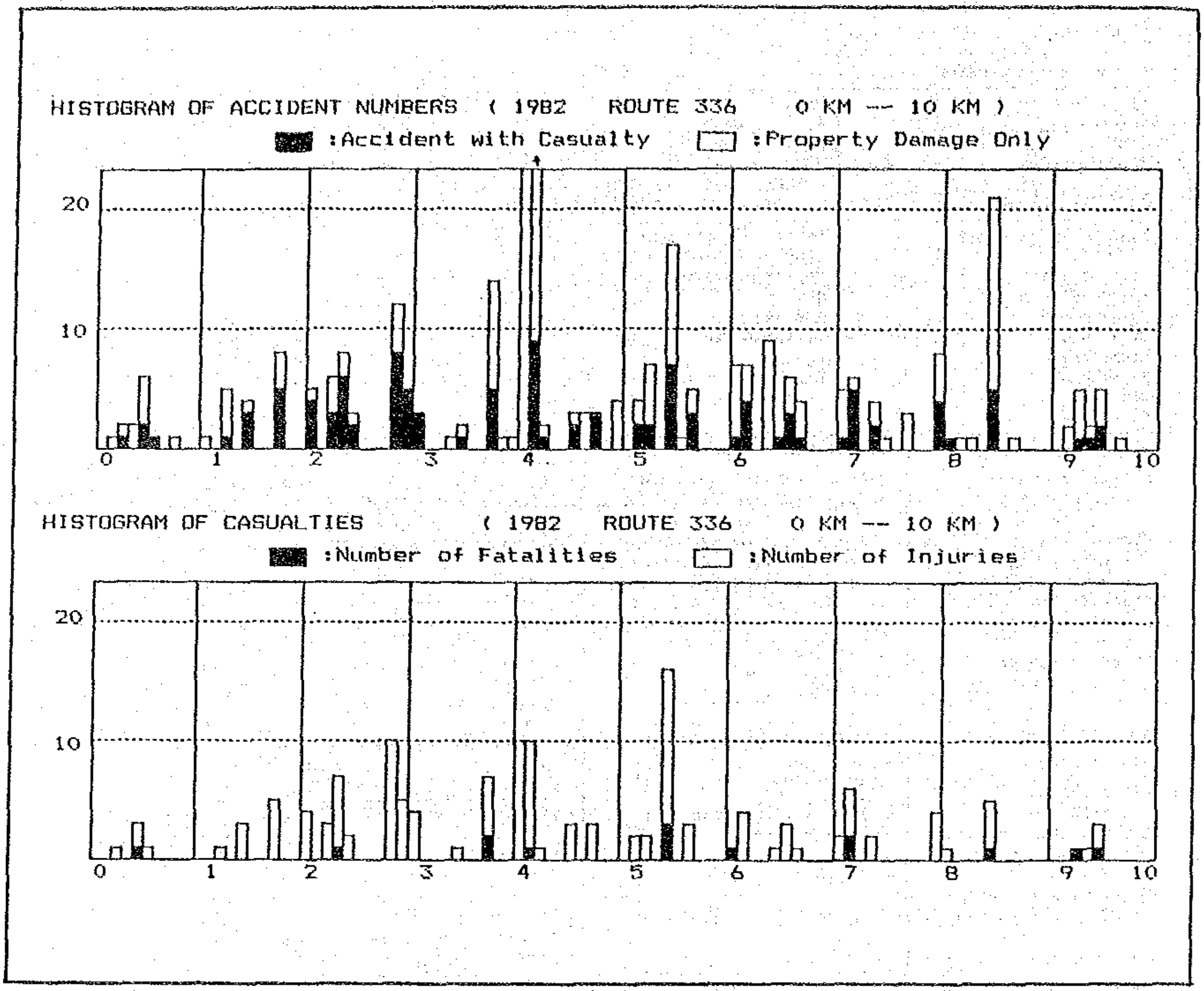


Figure 3.6 Accident Location Histogram

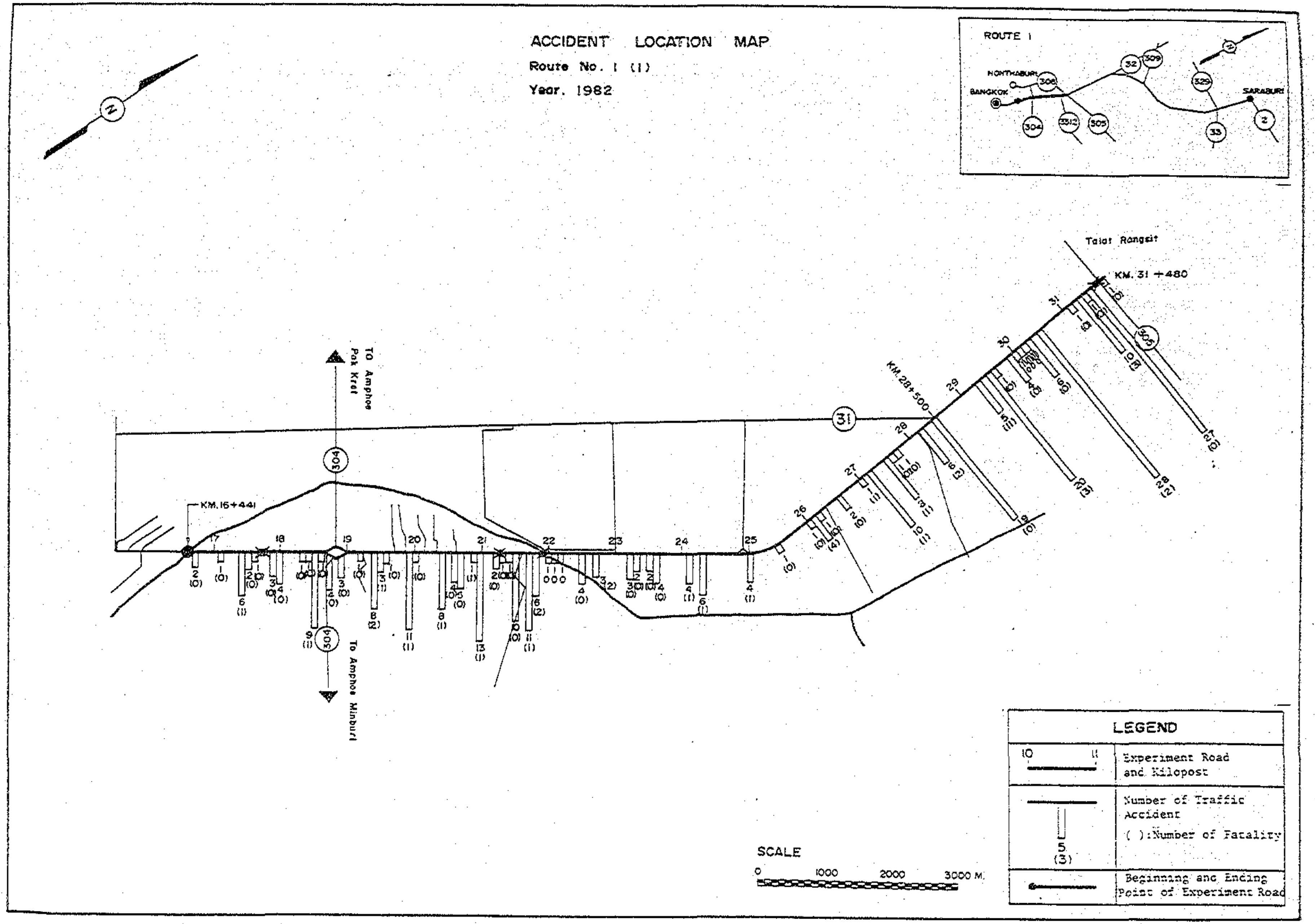
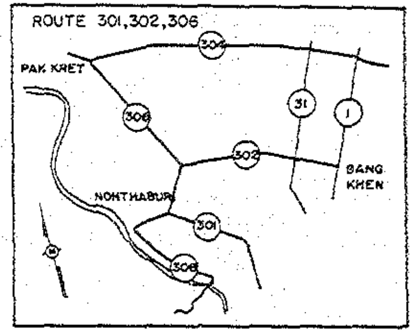
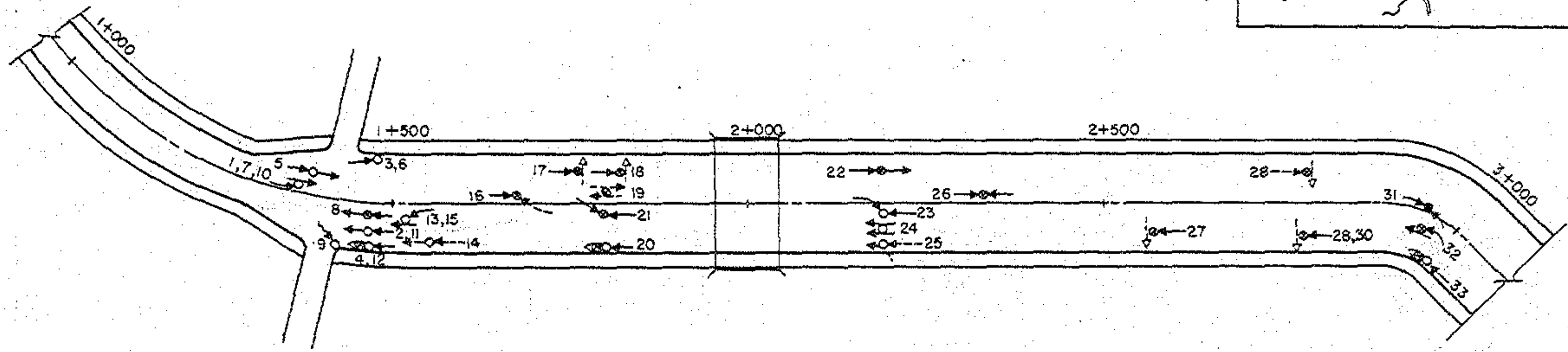


Figure 3.7 Accident Location Map

COLLISION DIAGRAM
Route 306 (KM.1 — KM. 3)
Year 1981

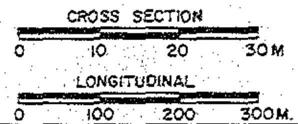




No.	Kilopost	Date	Time	Fatality	Injury
1.	1+480	14/Sep	12:00	-	-
2.	1+480	25/Dec	14:00	-	-
3.	1+480	18/Nov	05:00	-	-
4.	1+480	10/May	14:00	-	-
5.	1+480	29/Jan	10:00	-	-
6.	1+480	9/Jul	21:00	-	1
7.	1+480	8/Mar	17:00	-	-
8.	1+480	20/Aug	20:00	-	1
9.	1+480	19/Jun	21:00	-	-
10.	1+480	6/Oct	02:00	-	-
11.	1+510	27/Feb	15:00	-	1
12.	1+510	14/Mar	16:00	-	-
13.	1+520	18/Mar	11:00	-	-
14.	1+550	2/Nov	19:00	-	-
15.	1+560	13/Aug	07:00	-	-
16.	1+670	9/Jul	16:00	-	1
17.	1+760	14/Jan	20:00	1	-

No.	Kilopost	Date	Time	Fatality	Injury
18.	1+790	3/Sep	16:00	-	1
19.	1+790	6/Nov	12:00	-	1
20.	1+790	5/Aug	15:00	-	-
21.	1+790	13/Apr	15:00	-	1
22.	2+180	9/Aug	19:00	-	6
23.	2+180	21/Jan	11:00	-	-
24.	2+180	7/Sep	11:00	-	-
25.	2+180	29/Mar	19:00	-	-
26.	2+330	30/Oct	10:00	-	1
27.	2+570	22/Feb	00:00	-	1
28.	2+700	11/Nov	12:00	-	1
29.	2+770	16/Feb	22:00	-	1
30.	2+770	23/Jul	15:00	-	1
31.	2+960	17/Jan	18:00	3	1
32.	2+960	29/Jul	18:00	-	1
33.	2+980	11/Nov	14:00	-	1

SCALE



LEGEND

←	VEHICLE EXCLUDING MOTORCYCLE	●	ACCIDENT WITH FATALITY
←---	MOTORCYCLE	⊗	ACCIDENT WITH INJURY
⇐—	BICYCLE	○	ACCIDENT WITH PROPERTY DAMAGES ONLY
⇐---	PEDESTRIAN	←~~~	LOOSING CONTROL
⇐═	TRAIN	←∽∽∽	OVERTURNING
⊲═⊳	PARKING OR STOPPING VEHICLE		

Figure 3.8 Collision Diagram

Chapter 4

METHOD FOR IDENTIFICATION OF HAZARDOUS ROAD LOCATIONS

Chapter 4 METHOD FOR IDENTIFICATION OF HAZARDOUS ROAD LOCATIONS

4.1 Introduction

The aim of this Chapter is to propose methods for identifying hazardous road locations in the road systems administrated by the Department of Highways (DOH). A case study to demonstrate approaches to set up criteria in the proposed methods is also carried out, by using the available data at DOH and some from Local Police stations (see Table 3.5 in Chapter 3).

Traffic accident problems should be tackled on a priority basis, within a limitation of manpower and budget, and it is extremely helpful to establish a systematic approach to identify high risk road locations from the vast range of DOH's road networks.

In this study, a "hazardous road section" can be defined as the site where a high frequency of traffic accident or a large number of casualties occur and some remedial measures are required. The definition of "hazardous", however, is always relative and not an absolute account.

There are various methods to identify the hazardous road locations depending upon the factors to be incorporated. And a final identification method for practical purpose should be established in consideration of various aspects such as available data, information as to budget and policies. In selection of hazardous section, it is a general practice that different methods are adopted to roadways and intersections respectively because characteristics of accidents are different each other.

4.2 Review of Identification Methods

4.2.1 Review of Available Methods

This section deals with reviews on the following 6 methods available for identifying high risk road locations.

- accident number method;
- accident density method;
- accident rate method;
- number-rate method;
- rate-volume method;
- statistical method;

(1) Accident Number Method

This method is the simplest of all and the easiest approach to adopt. In this method, the sections with a higher number of accidents (i.e. a certain absolute number of accidents or casualties) are identified as hazardous regardless of the traffic volume in the section.

(2) Accident Density Method

When there is a considerable difference in the road section length, the identification method using the number of accidents alone can lead to a misleading conclusion. In this case, "accident density" represents a better criterion for the detection of high accident frequency road locations.

Accident density is defined as the number of accidents (or casualties) per unit length of road section, and sections which exceed a certain critical density are identified as hazardous regardless of traffic volume same as accident number method.

This method can be said rather simple because it requires only number of accidents and a certain length of road section. But this tends to choose the section with high traffic volume because traffic accident frequency is generally proportional to traffic volume.

(3) Accident Rate Method

With a similar argument introduced in the accident density method, the difference in traffic volume also creates some confusion. This means that two sections with the same number of accidents (or accident densities) should not be regarded to have the same degree of hazard potential, especially when one of them carries much more traffic than the other. This leads to the concept of "accident rate". In general, accident rate (Ra) is calculated by the following equation.

$$Ra = \frac{(\text{Number of accidents or casualties}) \times 10^8}{(\text{Average daily traffic volume}) \times (\text{Section length in Km}) \times 365}$$

When accident rate Ra exceeds a certain acceptable value, the section is identified as hazardous. This method is likely to choose the sections with low traffic volume where an accident leads to a higher accident rate as compared with the sections carrying high traffic volume.

(4) Number-Rate Method

When dealing with a set of road sections which have great difference in traffic volume, the accident rate method explained above tends to lose its reliability. For example, if one road section has a relatively low number of accidents, but when the traffic volume on this section is also low, the resulting accident rate could be very high. If this section is selected as a hazardous road section and is given a high priority, the policy on road traffic safety loses its efficiency.

The use of two indices, accident rate and accident number, is an obvious answer to this problem. If certain critical values for both indices are set as shown in Figure 4.1, the misleading explained above may be eliminated.

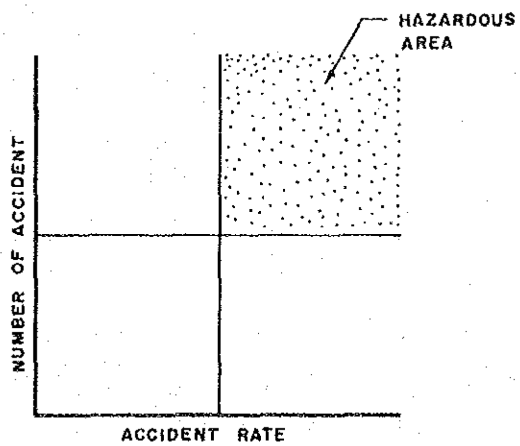


Figure 4.1 Number-Rate Method

That is, when both the number of accident and rate exceed the critical value, the location can be reasonably assumed to be hazardous. However, this method is likely to neglect the locations where traffic is very heavy, due to rather low accident rate in spite of high frequency of accident occurrence, or the locations where traffic volume is low regardless of possibly high accident rate.

(5) Rate-Volume Method

The sensitivity of accident rates in low traffic volume sections are noted in the previous paragraph. The number-rate method is proposed as one of approaches to this problem. The limit of applicability of this number-rate method is also discussed in the preceding paragraph. An analysis of the relationship between accident rate and traffic volume, then, leads to the rate-volume method.

The past records reveal that the relation between accident frequency and traffic volume is nonlinear but traces a curve with a diminishing rate of increase. This results in a commonly known tendency that accident rates show relatively higher values in low traffic volume section, and lower values in high traffic volume sections. Figure 4.2 shows the relationship between accident rate and traffic volume.

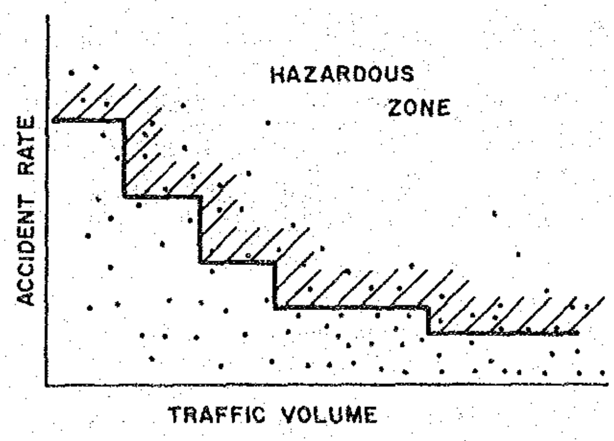


Figure 4.2 Hazardous Criteria in Rate-Volume Method

Then for practical purposes, the critical values are set in "staircase-like" lines shown in Figure 4.2 instead of a continuous curve (Refer also to Figure 4.3).

(6) Statistical Method

There are several kinds of methods to identify the hazardous section by statistical method in practice. One of popular methods is the so-called Rate-Quality Control Method which is often employed in the United States. This method was introduced by the same concept as quality control of products in factories.

The other is the method which uses the deviation between the actual accident index* and the estimated index which can be determined generally by using a multiple regression model.

The deviation value (Z_i) is calculated by,

$$Z_i = \frac{Y_i - Y_i}{\sqrt{Y_i}}$$

where, Y_i: actual accident index in section i
$\tilde{Y}_i$: estimated accident index in section i

When Z_i exceeds a certain critical value**, the section i is identified as hazardous from probability theory.

It is to be noted that the critical value for identification is computed for each location and compared to the actual value. That is to say each location has its own criterion which is calculated by the above formula.

4.2.2 Selection of Identification Method

As the available identification methods as previously mentioned have their particular characteristics, due considerations should be paid when selecting the method in this study. The followings are, in particular, the most important issues to be discussed:

- The method could identify hazardous road locations from nationwide road networks where traffic volumes vary from quite low to high.
- The method should be practical so that engineers can use it easily.

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* Such as accident density, accident rate, number of casualty and number of accident.

** With a confidence level at 95%, the critical value becomes 1.96.

Based on the previous reviews, and the consultation with DOH as well as the experience in Japan, Rate-Volume Method has been found reasonable and selected for the method of identifying hazardous sections on DOH roads.

4.2.3 Approaches to Determination of Identification Criteria for Rate-Volume Method

It is required that the reasonable criteria are to be set to identify the hazardous road locations based on the Rate-Volume Method. Two approach* to determine the criteria, i.e, statistical approach and empirical approach, are discussed in this section.

However, it is necessary to take into account economic and political considerations because hazardous road locations imply the recognized necessity of immediate remedy works requiring a large amount of investments.

(1) Statistical Approach

This approach utilizes the results of Statistical Method, and the procedure is as follows:

a) to determine road sections which are judged to be hazardous by using the statistical method (see Section 4.2.1 (6)).

b) to plot the results on a rate-volume diagram (see Figure 4.3). The circled points show the "hazardous sections" identified by the statistical method.

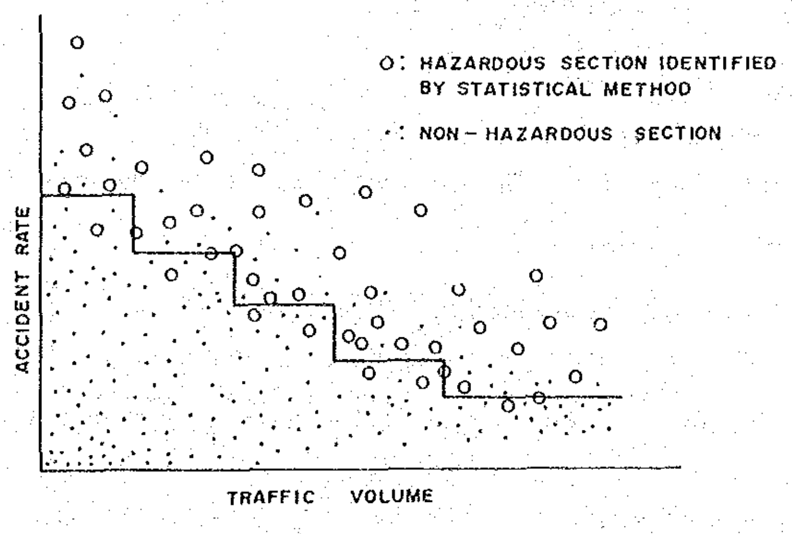

Figure 4.3 Setting Identification Criteria in Rate-Volume Method

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* In this section, the term "approach" instead of "method" for the means of determination of criteria in an identification method is used.

c) to determine the criteria line for each traffic-volume-rank in such a way that they can separate the sections between hazardous road sections and non-hazardous road sections.

(2) Empirical Approach

This approach is based on the experiences and judgement by the experts such as highway engineers and traffic engineers who are in charge of road administration and maintenance. They usually have the knowledge about the particular locations which are recognized to be hazardous from empirical and engineering points of views. The applicable criteria can be obtained utilizing their information on classification of hazardous and non-hazardous locations in the following steps.

- to identify the hazardous locations by highway engineers and/or traffic engineers.
- to plot the hazardous locations and non-hazardous locations with different marks on the same diagram of traffic volume and accident rate as same as shown in Figure 4.3.
- to determine the criteria for each traffic-volume-interval in the same manner as the statistical approach.

4.3 Application of Identification Method to DOH Roads

The occurrence of traffic accidents generally correlate closely to traffic flows, physical features of road and its environments. The traffic accidents also occur sporadically and incidentally in the road networks. To identify hazardous road locations in a systematic (or statistical) manner, it is reasonable to assess a road in terms of traffic safety by road sections, which are set out dividing a road into sections in which the traffic flow is uniform and the physical features of the sections are generally homogeneous.

In this study, the identification methods are discussed separately for the two parts of road, i.e., intersections and road-segments between intersections (referred to as "roadway"), because traffic behaviors, mechanism of accident occurrence and structural characteristics of roads between two parts of road could be significantly different.

As to road environments in connection with traffic accident analysis, land use along a road, that is, urban and rural, is a major factor to be taken into account. In this study, however, the classification by urban and rural was not incorporated in a development of identification methods, since sufficient accident data on the roads in urban areas are not available as mentioned in Chapter 3 in this report.

This does not necessarily deny the applicability of the identification criteria worked out in this study to the roads in urban areas, because the preliminary analysis based on the limited data on the roads in urban areas has revealed that both identification criteria for urban and rural are almost identical in the case of DOH roads.

4.3.1 Identification Criteria for Roadway

(1) <u>Section Length</u>

Application of identification approaches to roadway requires a determination of "section length". In theory, the shorter the section length is, the more the uniformity of road conditions within each section can be attained, and the identified sections are easily correlated to actual "hazardous sites" on the road network. As section length becomes longer, the road conditions become less homogeneous and the reasons why particular road sections are identified hazardous will become vague. This reduces the chance of finding efficient safety measures to the sections.

Although it is pointed out that the shorter section length is preferable in theory, in practice it is not always so. There is a fact that the sensitivity of the distribution property of accident rate increases as the section length becomes shorter, but as the section length becomes longer it gradually stabilizes.

Figure 4.4 proves the above relation, which was obtained by using accident data on DOH roads in HPD area.

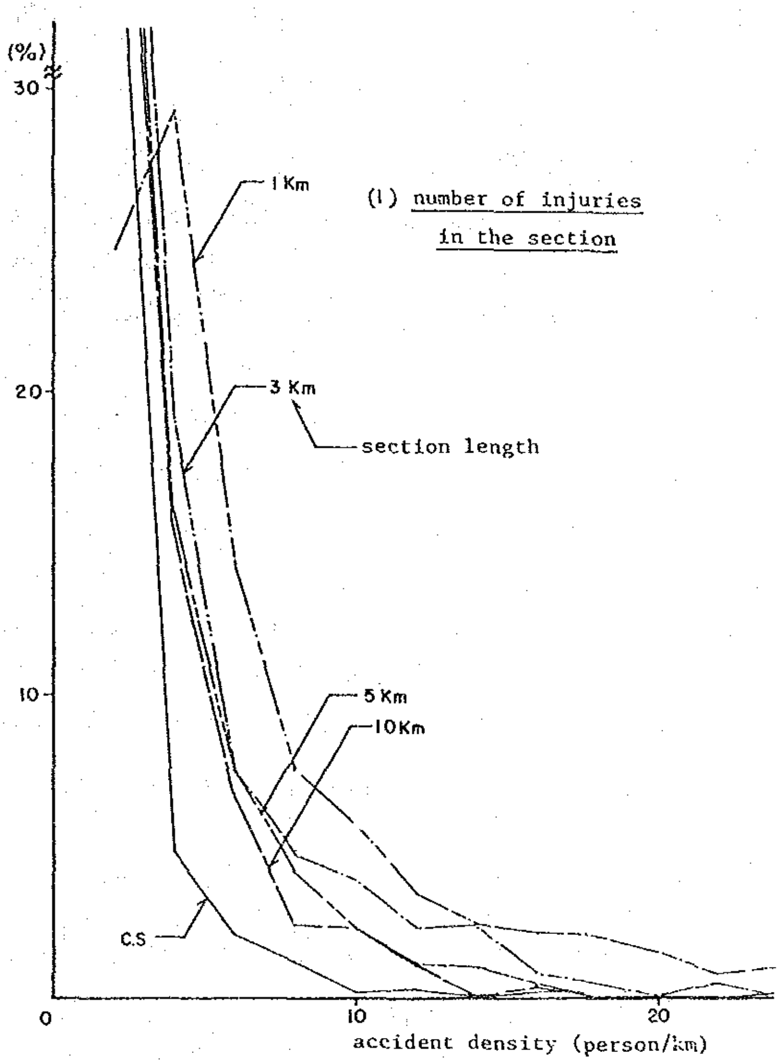

Figure 4.4 Distribution of Accident Density by Section Length

The figure indicates that when the unit length exceeds 3 kms, in the vicinity of accident rate of 5 persons/km or less, where most of the observed data falls in, the distribution property of the accident density stabilizes. On the other hand, an excessively concentrative distribution of accident density restricts the applicability of the proposed statistical method. And the sections of too short length also results in undue work load in data resortment and calculations.

Judging from the present DOH's road network, the uniformity of road conditions over any section of three kilometers can be ensured for roadway. Three kilometers of unit length, then, appears to be an appropriate section length to the present analysis.

(2) Process of Establishing Criteria

Figure 4.5 shows the process of establishing identification criteria. This diagram describes the flow of analytical process, the data handling and processing to lead to the setting of identification criteria.

(3) Regression Model

Statistical approach mentioned in 4.2.3(1) requires the prediction of accident indicators - density or rate.

The prediction is usually made by using regression models. Several factors such as road environment and traffic characteristics usually enter as the explanatory variables. In this analysis, however, only "traffic volume" is used in the model, since the road inventory of DOH roads was not yet completed.

The regression model used in this analysis is in the form of:

$$Y = a X^{b}$$

where,

Y: accident indicator

X: traffic volume (veh/day)

a, b: parameter

Another model used for a comparison purpose is a linear additive form; by using the same notation;

$$Y = a + bX$$

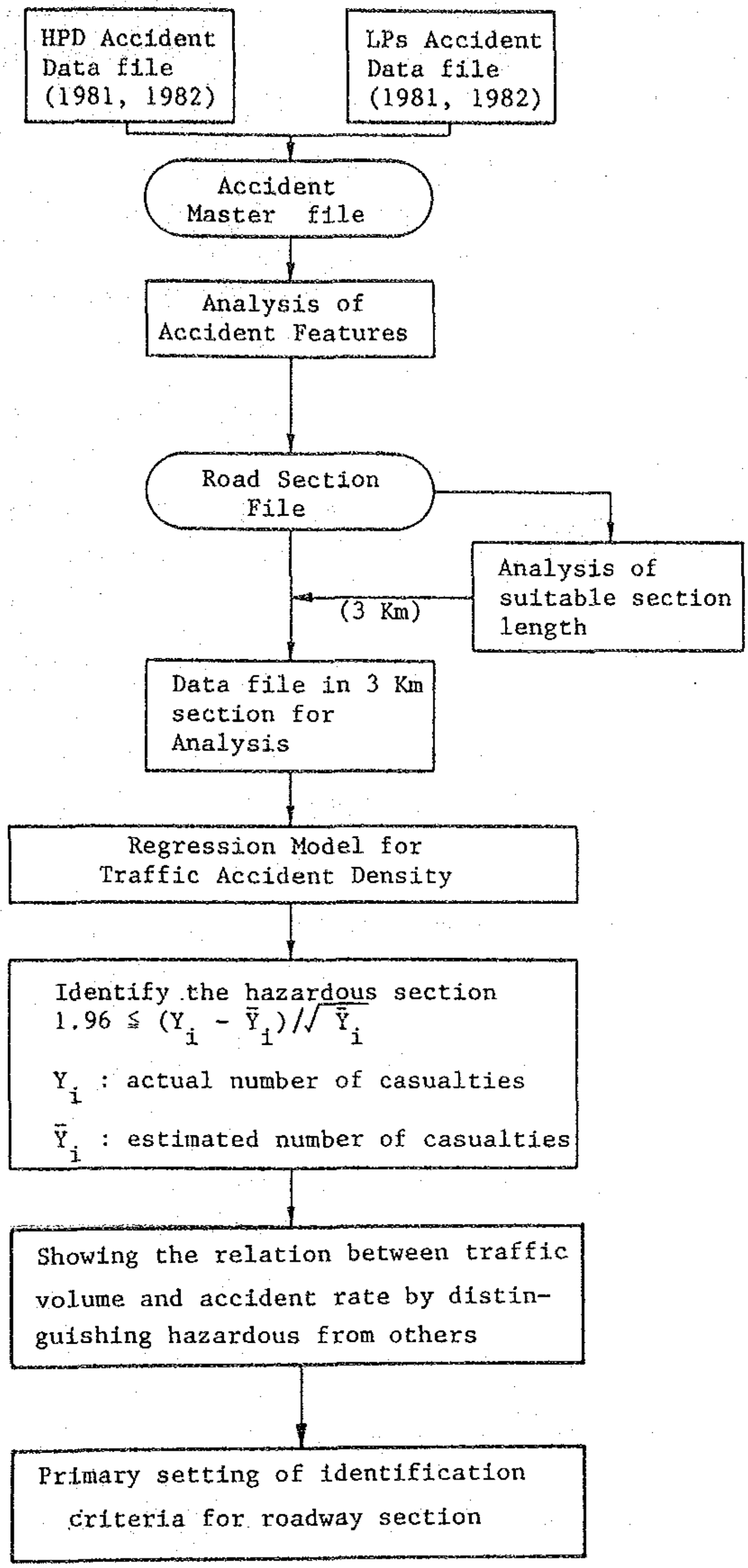

Figure 4.5 Process of Establishing Criteria for Roadway

The hazardous sections identified by above two models were almost same and the former model was adopted, because this form is widely used. The final result is shown below.

$$Y = 0.56\,X^{0.196} \quad (R = 0.48)$$

where,

Y: accident density (persons/km)

X: average daily traffic (veh./day)

The correlation coefficient R was statistically significant.

The model is, then, used for deriving predicted accident density in every road section i ($\bar{Y}_i$ in equation) and the sections with the Z_i exceeding 1.96 (confidence level is at 95%) are identified as hazardous. The result is shown in Figure 4.6.

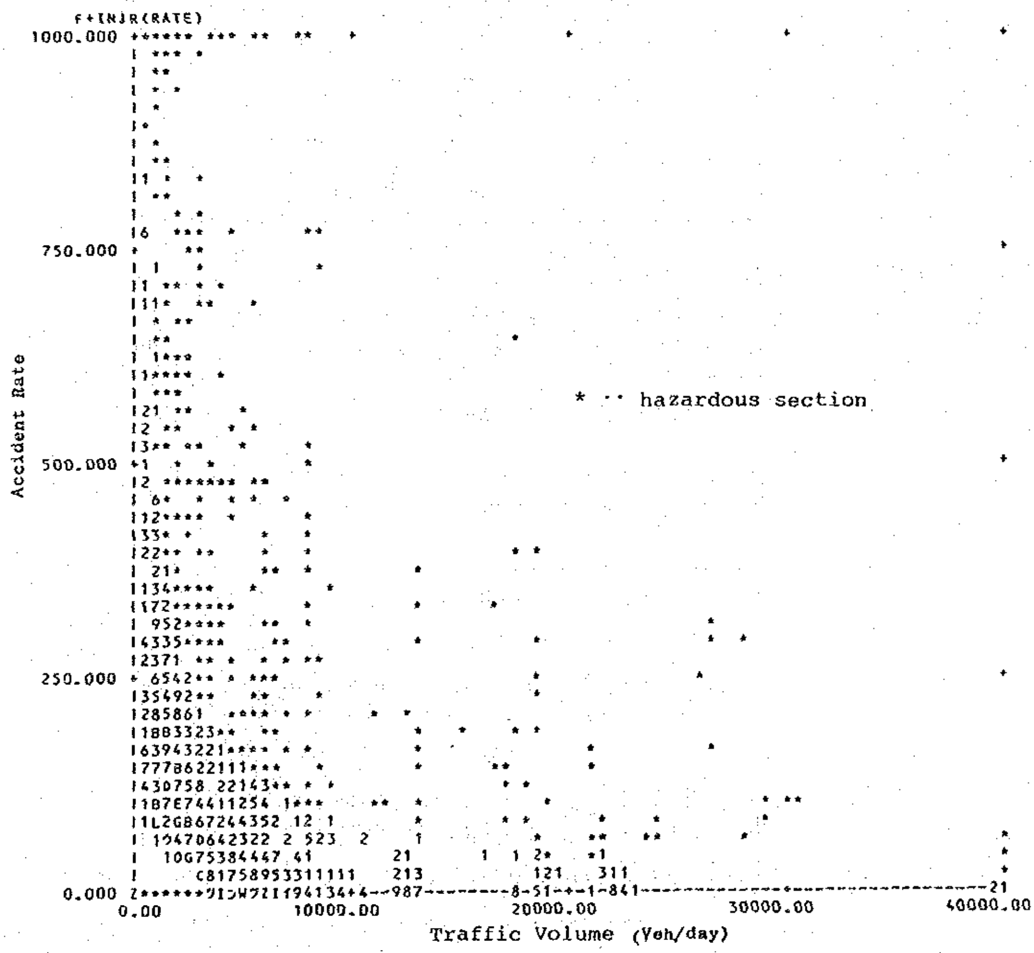

Figure 4.6 Identified Hazardous Section in Roadway

As it can be observed from the figure, fairly clear delineation exists between selected and non-selected sections. In order to use this result properly and conveniently, the criteria for several categories of traffic volume need to be established.

Regarding the ranking of the traffic volumes when applied to the DOH roads, the following rankings deemed adequate. These rankings are set taking into account the design standard of DOH. The sections with less than 500 veh./day are eliminated for identification, because the hazard in the section with very low traffic volume could be recognized automatically.

The traffic volume ranking used in the study are as follows:

500	-	1,000	vehicles/day
1,001	-	2,000	
2,001	-	3,000	
3,001	-	5,000	
5,001	-	10,000	
10,001	-	15,000	
15,001	-		

The identification criteria for each traffic volume category are presented in Table 4.1. The figures are set by taking the following two points into account.

a) The absolute number of casualties in the lower traffic volume ranking must be smaller than that of the higher traffic volume ranking.

$$N_i \leqq N_{i+1}$$

where, N_i is the product of accident rate of i-th category and the average daily traffic of that category.

b) The criteria for lower traffic categories need to be modified so that enough number of road sections fall in the hazardous area.

The above identification criteria are entirely the results of mathematic works. This method to identify hazardous sections has been proved effective through various experiences and practices in many places. But it is advisable to certify the propriety of the criteria worked out in this method utilizing available relevant information. This was carried out by the empirical approach by using the questionnaire (see Appendix 4.1 "Questionnaire to DOH engineers").

The proposed identification criteria (see Table 4.1) in this study has closely been agreed with empirical judgements by the district engineers of DOH. In other words, out of 110 locations which have experiences one or more traffic accidents and found hazardous by the engineers, 90 locations (82%) fall in the category of high risk sections as defined by the proposed criteria.

Thus, the proposed identification method for roadway appears to be well applicable for the DOH roads. However, since the criteria in this chapter have been worked out based on the rather limited number of traffic accidents on DOH roads, the criteria should be reviewed and revised if found necessary when more accident data in the DOH road network system will be made available.

Furthermore, it should be noted that identification criteria also should be determined taking into account not only engineering judgement but available financial resources, as the definition of hazardous is always relative and not an absolute account.

(4) Result of Identification

The numbers of hazardous road sections and the casualties on the sections identified by the criteria in Table 4.1 and Figure 4.7 are summarized in Table 4.2.

Table 4.1 Identification Criteria for Hazardous Road Section in Roadway

Average Daily Traffic (veh.)	Identification Criteria (rate)
- 500	not defined
501 - 1,000	400
1,001 - 2,000	300
2,001 - 3,000	250
3,001 - 5,000	200
5,001 - 10,000	150
10,001 - 15,000	100
15,001 -	100

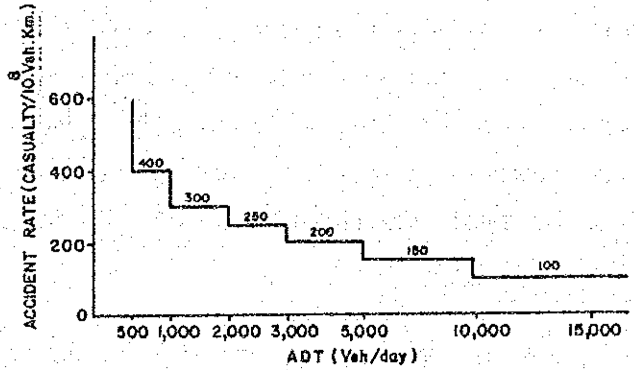

Figure 4.7 Identification Criteria for Roadway

Table 4.2 Number of Hazardous Road Sections and Casualties

Area	Road Length (Km)	Number of Sections	Number of Hazardous Sections	Number of Casualties
HPD area	15,700	4,844	375	4,470 [1)]

1) This figure consists of 1,037 killed and 3,433 injured. 4,470 persons is 61% of total casualties (7,277 persons, annual average for 1981 and 1982) on DOH roads in HPD area.

4.3.2 Identification Criteria for Intersection

(1) Approach to Establishment of Criteria

The most fundamental concept to identify hazardous road locations is to look into every inch of road networks together with sufficient data and their analyses. This approach is, however, really time consuming and not practical when to select hazardous locations from a large number of road sections.

This leads to development of identification method by which all roads are assessed and hazardous locations are selected rather automatically. Although final decision on "hazardous" or "non-hazardous", shall be made through various reviews including field investigation, the method is quite useful and effective for the roadway (road-segment between intersections), as found in the previous section of "Identification Criteria for Roadway".

The approach to determine the criteria for roadways hold good on condition that occurrences of traffic accidents on similar road conditions, when the number of accident is large enough, follow a certain rule so that they can be analysed and treated statistically.

This identification method can not be ruled out in the case of intersections. However, most intersections on DOH roads have their own specific characteristics in traffic movements, configurations and structures, whereas in the case of the roadways, a certain uniformity of characteristics over sections is secured when they are properly divided.

Furthermore, it is obvious that the mechanism of accidents at intersections is more complex than that of roadways. Thus, to formulate any regression model, more explanatory variables than the roadways are required. Meanwhile, at present there are almost no road inventory data as to intersections and even the traffic volumes of the crossing roads are not available when the crossing roads are administrated by other agencies than DOH.

As such the application of the statistical approach to the intersections is found impractical in this study. Since the number of the major intersections in the road network of DOH is estimated at around 1,500, the employment of the basic concept to look into each intersections and make assessment on them from the traffic safety point of view, may be one of alternatives to determine criteria for intersections.

The questionnaires detailed in the previous section have brought a large amount of useful information on the intersections throughout the country. The Team have, therefore, decided to make use of the information which, among others, includes the district engineers' judgement on hazardous intersections. Thus the identification criterion for intersections has been established by an empirical approach mainly based on the traffic accident data and district engineers' experiences and knowledges.

The information obtained from the questionnaires is based on the best judgement by the district engineers under the given circumstances and seems generally reasonable. It is a possible way to determine a criterion such a way that all intersections selected by district engineers would be identified as hazardous. However, as the definition of "hazardous" is relative and subject matters, it can be assumed that there might be individual variations among the judgements on the intersections as found hazardous by the district engineers.

This implys that the engineers' empirical judgements may not be directly used to the establishment of criteria on hazardous intersections which shall be applicable to all DOH roads, and leads to necessity of analyses on the judgements. The analyses have been made as to the traffic volumes and the number of casualties at the intersections found hazardous by the district engineers, average number of casualties ($\bar{X}$) per intersection and standard deviation (σ) for all intersections as well as for the groups of intersections classified by traffic volume.

Although there are no definite ways to check the confidence of the individual judgements on this sort, in the study, the standard deviation has been considered as a threshold of confidence in the judgements (See Fig. 4.7), that is, the intersections of which casualties are more than ($\bar{X}$ - σ) could be assumed hazardous. In other words, the value of ($\overline{X}$ - σ) could be criterion for identification of hazardous intersections.

The followings and Figure 4.8 show the process for the establishment of criterion in the study.

- Identify intersections that are judged "hazardous" by district engineers of DOH.
- Enumerate casualties and traffic volume (of main approach) at each hazardous intersection by using the Road Section File (see Chapter 3.6(3)).
- Calculate the average number of casualty ($\overline{X}$) and standard deviation (σ).
- See up the criterion* (S).

$$S = \overline{X} - \sigma$$

The analyses for the 98 intersections** show that the average number of casualties per intersection ($\overline{X}$) and the standard deviation (σ) are 6.2 and 2.1, respectively. The analyses also reveal that the average number of the casualties among the intersections classified by traffic volume ranks are slightly on a upward trend in proportion to traffic volume.

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* By this criterion, approximately 15 percent of the intersections as found hazardous will be excluded.

** The number of the intersections which are found hazardous by district engineers. The engineers judgement does not cover the whole DOH road intersections.

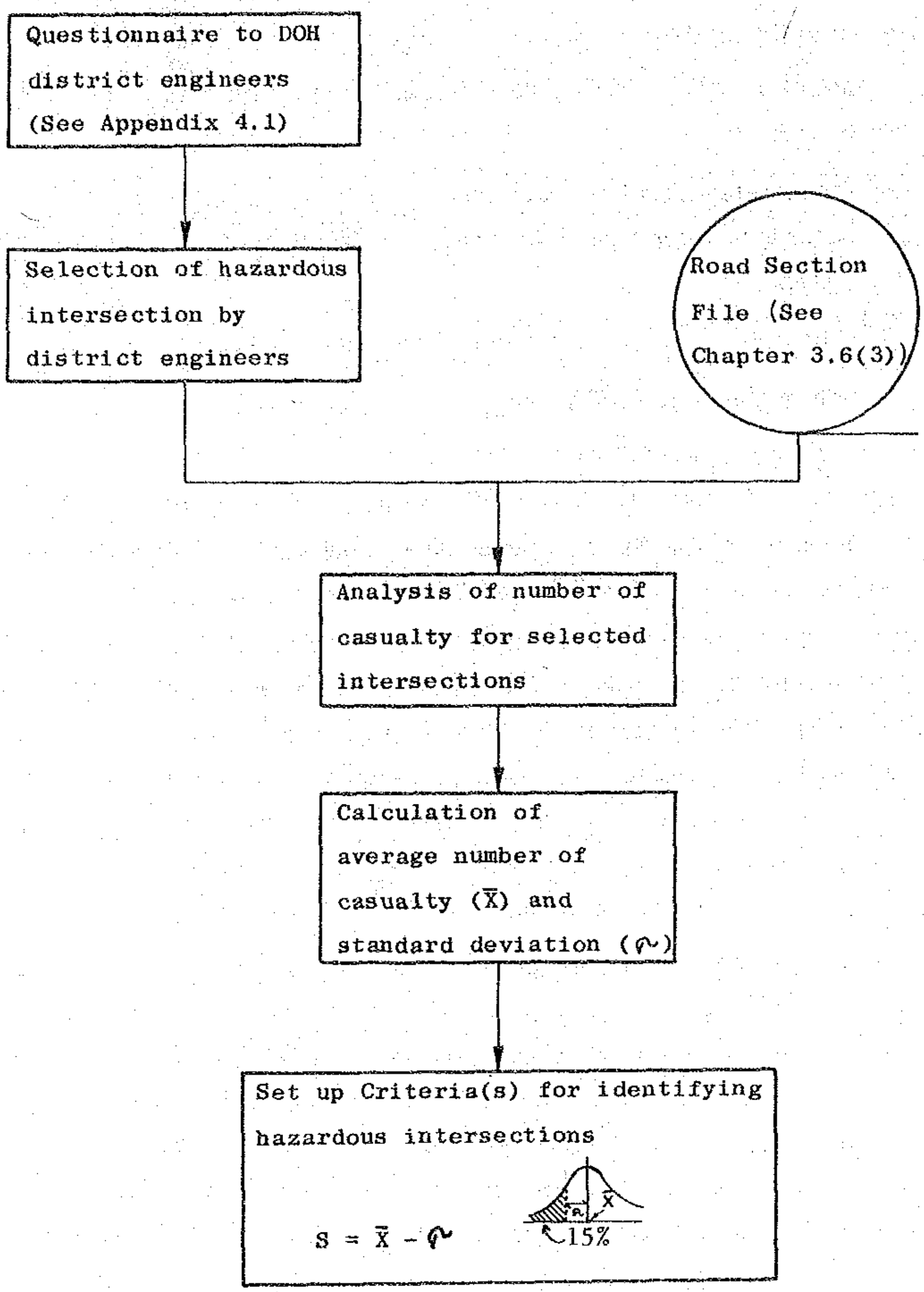

Figure 4.8 Process of Establishing Criteria for Intersection

(2) Identification Criterion for Intersections

The average number of casualties at the intersections identified as hazardous by the district engineers increases slightly as average daily traffic volume increases as aforementioned. This is the well accepted trend and indicates that the district engineer's judgements are reasonable. Since the difference between the highest and lowest casualties' number among the intersections classified by traffic volume ranks is about 0.9 and not significant for practices, in this study, the identification criterion has been decided at 4 casualties per year, regardless of traffic volume. The number of hazardous intersections and casualties on DOH road in HPD area is shown in Table 4.3.

Table 4.3 Number of Hazardous Intersections and Casualties

Area	Total Length (Km)	Number of Hazardous Intersections	Number of Casualties
HPD area	15,700	78	341[1)]

1) This figure consists of 58 killed and 283 injured. 341 persons is 76% of total number of casualties on DOH roads in HPD area.

Chapter 5

TECHNICAL GUIDELINES ON TRAFFIC SAFETY DEVICES

Chapter 5 TECHNICAL GUIDELINES ON TRAFFIC SAFETY DEVICES

5.1 General

5.1.1 Traffic Safety Improvement

Road traffic accidents can be divided into two categories according to their causes; i.e., accidents due to conflicts among road users like vehicle and pedestrian or vehicle and vehicle, and accidents caused by deficient road structure or geometry. Then, the traffic safety can be promoted through the improvements of traffic environment based on the following principles:

- to separate the conflicting traffics by time and/or by space,
- to simplify the traffic streams, and
- to create the proper driving circumstances.

Since traffic accidents, in nature, cannot be avoided completely, it is also an important principle in the traffic safety improvement to mitigate the accident severity.

To accomplish traffic safety improvement based on these principles, two engineering approaches should be harmonized appropriately; one is the installation of road appurtenances for traffic control, and the other is the improvement of road itself. Table 5.1 is the list of typical measures for traffic safety improvement classified in compliance with the above-mentioned two approaches. These measures should be selected and applied with a due consideration. The method to prepare practical safety plan to specific road locations applying these measures is discussed in Chapter 6.

These measures prove to be very effective in safety improvement particularly when they are appropriately planned and accompanied by adequate educational programs and the strict enforcement of laws and regulations to the road users. On the other hand, improper installation of them are not only ineffective but sometimes even causes danger because they may induce uneasiness to road users. Therefore, it is very important to prepare the guidelines on the traffic safety improvement measures, in particular, for the road appurtenances and some road improvement (They are referred to as traffic safety devices* for practical purpose hereinafter).

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* Traffic safety devices in this study include not only the road appurtenances but the portion of road structure such as median, sidewalk or bus bay.

Table 5.1 Traffic Safety Improvement Measures

Principle of Safety Improvement	Traffic Safety Improvement Measures	
	Installation of Road Appurtenances	Improvement of Road
To separate the conflicting traffics by time and/or by space	Traffic Signal Stop Control (Sign, Marking) Guardfence Longitudinal Pavement Markings Raised Pavement Markers Crosswalk	Construction of By-pass and Expressway Sidewalk Bicycle Path Bicycle-Pedestrian Path Pedestrian Overpass Median Frontage Road Refuge Island
To simplify the traffic stream	Channelization of Intersection Pavement Markings Guide Signs Access Control One-Way System Parking Restriction	Bus Bay Grade Separation Traffic Island
To create proper driving circumstances	Highway Lighting Post Delineator Curve Mirror Warning Signs Guide Signs Glare Screen Traffic Information System	Elongation of Sight Distance Improvement of Shoulders Road Geometry Improvement (Alignment, Cross-Section) Anti-Skid Treatment Pavement Leveling
To mitigate the accident severity	Guardfence Speed Control Overtaking Control Breakaway Treatment of Roadside Appurtenance	Pavement Grooving Side Slope Flattening

Note ; Measures listed in the table are not all-inclusive.
Classification was made according to the principal facet of each measure.

Moreover, some of the traffic safety devices such as traffic sign, pavement marking, traffic signal, are intended to convey particular "message" to the drivers and pedestrians. This also inevitably leads to the necessity of establishing technical guidelines which unify the application and result in the maximum effectiveness of these devices.

5.1.2 Preparation of Technical Guidelines

The technical guidelines for the uniform and effective application of traffic safety devices should cover (1) warranting condition of installation, (2) installation planning, (3) standard shape and dimension of safety devices, and (4) operation and maintenance method. The succeeding sections deal with the development of the technical guidelines, mainly on the warranting conditions and installation planning for major traffic safety devices.

DOH has already developed the guidelines for traffic signs and pavement markings, and the Team has made reviews on them. The result of the review is shown at the last part of this chapter. In this study, therefore, technical guidelines on the following essential safety devices have been prepared.

- Traffic signal,
- Guardfence,
- Lighting,
- Delineator,
- Sidewalk and bicycle path, and
- Crossing facility for pedestrians.

In addition, useful information as to the skid resistance and evenness of road surface is presented in this report.

Development of guidelines is a delicate task because it should consider a number of factors such as the accumulation of engineering and technical experiences, change of traffic features, road users' behaviors and available budget. Therefore, the guidelines need to be worked out based on the accumulated latest knowledge gained through studies, researches and practices.

In this study, preparation of technical guidelines has been made through following procedures:

a) Collect the informative documents related to each traffic safety device,

b) Conduct field reconnaissance on the state of present installation,

c) Examine collected information from engineering standpoint, and

d) Propose technical guideline for each traffic safety device.

The guidelines prepared in the above-mentioned procedures are presented in succeeding sections. Since there are not many studies and researches conducted on traffic safety devices in Thailand, the technical guidelines presented in this report have been prepared mainly based on the relevant information, data and literatures in other countries, as well as the information acquired through the experimental works. It should, therefore, be noted that the technical guidelines in the following sections are not conclusive but tentative. These technical guidelines are, by nature, subject to revisions, and such revisions should be made based upon the accumulated knowledge gained through practices in the field, and the changes in safety planning environment.

5.2 Traffic Signal

5.2.1 Function of Traffic Signal

(1) Purpose of Traffic Signal Installation

Traffic signals assign alternately the right-of-way to the competing traffic movements at the intersection by light of red, yellow and green, and thus they ensure an orderly flow of traffic.

Traffic signals have following advantages when they are well-designed, effectively placed and properly operated:

- They can maintain orderly traffic flows and increase the traffic capacity of the intersection.
- They can reduce the total delay of vehicles at heavy traffic intersection, and relieve the vehicle on minor road and pedestrian from suffering extraordinary delay to cross the main road.
- They can reduce the frequency of certain types of accidents.

Following three paragraphs present more detailed explanations as to the aforesaid features of traffic signals.

(2) Traffic Capacity of Signalized Intersection

It is obvious that the signalization at low-traffic-volume intersection reduces the traffic capacity of the intersection. But when the traffic volume at an intersection exceeds a critical volume*, a traffic signal can increase the capacity of traffic at the intersection as far as the intersection is not saturated with traffic.

The maximum number of crossing vehicles per hour during the green phase of the signal is called as "saturation flow rate". Although the saturation flow rate varies with the number of lanes and volumes of right- and left-turning vehicles, or pedestrians at the intersection, the constant value of 2,000 PCU** per hour for one lane can be applied practically for any intersection. The quotient obtained by dividing the design traffic volume at each approach by its saturation flow rate shows the ratio of the 'effective green time' to the

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* Such critical traffic volume that signal can increase the capacity of intersection shall be one of the warranting conditions of installation, as discussed in next section.

** PCU is the acronym of Passenger Car Unit. This 2000 PCU was obtained by surveys on traffic volumes at various intersections.

cycle length required for handling the design volume.

Usually, one phase covers two approaches or more and the maximum of the above ratios of these approaches, is called the 'degree of saturation of the phase'. The sum of the saturation degrees of all the phases is called the 'saturation degree of the intersection'.

The saturation degree of an intersection is the ratio of the sum of the minimum necessary green periods of all the phases to the cycle length; if this value exceeds 1.0, it means that the intersection is oversaturated in the view of traffic capacity, and that the intersection cannot handle the design volume.

In this case, more sophisticated countermeasure should be considered, such as coordinated signal control system, grade separation or one-way system.

(3) Delay at Signalized Intersection

Signal control can eliminate the delays to minor-road vehicles waiting for acceptable gaps, but it will cause vehicles on a major-road to suffer some delay while waiting for a green light. It should be noted that the substitution of a signal for stop control by signs and markings does not always reduce the total intersection delay.

Relation between traffic volume entering intersection and average delay is shown in Figure 5.1*, in which it is evident that at reasonably low levels of

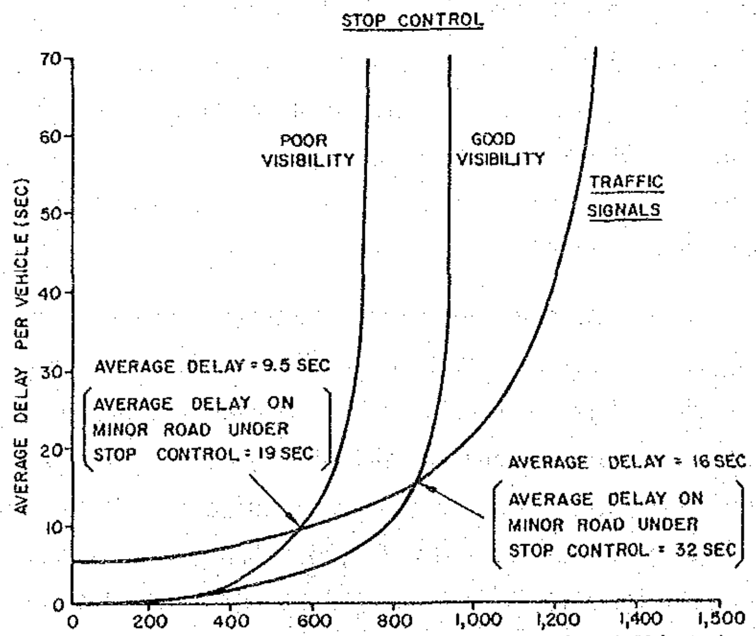


Figure 5.1 Relationship between Traffic Volume Entering Intersection and Delay of Vehicle

* F.V. Webster and J. G. Wardrop, "Capacity of Urban Intersections," Sixth International Study Week Traffic Engineering, Saltzburg, 1962.

traffic volume, the stop control is preferable to the signalized control when the total delay at the intersection is a primary concern.

(4) Effect of Traffic Signals for Safety Improvement

Installation of traffic signals usually reduces accidents substantially, though rear-end collisions tend to increase slightly in many cases. However, the installation of two or more signal faces to each approach can prevent the increase of rear-end collisions.

Pedestrian signal faces are useful to prevent pedestrian accidents. Separated vehicular turning phase together with provision of turning lanes is effective in avoiding right-turn vehicle accidents.

According to the experimental works conducted in this study at the intersections on Route 336 of DOH road where traffic signals have been installed, the number of traffic accidents is reduced by about 50%. This reduction rate agrees generally with the experiences in other countries.

5.2.2 Warranting Conditions

In this study, warrants on installation of traffic signals are proposed for the following three types of signal systems: i.e., (1) pretimed signal, (2) semi-traffic-actuated signal, and (3) pedestrian signal. A criterion of installing signals for accident prevention is also proposed.

(1) Warrant of Pretimed Signals

A pretimed signal is operated by a fixed-timing program which has been determined by taking into account the traffic volumes of the approaches, and traffic composition as well as the geometric characteristics of the intersection.

On condition that traffic volume remains within a certain level at intersections, it is possible to handle the traffic smoothly by traffic regulation such as stop control. When traffic volume exceeds this level, it becomes difficult to guarantee a smooth flow of traffic and the resulting traffic congestion may induce traffic accidents.

According to the simulation carried out for a non-signalized intersection where the major road has 4 lanes and minor road has 2 lanes, the maximum traffic capacity at the intersections can be calculated by the following formula.

$$M = \frac{Ne^{-NL}}{1 - e^{-NL}} \tag{5.1}$$

Where,

M: Vehicles per hour on higher-volume minor-road approach (one direction only, vehicles/hour)

N: Vehicles per hour on major road (total of both approaches, vehicles/hour)

e: Base of the natural logirithm

L: Vehicular gap to enter the intersection from minor road (sec.)

The value of L in the formula is determined by running speed and crossing movement, both of which depend on the types of roads and characteristics of the area. Supposing that 85% running speed is about 50-60 km/hr, the value of L is estimated at about 6 seconds.

Value of M is the maximum traffic capacity in the case for stop control at the intersection where major road has 4 lanes and minor road has 2 lanes. At the other types of intersections, the value of M is obtained by considering the fact that the wider the road is, the smoother the flow of vehicles becomes.

Figure 5.2 shows warranting condition for pretimed signal proposed in this study.

(2) Warrant of Semi-Traffic-Actuated Signals

A semi-traffic-actuated signal utilizes vehicle detectors only on the minor approaches. This type of control may be applied at the intersections where vehicles on minor approaches cannot cross the major road safely without traffic signals.

In this study, warranting conditions for semi-traffic-actuated signal have been worked out based on the experiences in Japan, and the results are shown in Table 5.2.

(3) Warrant of Pedestrian Signals

As for a traffic signal of which primary objective is to control crossing pedestrian, it is necessary to consider the volume of pedestrian traffic, the width and the vehicular traffic volume of the approaches.

In this study, the subject is focussed on the road whose carriageway is from 9 to 12 m wide with pedestrian crosswalks. In such road, a minimum traffic volume that makes pedestrian crossing difficult is said to be from 650 to 700 vehicles/hr.

Table 5.3 shows warranting conditions for pedestrian signals which have been determined by taking the empirical examples of other countries into account.

(4) Warrant for Traffic Accident Prevention

When a traffic signal is installed at an intersection, rear-end collisions may increase but the accidents such as head-on collisions and pedestrian accidents etc. may be reduced. There are some evidences to suggest that a substantial number of accidents can be prevented by traffic signals. The traffic signals are essential when other less restrictive measures fail to reduce the accidents.

In this study, to ensure traffic safety at the intersections with the history of traffic accidents, warranting conditions based on accident data have been proposed in reference to the examples in other countries. (Table 5.4)

(5) Summary of Warrants

1) Pretimed Signal

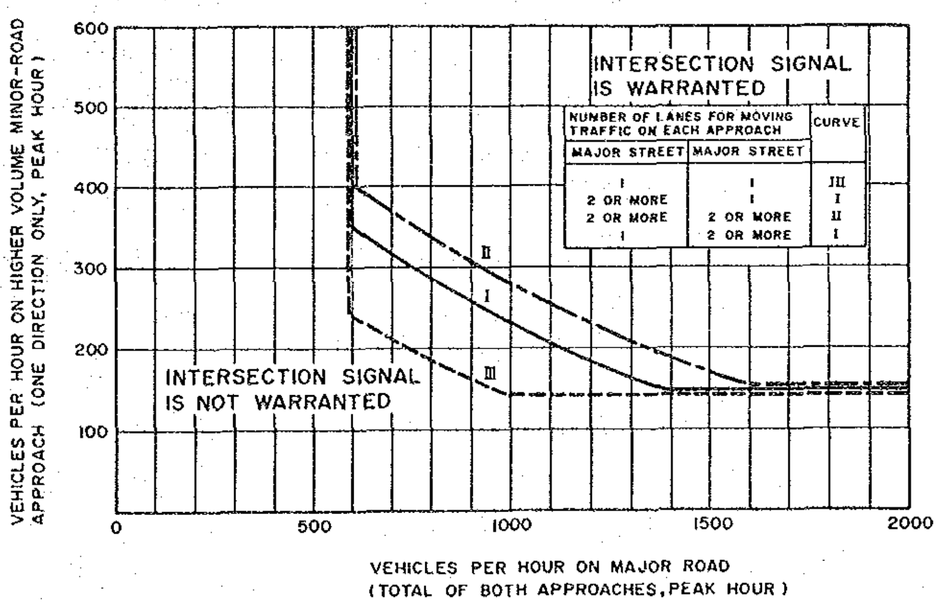


Figure 5.2 Warrant for Traffic Control by Pretimed Signal

2) Semi-Traffic-Actuated Signal

Table 5.2 Warrant for Traffic Control by Semi-Traffic-Actuated Signal

	Vehicle per hour on major road (total of both approaches)	Vehicle per hour on higher-volume minor road approach (one direction only)
Peak hour traffic volume	900 or more	100 or more

3) Pedestrian Signal

Table 5.3 Warrant for Traffic Control by Pedestrian Signal

	Vehicle per hour on the street (total of both directions)	Pedestrian per hour on the crosswalk crossing the road
Peak hour traffic volume	650 or more	200 or more

4). Accident Prevention

Table 5.4 Warrant for Traffic Accident Prevention by Traffic Signal

	Accidents Preventable by Traffic Signals
Number of Accidents within a 12-month Period	5 or more

5.2.3 Selection of Signal Control Systems

There are two types of traffic control system, they are (1) independent control and (2) coordinated control. Following paragraphs are devoted only to the independent control, as the coordinated control is effective and applicable only to extensively developed road networks in urban area.

The independent control by traffic signals, in principle, may be applied to intersections where the section distance between neighbouring intersections is generally long for the platoon of the traffic to disperse over the section.

Independent control is further classified into the following types.

(Pretimed Control)
- single-program control
- multi-program control

(Traffic-Actuated Control)
- semi-traffic-actuated control
- full-traffic-actuated control

The pretimed control operates with a time table in which the cycle length and intervals are predetermined and fixed. Single-program control, the most simple control system, applies constant parameters around the clock. The multi-program control, on the other hand, is operated by variable parameters of cycle length and intervals. These parameters change throughout the time of the day, and the switchover of parameters are carried out automatically by the built-in clock.

Traffic-actuated control is the type in which the length of the green period varies according to the fluctuation of traffic volumes on the approaches. The change in traffic volume is detected by using traffic detectors. In this system, the length of green period is prolonged by detecting vehicles on the approaches.

The one is which the time intervals of all signals are changed in accordance with the traffic flows on all approaches, is called "full-traffic-actuated control", and the other in which only a traffic fluctuation on a minor approach is reflected upon the allocation of time splits of the signal is called "semi-traffic-actuated control".

The following is the summary of selection method for independent control types.

- Where crossing roads are arterials and their traffic volumes are relatively high, <u>multi-program control</u> is proper.
- Where an arterial road with high traffic volume and a minor road carrying low traffic volume cross each other, <u>semi-traffic-actuated control</u> is proper. In this case, it is necessary to install a push button signal for pedestrians to cross the arterial road. If pedestrian crossings are frequent on the arterial road (more than 1 person per 1 minute), the multi-program control is generally desirable.

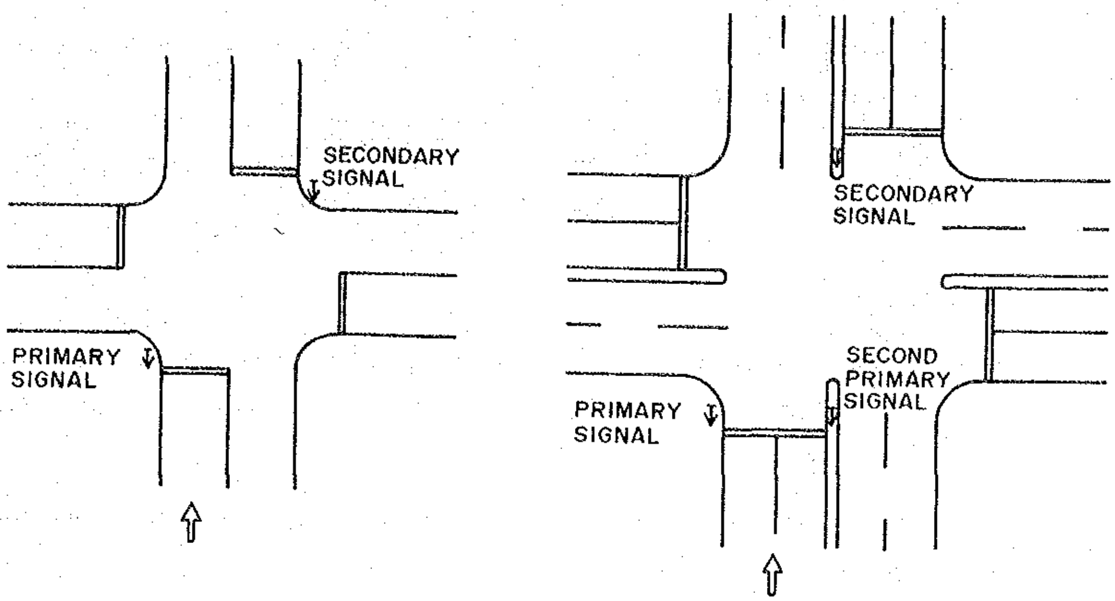
- Where two roads of which traffic volumes are relatively low intersect, single-program control is proper. However, if there are few crossing pedestrians (less than 1 person per 1 minute), full-traffic-actuated control may be desirable. When full traffic-actuated control is adopted, it is necessary to install push button signal for pedestrians.

5.2.4 Placement of Signals

Current placing of traffic signals are prescribed in "General Specification for Road Traffic Signals and Flashing Traffic Signals, DOH, 1980" (hereafter referred to as the "Specification of Signals").

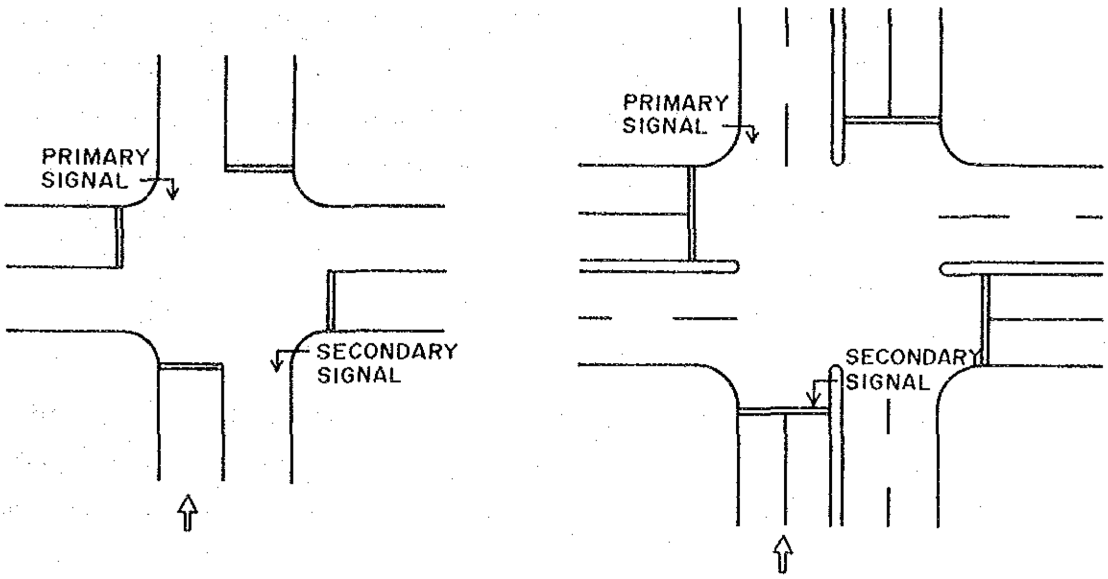
According to this Specification of Signals, the placement of signal faces is set out as indicated in Figure 5.3. The placement is planned on the premise that the type of signal is pedestal or overhang type. This signal placing method is characterized by nearside positioning of primary signal (hereafter called Method A). On the other hand, the placing method indicated in Figure 5.4 is of farside positioning of primary signal which is overhang type. (hereafter called Method B) Method B has several advantages, i.e., smaller number of signal faces needed, high visibility from approaching vehicles and less expensive installation cost. Method A is widely prevailing in Thailand, but its inferior visibility from high speed approaching vehicles encourages the adoption of overhang type signals, and accordingly, superiority of Method B can be stressed. Therefore, the introduction of Method B is desirable at intersections where approaching speeds are high, and require visibility from a distance.

Following paragraphs explain the signal placing method (Method B) for practical application.



(a) Small Intersection (b) Large Intersection

Figure 5.3 Standard Placement of Signal Faces (Method A)



(a) Small Intersection (b) Large Intersection

Figure 5.4 Standard Placement of Signal Faces (Method B)

(1) Signals for Vehicular Traffic

1) Primary Signal

- To be installed at far-left location of the intersection, facing exactly opposite to the running direction.
- When an approach is split and channelized by traffic islands, each channelized lane is to be considered as an approach

2) Secondary Signal

- To be installed at near-right location of the intersection. Generally it is attached to backside of the primary signal for the opposite directions.
- To be installed at median strips, when the approach has more than 3 lanes and median strip is 1 m wide or more.
- Secondary signal for minor road is omissible when the width of minor road is less than 5.5 m, heavy vehicles are few and visibility is well secured.

3) Advance Notice Signal

- When necessary due to insufficient sight distance at locations such as curved section, advance notice signals are required at about 50 m this side of a spot where primary signal or secondary signal can be seen. It is desirable that advance notice signals are of flashing yellow color beacon, and attached with a sign to indicate existance of traffic signals ahead.

(2) Pedestrian Signal

The pedestrian signal shall be positioned so as to provide maximum visibility at the beginning of the crossing, and to avoid to be an obstacle in the pedestrian flow. Placement at far-side right or left end of the crossing area may meet this requirement.

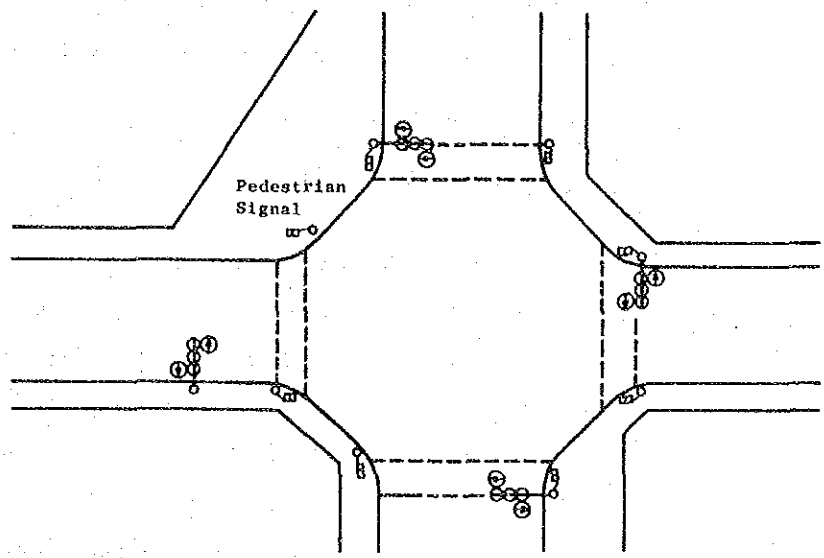
(3) Enhancement of Visibility

Visors should be used on all signal faces to aid in directing the signal indication specifically to approaching traffic, as well as to reduce the impaired visibility resulting from external light entering the optical units.

Also, when the visibility of signal is obstructed by the sunlight at dawn or sunset, following betterments should be taken into consideration; i.e., (i) use of back-plates, (ii) relocation of primary signal, (iii) installation of secondary signal.

Based upon the aforementioned instructions, typical placement plans of traffic signals at intersections are shown in Figure 5.5.

(a) TYPICAL INTERSECTION



(b) DEFORMED INTERSECTION

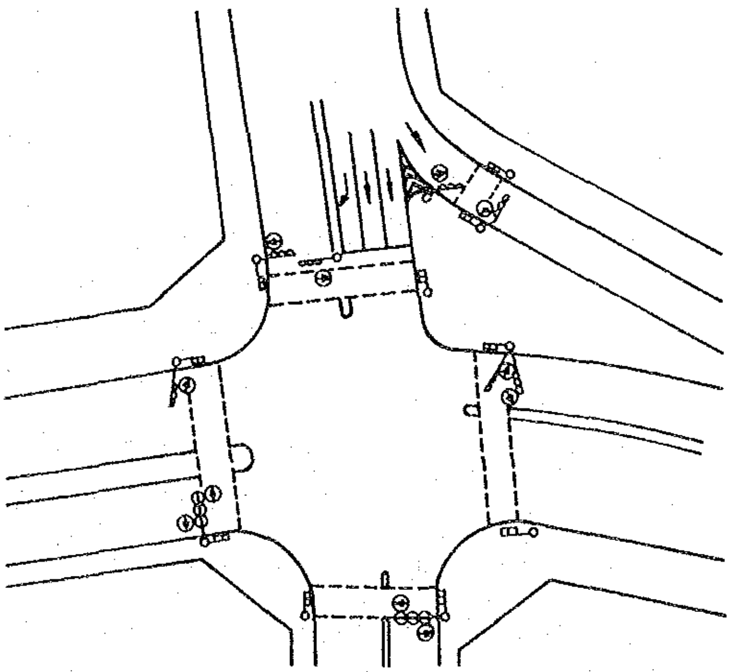


Figure 5.5 Examples of Signal Arrangement

5.3 Guardfence

5.3.1 Function and Classification of Guardfences

(1) Function

The main function of guardfences is to restrain errant and uncontrolled vehicles from running into the hazards and getting severe damages. In addition, there are following other functions:

- to minimize damage to vehicle as well as its occupants,
- to redirect errant vehicle without endangering other traffic,
- to ensure pedestrian safety, and
- to restrain pedestrians from crossing roadway recklessly.

There are a number of papers reporting that guardfences which are designed and placed in appropriate manners bring delightful results to road safety. Guardfences, on the contrary to the multi-purpose functions as mentioned above, can also be serious roadside hazards to the drivers when improperly installed. Hence, the study leads to an understanding that guardfences shall be a great help to road safety, only when installed by "sound engineering judgement". This also requires the need of a careful and comprehensive guideline for guardfences as regard to warranting conditions, design and material.

(2) Classification by Type

Since there are various sorts of guardfences, classification and definition are attempted in this study for better understanding of guardfences. Among the many kinds of guardfences, following four types of guardfence are in general use, i.e., guardrail, guardpipe, box-beam guardfence, and guard-cable. The major features each type of guardfence are briefly described below.

1) Guardrail, as defined in this report, is a fence of which rail is made of corrugated steel beam in a shape of "W", being supported by a row of steel or wooden posts. Guardrail absorbs collision energy with plastic deformation of "W" beam.

2) Guard-pipe, which is used mainly aiming at pedestrian safety, is composed of plural number of steel pipes and supporting posts. Collision energy is absorbed in plastic deformation of pipes.

3) Box-beam guardfence is composed of fabricated box-section steel beams and supporting posts. This type of guardfence possesses an advantage to be installed on median, because of its symmetrical cross section. Box-beam guardfences cope with collision impact by bending resistance.

4) Guard-cable consists of strained steel cables and supporting posts. It resists collision impact by elastic tension of steel cables.

Guardfences are further divided into three categories by purpose of installation, i.e., roadside guardfence, median guardfence and sidewalk guardfence.

Roadside guardfence is installed mainly to protect the uncontrolled vehicle from lateral dropoff where sidewalk is not existing. Median guardfence installation aims at decreasing head-on collision between contra flow vehicles, while sidewalk guardfence is to assure pedestrian safety.

(3) Present State of Installation

According to the survey conducted by the Team, about 55% of guardfences are erected along curves, 25% are on embankment and 20% are at bridge approaches. Median guardfence and sidewalk guardfence to separate conflicting traffics are rarely installed on DOH roads.

5.3.2 Warranting Conditions

(1) Roadside Guardfence

Roadside guardfences are needed where errant or uncontrolled vehicles are apt to run into roadside hazards resulting in serious damage if guardfence were not installed. Road sections that justify guardfence installation are as follows:

- Sections where roadside areas could be serious hazards,
- Low-standard design sections,
- Proximity to bridges, culverts, etc., and
- Sections which have the experiences of a number of accidents.

1) Sections where roadside areas could be hazards

Typical road section in this category is that with high road surface level to ground such as embankment road or cut road on a hillside. Degree of hazardousness at such road section varies according to its steepness of side slope and height of road; i.e., the gentler the side slope is, the safer situation it gives. The oblique line in Figure 5.6 is a threshold for warrant to install roadside guardfence. The line is regarded as "equi-damageable" for lateral dropoff of vehicle, and it is determined by reference to the technical information in other countries.

Even when road height and side slope combination does not meet the above criterion, the existence ot hard obstacles in the very proximity to the carriageway such as big rocks, big trees, sign supports, lighting poles, houses, etc., can generally justify the guardfence erection.

Besides, sections along the waters such as sea, lake, pond, river, ditch, etc., are generally regarded as the dangerous sections which require the provision of guardfences, when they have a certain depth. One and a half meter of depth is considered as a limit whether passengers are relieved or not from the vehicle sunk in water.

2) Low-standard design section

Relations between geometric parameters of roads and traffic accidents have been widely examined and reported on many occasions, indicating that smaller radii of curves and steep downgrades make the roads more hazardous.

Regarding curve radius, the curves with radii of less than 200 m are considered as dangerous as seen in the figures in Appendix 5.1, while moderate curve sections produce safer driving conditions. On the other hand, the value of "safe" curve radius can be calculated, i.e., the formula

$$R = \frac{V^2}{127\,(i+f)}$$

gives a limit value of a vehicle's lateral slip, where R = limit curve radius; V = driving speed; i = superelevation; and f = lateral force coefficient. When 80 km/hr for "V", 0.06 for "i", and 0.2 for "f" are substituted in the formula, the resultant curve radius "R" comes out to be 194 m. This indicates the curve of which radius is less than 200 m is rather dangerous to a vehicle running at 80 km/h or more in a bad weather such as heavy rainfall.

In respect to the relation between roadway gradient and traffic accidents. The down slopes having 4% or more gradient are highly dangerous as seen in the figures in Appendix 5.2. This is because drivers are apt to speed up and lose car control at such down slopes.

The sections where the effective width of carriageway or number of lanes is reduced abruptly (rate of transition is larger than 1:20), are also dangerous, especially at nighttime and need for guardfence.

3) Proximity to bridges, culverts, etc.

Approaches to bridges, viaducts, or culverts where carriageway width changes sharply, require guardfences. Collisions with those structures are expected to induce severe damage to the passengers as well as structures themselves.

Sections where bridge pier, abutment, retaining wall or other rigid structure exists in the very vicinity (within about 2 m zone) to the carriageway are regarded hazardous and require guardfences.

4) Sections which have the experience of a number or accidents

The determination whether guardfence should be installed or not requires, in most cases, a close examination by highway engineer on a case-by-case basis. In other words, it depends on "sound engineering judgement" of concerned engineers.

However, it is supposed that such sections which have the experiences of a considerable number of run-off-road accidents should be provided with roadside guardfences.

(2) Median Guardfence

Effectiveness of median guardfence in traffic safety may be a somewhat controversial subject. There are some papers reporting that median guardfence increases the number of accidents. These prove that guardfence itself can be a hazard to vehicles. Nevertheless, most of reports stress that run-over-the-median accidents, which are mostly fatal, would notably decrease after construction of median guardfence. There is a report that run-over-the-median accidents with median guardfence is reduced to 1/3 in Japan.

It is desirable that the road sections with anticipated frequent head-on collisions,e.g, sections of high vehicle speed, considerable amount of vehicular traffic, relatively narrow median, and poor geometrical alignments, are provided with guardfence on the median.

An example of a relation between curve radii and traffic accidents of expressways is shown in Appendix 5.2. It indicates that when vehicle speed is relatively high, curve radius of less than 750 m produces increased danger to the drivers. An example showing ratios of head-on collision accidents to all accidents at gradients is presented in Appendix 5.2. This example indicates that the gradient of more than 3% induces higher ratio of head-on collision. Thus median guardfences are advisable at the sections mentioned above.

(3) Sidewalk Guardfence

The major objectives of sidewalk guardfences are as follows:

- to safeguard pedestrians from uncontrolled vehicles,
- to prevent pedestrian or cyclist from dropping off the sidewalk or bicycle path,
- to prevent vehicles from running off the road,
- to discourage pedestrians to cross carriageways, and
- to separate pedestrians from vehicular traffic.

At the sharp curvature of road, it is possible for errant vehicle to run off the road into the sidewalks bringing calamity to pedestrians and passengers. Such road sections, where the drivers are inclined to misoperate their vehicles because of road geometry, need for the provision of guardfences.

For the roads, it is desirable to install guardfences on sidewalks at the sections where considerably high speeding vehicles endanger pedestrians or cyclists.

The guardfences on sidewalks, where pedestrians jaywalk carriageways to jeopardize traffic and endanger themselves, are very effective.

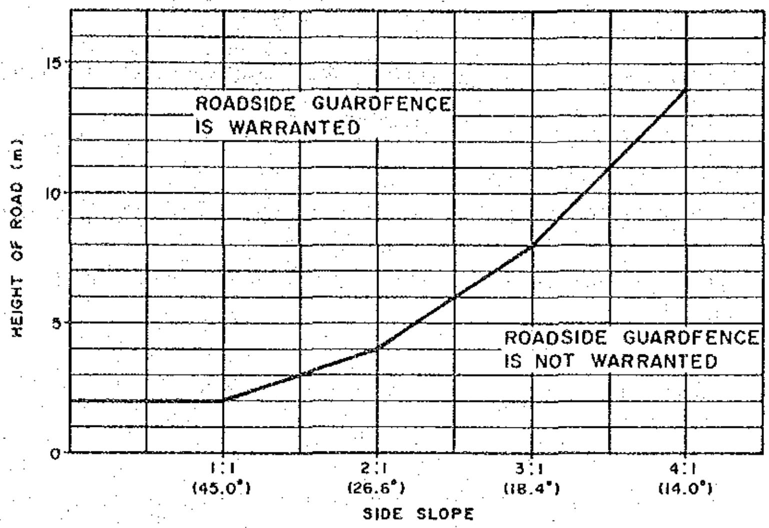
(4) Summary of Warrants

The following summarizes the warrants for roadside guardfence, median guardfence, and sidewalk guardfence.

1) Roadside guardfence

Sections having serious roadside hazards

a. Road sections which height and side slope combinations are fallen above the line in the Figure 5.6.



NOTE : "SIDE SLOPE" MEANS LATERAL LENGTH CORRESPONDING TO VERTICAL HEIGHT WHICH IS ASSUMED 1.

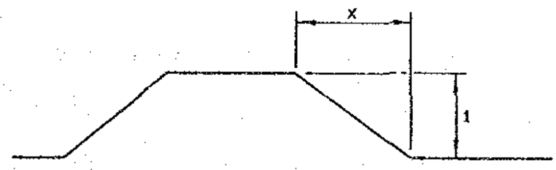


Figure 5.6 Guardfence Warrant for Road Height and Side Slope

b. Road sections which have obstacles, e.g., big rocks, big trees, houses, in the 2 m zone to the carriageway.

c. Sections along the water such as sea, lake, pond, river, ditch, etc., which depth is more than 1.5 m.

Low-standard design sections

a. Curves having radius of 200 m or less.

b. Downgrades of 4% or more.

c. Sections where the roadway width or number of lanes is reduced abruptly.

Proximities to bridges, culverts, etc.

a. Approaches to bridges, viaducts, tunnels or culverts.

b. Sections where pier, abutment, retaining wall or other rigid structure is in the 2 m zone to the carriageway.

Sections which have numbers of accidents

a. Sections where considerable number of run-off-road accidents happened or are suspected to happen.

2) Median guardfence (when median width is less than 10 meters)

a. Sections where 85 percentile speed is 80 km/hr or more and meet one of the following conditions:

- longitudinal gradient is 3% or more, or
- curve radius is 750 m or less.

b. Sections where median guardfence installation is necessitated because of high running speed.

3) Sidewalk guardfence

Guardfence to restrain the errant vehicle

a. Sections where vehicles are suspected to run into pedestrians on sidewalks due to poor horizontal alignment.

b. Sections where prevailing speed is considerably high and safeguard of pedestrians or bicycles is considered to be requisite.

Guardfence to discourage pedestrian from crossing the carriageway

a. Sections where roadway crossing by pedestrian should be prohibited.

Guardfence to prevent pedestrian or cyclist from dropping off

a. Sections along the roadside hazard such as ditch, river or low-height ground.

5.3.3 Selection of Guardfence Type

In selection of guardfence, information on merit and demerit of each type of guardfences will be of a great help. Characteristics of four types of guardfences are described in Table 5.5. This table suggests that careful and sound judgement is required in guardfence selection since each type has distinctive characteristics.

Table 5.5 Characteristics of Various Guardfences

Type of Guardfence	Advantage	Disadvantage	Usage
Guardrail	- Appropriate rigidity and tenacity - Easy replacement of damaged part - Good visual guidance to drivers - Good adaptability to small-radius curve	- Easily stained	Roadside Median Sidewalk
Guard-pipe	- Good adaptability to small-radius curve - Good scenic view from passengers	- Difficulties in pipe connection	Sidewalk
Box-beam guardfence	- Good adaptability to narrow median - Good scenic view from passengers	- Difficulty to install to small radius curve	Median
Guard-cable	- Easy rehabilitation through reusing the steel cable - Better scenic view from passengers - Free placement of supporting posts - Allowable to differential settlement of posts	- Difficulty to install to small radius curve - Uneconomical to short section - Difficulty in repairment of cable terminals	Roadside Median

Table 5.6 is prepared for practical use so that engineers can easily get the information regarding which guardfence has a suitability for a certain road section. It is obvious that the final decision shall be made based on thorough field investigations and taking economical and social conditions into consideration.

Table 5.6 Applicability to Specific Road Sections

Road Section of...... \ Type of Guardfence	Guardrail	Guard-pipe	Box-beam guardfence	Guard-cable
Small-radius (R=300m) curve	◎	○		
Visual guidance needed	◎			
Good scenic view needed		○	○	◎
Narrow median	○		◎	○
Big differential settlement				◎
Corrosion resistance needed	○	○	○	○
Long tangent roadway	○	○	○	◎

Legent ; ◎ : Highly Applicable
○ : Applicable

5.4 Lighting

5.4.1 Function of Lighting and Visual Information

Nighttime brings increased hazards to road users through limited visibility. Night driving is considerably more hazardous than day driving. The main purpose of highway and street lighting is to assure safe driving at nighttime providing increased visibility so that drivers can perceive the following important information as clear as in the daytime.

- Positional information: Required for steering and speed control
- Situational information: Required for changes in speed, direction and lateral positions.
- Navigational information: Required for selecting a route to a destination.

Table 5.7 indicates the major elements required for the safe nighttime driving. Elements in this table should be taken into account for planning of lighting systems.

Table 5.7 Major Elements of the Nighttime Visual Improvement

Kind of Information	Elements
Positional Information	Roadway geometry, Channelization, Lane Marking, Roadside and Roadside objects, Curbs, Vehicles, Pavement edge, Delineation
Situational Information	Roadway geometry, Intersection, Channelization, Lane Markings, Roadside and Roadside objects, Curbs, Pedestrians, Vehicles, Signs, Signals, Delineation, Roadway object, Road condition.
Navigational Information	Intersection, Roadside and Roadside object, Guide Signs

In order to give sufficient visual information to the drivers at night, highway lighting should be designed properly in terms of brightness, uniformity of light, glare and so forth.

However, it would not be appropriate to furnish highway lightings to the whole road network of DOH, because installation and operation of lightings are costly. Therefore, an effective lighting system should be planned prior to the installation of any lighting units. The word "effective" used here has two facets as noted below:

- Superiority over other alternative measures such as delineators, marking, guardrail, etc.
- Efficient lighting design comprising selection of light source, placement and height of luminaires, glare control and some other important elements.

The requirements for highway lighting installation vary with sites according to visual information elements specifically needed. For example, a certain road location may need clear road geometry among others, while another location may require to light up pedestrians. Some of these locations may be substituted by other safety devices with lower costs than the highway lighting. Table 5.8 presents possible alternative safety devices which may substitute lighting and should be discussed in advance of the determination of lighting installation. Installation should be limited to the locations where other safety devices prove to be ineffective.

Table 5.8 Alternative Countermeasures to Highway Lighting

Element	Alternative Countermeasure
Road geometry	Road delineators Reflective raised pavement markers on center line Longitudinal marking (edge line, center line)
Intersection channelization	Hazard identification beacon (Flashing signal) Intersection identification marker; to smaller intersection Stop control (Sign, Marking) Speed control Channelization by marking Reflective curb markers Reflective markers along zebra (Chevron) marking
Roadside objects	Guardrail with delineators Object marking Clearance of roadside object
Pedestrians	Guardrail with delineators Spot lighting of crosswalk
Alignment change	Guardrail with delineators Pavement markings and signs Reflective raised pavement markers

5.4.2 Warranting Conditions

As remarked in the preceding section, determination whether highway lighting should be provided or not is to be made through extensive studies. The general principles for lighting installation are that priority shall be placed (1) where a study indicates that lighting is expected to remarkably improve the nighttime safety, or (2) where there are many road users who get benefits from the lighting.

(1) Determination of Warrants

There are two types of installation for highway lighting, i.e., continuous lighting and specific lighting. When luminaires are placed successively along a certain length of roadway, usually more than 0.5 km, such an illumination method is called "continuous lighting". On the other hand, "specific lighting" is a general term for the lighting for specific sites such as intersection, bridge, toll plaza, etc.

1) Continuous Lighting

Continuous street lighting in built-up area is generally approved for creation of better environments and crime prevention. However, since the lighting of DOH roads is mainly oriented to traffic safety, continuous lighting in urbanized area should be confined to the cases where a certain traffic or geometric requirement is met.

Benefit from reduction of accidents is deemed to increase proportionally to traffic volume. A road with more than 25,000 daily traffic volume is expected to yield enough benefit from continuous lighting. But even when traffic volume is less than 25,000 per day, some road sections may require continuous lighting where there are considerably high pedestrian traffic at night and are assumed to create dangerous situations.

2) Specific Lighting

Intersections generally create complicated traffic streams that produce very hazardous spaces for road users. Crosswalk is also a dangerous spot where pedestrians and vehicles frequently meet. Therefore, intersections and crosswalks need to be clearly seen by drivers at a point with enough distance to assure proper response of drivers.

Warrants of traffic signals (including pedestrian signal) require certain amounts of vehicular traffic for installation of them. Accordingly, the lightings at the intersections and crosswalks where traffic signals are warranted and installed are expected to bring enough economic benefits.

At nighttime, visual information on road alignment and geometry are essential for safe driving. Road sections where alignment or geometry of road changes abruptly, may be considered to be illuminated. Such sections include:

- curve or bend with insufficient sight distance,
- road section having poor continuity of horizontal alignment,
- steep slope, and
- road section where number of lanes or carriageway width reduces suddenly.

Besides above, road sections where the ratio of night to day accident rate is more than 2.0, are generally regarded as seriously dangerous at night and need for lighting.

In the preceding paragraphs, typical road locations which should be lighted are discussed. However, whether a location shall be illuminated or not is, in principle, a matter of engineer's judgement. This leads to a conclusion that sections where a study indicates that lighting is expected to significantly reduce the nighttime accident shall be warranted.

(2) Summary of Warrants

1) Continuous Lighting

Continuous Lighting in urban area is warranted where:

a. ADT is 25,000 vehicles or more,

b. Adjacent area has a high illumination level, which interferes with driver's visibility,

c. Pedestrian traffic at night is considerably high, or

d. Road segment shorter than 1 km which is located between two lighted sections.

Continuous Lighting in rural area may not be warranted.