8.2.8 Street Lighting

(1) Technical Guideline

a) Summary of Warrants

1) Continuous lighting

| |
|---|
| Continuous lightings in urban area are warranted where: |
| A. ADT is 25,000 vehicles or more. |
| B. Adjacent areas have high illumination levels, which interferes with driver's visibility. |
| C. Pedestrian volume at night is considerably heavy. |
| D. Road sections shorter than 1 km which are located between two lighted sections. |
| Continuous Lighting in rural area may not be warranted. |

2) Specific lighting

| |
|---|
| Specific lightings are warranted in principle at: |
| A. Intersections where traffic signals are warranted and installed. |
| B. Crosswalks where pedestrian signals are warranted and installed. |
| C. Long bridges. |
| D. Sections where the ratio of night to day accident rate is more than 2.0. |
| Specific lightings may be installed at the following locations, if it is necessary. |
| E. Unsignalized intersections. |
| F. Unsignalized crosswalks. |
| G. Road sections where the cross section abruptly changes. |
| H. Sharp bend or steep gradient. |
| I. Railway crossings. |
| J. Toll plaza and its approaches. |

K. Bus stops.

L. Access roads to a public facility such as a station plaza.

M. Other road sections where the installation of a specific lightings are desirable.

b) Summary of Design Factor for Street Lighting

1) Average road surface luminance

**Table 8.11 Recommended Average Road Surface Luminance**

Unit : $cd/m^2$

| Roadside Condition / Road Class | A | B | C |
|---|---|---|---|
| Expressway | 1.0 | 1.0 | 0.7 |
| Major Trunk Roads | 1.0<br>(0.7) | 0.7<br>(0.5) | 0.5<br>( - ) |
| Major Roads<br>Minor Roads | 0.7<br>(0.5) | 0.5<br>( - ) | 0.5<br>( - ) |

Note : Values in parentheses are applied to roads where median is furnished with glare screen.

2) Light Distribution Type

**Table 8.12 Selection of Light Distribution Type**

| Roadside Condition / Road Class | A | B | C |
|---|---|---|---|
| Major Trunk Roads | Semi-cut-off | Cut-off | Cut-off |
| Major Roads<br>Minor Roads | Semi-cut-off | Semi-cut-off | Cut-off |

## (2) Engineering Specification

### a) Lighting Apparatus

1) Performance

- The lighting apparatus should have good light distribution characteristics able to achieve high coefficient of utilization with limited glare.

- The lighting apparatus should contain the necessary electrical, mechanical, water proof and anti-corrosive efficiencies, in order to achieve a satisfactory working order over a long period.

2) Mechanism

- The mechanism of the lighting apparatus should permit easy inspection. In addition, beautification of lighting apparatus should also be considered in the same way as road apparatus.

- The joint connecting the lighting apparatus with lighting poles or other road apparatus should have adequate strength. However, the works required to attach the lighting apparatus should be simple.

3) Material

Materials used for the lighting apparatus should be of good quality, with long durability and efficiency against anti-corrosion and anti-deterioration.

### b) Lighting Pole

1) Structure

- The lighting pole should hold the lighting apparatus properly in order to fully maintain the efficiency of the lighting apparatus. Hence the shape and the structure of the lighting pole should satisfy this condition. In addition, due consideration should also be paid to the economics and the appearance in accordance with the illumination distribution.

- The lighting pole should have adequate strength against external forces to both the lighting apparatus as well as the lighting pole.

- The structure of the lighting pole should be able to accommodate the stabilizer, etc.

2) Material

The material utilized for the lighting pole should have adequate strength and be of good quality in order to hold the lighting apparatus properly.

3) Anti-corrosive treatment

Hot-dip zinc coating or anti-corrosive painting is required on the lighting pole in order to prevent corrosion and to keep the appearance.

c) Other Equipments

1) Stabilizer

The stabilizer should have high efficiency and conformity with the luminaire used. When it is necessary to control illuminance, a stabilizer with dimmer should be used.

2) Automatic switching controller

The automatic switching controller should function with high reliability over a long period with a stable condition.

3) Distribution board

The distribution board should contain the necessary functions either to switch on/off a lamp or control illuminance. The shape and the structure of the distribution board should suit the conditions of the installation site.

4) Electric cable

The electric cable used for the wiring should have sufficient thickness in consideration of the allowable electric current and the voltage drop. The electric cable should be covered by insulation or the equivalent according to the site condition.

5) Duct

The duct should have sufficient diameter and strength in order to protect the electric cable to be installed. Also, it should have anti-corrosive and installation efficiencies suitable to the site condition.

d) Installation Process of Street Lighting

The rational and the economical design of street lighting and wiring as well as installation are desirable based on the preliminary installation planning of street lighting.

e) Design of Street Lighting

The luminance source, the light distribution type and the arrangement of the luminaire should be determined in order to maintain the standard illuminance.

f) Design of Wiring

A. The most economical electricity supply method to the luminaire should be used in consideration of the supply distance, the wattage of luminaire, number of luminaires, and the arrangement of the distribution circuit.

B. The voltage drop due to the wiring should be within a range able to maintain the stable lighting of the luminous source as we as to prevent drastic reduction of the luminous flux and efficiency.

g) Installation

A. The foundation of the lighting pole should be constructed properly in order to firmly support the lighting pole at the fixed point and to prevent harmful sinking or tilting.

B. The lighting pole should be installed by the vertical angle facing to the fixed direction.

C. The lighting apparatus should be firmly attached to the fixing position and angle.

D. The wiring should be properly carried out in order to maintain electricity supply and protect the insulation.

h) Inspection

It is desirable to carry out routine inspection of the street lighting for the following items.

1) Lighting condition

- Failure to light up during night time and light operation during daylight hours.

- Measurement of illuminance.

2) Lighting apparatus

- Condition of the cover attachment and the luminaire.

- Condition of the lighting apparatus attachment with the lighting pole.

- Presence of dirt both inside and outside the lighting apparatus.

3) Lighting pole and foundation

- Tilting and bending of the lighting pole.

- Condition of the join between lighting pole and foundation.

- Condition of paint on the lighting pole.

4) Wiring and electricity distribution equipment

- Measurement of the insulation resistance.

- Condition of the distribution board.

- Condition of the stabilizer.

- Drainage condition in the manhole or the hand hole.

In addition to the routine inspection, it is desirable to carry out an inspection after a natural disaster, such as a typhoon.

i) Cleaning and Maintenance

1) Cleaning

Dirt inside and outside of the lighting apparatus results in a reduction of the surface luminance. Based on eye inspection or the measurement of the surface illuminance, it is necessary to carry out cleaning of the lighting apparatus.

2) Maintenance

If any fault is found during inspection, it is necessary to rectify it.

A. Change of luminous source

After consideration of the inspection results of lighting condition and the life span of the luminous source, it is necessary to determine the procedure for changing the luminous source. According to this procedure, the luminous source is then changed.

B. Painting

Repainting should be carried out according to the deterioration of the paint. When the painted surface is removed by damages, it is necessary to repaint as soon as possible.

C. Wiring and electricity distribution equipment

Inadequate insulation and a fault in the control function of the electricity distribution equipment directly result in non-performance of the street lighting. Hence, it is necessary to locate the cause and rectify it.

j) Record

A. When the street lighting facility is installed, it is desirable to prepare a record, containing the structure and the mechanism of the lighting apparatus, the lighting pole, the foundation, the electricity distribution equipments and the street lighting number.

B. When the cleaning and the maintenance is carried out, date, cause of fault and contents of works should be recorded.

### 8.2.9 <u>Delineator</u>

(1) Post Delineator

a) Technical Guideline

1) Summary of warrants

Post delineators may be installed along the following sections except where guard fences are installed.

A. Curve sections of which radius is 400m or less, and approaches to the curve.

B. Sections where number of lanes or width of carriage-way changes abruptly.

C. Sections where there are many accident records of run-off type at nighttime or where found as necessary by engineering study to ensure safe traffic flow.

b) Engineering Specification

1) Reflector

A. The reflector is the main part of the delineator and it reflects light from the headlight of the vehicle.

B. The shape of the reflector should be circular with diameter of between 70 and 100mm. The back of the reflector should sealed in order to prevent water and dust intrusion.

C. The color of the reflector should be white or orange.

D. The reflective capability of the reflector should be more than the value shown in Table 8.13.

E. The frame of the reflector is used to attach the reflector on to the supporting post. Also, it protects the back of the reflector from the atmosphere.

Table 8.13 Standard Reflective Capability of Reflector

(Unit : cd/lx·m²)

| Color / Incident Angle / Observation Angle | White | | | Orange | | |
|---|---|---|---|---|---|---|
| | 0° | 10° | 20° | 0° | 10° | 20° |
| 0.2° | 850 | 680 | 510 | 530 | 430 | 310 |
| 0.5° | 410 | 340 | 240 | 270 | 220 | 140 |
| 1.5° | 13 | 11 | 8 | 8 | 7 | 5 |

Note : Relation between an observation angle and an incident angle is shown in Figure 9.4 in the "Technical Guidelines and Engineering Specifications".

2) Supporting post

A. The structure of the supporting post should be able to reliably fix the reflector at prescribed position.

B. The color of the supporting post should be white or similar color.

C. When steel material is used for the supporting post, it is necessary to carry out anti-corrosive treatment.

3) Installation

During installation of the delineator, it is necessary to pay attention to traffic safety and the effects of other structures.

4) Routine inspection

Routine inspection of the delineator should be carried out in order to check for any faults of the delineator. In addition, it is also necessary to carry out inspection for the following items, if it is required.

A. Reflective condition.

B. Fixing condition of the reflector and the supporting post, damage and dirt.

C. Fixed angle of the reflector.

D. Visibility of the reflector.

5) Cleaning and maintenance

A. Cleaning

Since dirt on the reflector reduces the visual guidance effect, it is necessary to clean the surface of the reflector according to the result of an inspection.

B. Maintenance

When any damage is found through inspection, maintenance should be done as soon as possible.

(2) Raised Pavement Marker (Reflective Raised Bar)

a) Technical Guideline

1) Summary of Warrant

Series of raised pavement markers may be installed along:

A. Curve sections of which curve radius is 150m or less.

B. Sections where center line crossing by vehicles is to be prohibited.

C. Boundary of chevron marking which is drawn on the pavement near to rigid hazards, e.g., raised traffic island, pier in the carriageway, etc.

8.2.10 Guard Fence

(1) Technical Guideline

a) Summary of Warrants

1) Roadside guard fence

A. Sections having serious roadside hazards

- Sections which height and side slope combinations are fallen above the line in Figure 8.5.

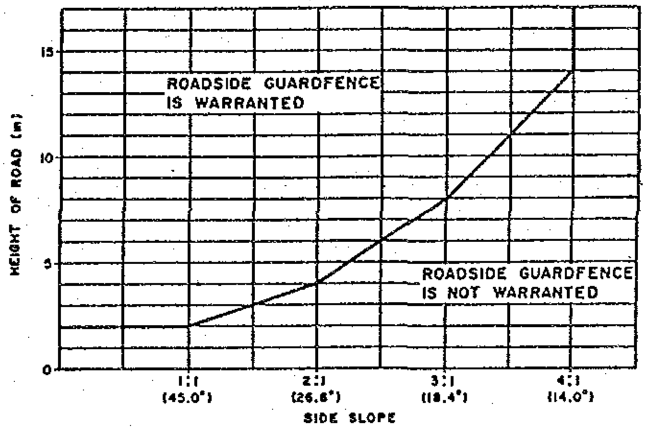



Figure 8.5 Guard Fence Warrant for Road Height and Side Slope

- Sections which have obstacles, such as big rocks, big trees, traffic signals and houses, in the 2m zone to the carriageway.

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

- Sections on bridges and flyovers.

B. Low-standard design sections

- Curves having radius of 200 m or less.

- Down slopes having 4% or more gradient.

- Sections where the carriageway width or number of lanes is reduced abruptly.

C. Proximities to bridges, culverts, etc.

- Approaches to bridges, viaducts, tunnels or culverts.

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

D. Sections which have numbers of accidents

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

2) Median guard fence (width of less than 10m)

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.

- Curve radius is 750m or less.

B. Sections where median guard fence installation is necessitated because of high running speed.

C. Sections where carriageway crossing by pedestrians should be prohibited.

D. Sections where prevention of glare by headlight (high-beam) of vehicles from the opposite direction are desirable.

3) Sidewalk guard fence

A. Guard fence to restrain the errant vehicle.

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

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

- Sections on bridges with sidewalk.

B. Guard fence to discourage pedestrians from crossing

- Sections where carriageway crossing by pedestrians should be prohibited.

C. Guard fence to prevent pedestrians or cyclists from dropping off

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

(2) Engineering Specification

a) Classification of Guard Fence

A. The guard fence is classified as shown in Table 8.14 according to the road type applying to the guard fence.

Table 8.14 Classification of Guard Fence Application

| Guard Fence Type | Guard Fence Class | Guard Fence Application According to Road Type | Applicable Design Speed (km/h) |
|---|---|---|---|
| Roadside Guard Fence | A | Expressway<br>Motorway<br>Major Trunk Highway (Important) | 60 - 120 |
| | B | Major Trunk Road<br>Major Road<br>Major Trunk Road in Urban Area | 60 |
| | C | Other Road | 20 - 50 |
| | S | Road section where run-off type of accident should be completely prevented | 20 - 120 |
| Median Guard Fence | Am | Expressway<br>Motorway<br>Major Trunk Highway (Important) | 60 - 120 |
| | Bm | Other Road | 30 - 60 |
| Sidewalk Guard Fence | Ap | Major Trunk Highway (Important) | 80 |
| | Bp | Major Trunk Road<br>Major Road<br>Major Trunk Road in Urban Area | 60 |
| | Cp | Other Road | 20 - 50 |
| | P | Installation on simple sidewalk<br>Prevention of random crossings<br>Prevention of falling onto roadside by by pedestrians and bicycles | 20 - 80 |

B. At road sections where the composition of heavy vehicles is high, the roadside is particularly hazardous, velocity of vehicles is very high and all run-off type of accidents should be prevented, it is desirable to use the higher rank class of guard fence.

C. Each class of guard fence should be designed according to the design condition as shown in Table 8.15.

D. At a road section where the design speed is set because of special considerations, the same class of guard fence should be applied on both sides of this section.

Table 8.15 Design Condition of Each Class of Guard Fence

| Guard Fence Class | Collision Speed of Vehicle (km/h) | Weight of Vehicle (t) | Collision Angle (Degrees) | Vehicle Deceleration (g) | Maximum Allowable Run-Off Distance by Vehicle: Post Planted in the Ground (m) | Maximum Allowable Run-Off Distance by Vehicle: Post Installed in Concrete Structure (m) |
|---|---|---|---|---|---|---|
| A | 60 | 1.4 and 3.5 | 15 | Not exceed 4 | Not exceed 1.1 | Not exceed 0.3 |
| B | 40 | | | | | |
| C | 35 | | | | | |
| S | 80 | | | - | | |
| Am | 60 | 1.4 and 3.5 | 15 | Not exceed 4 | Not exceed 1.5 | Not exceed 0.5 |
| Bm | 40 | | | | Not exceed 1.1 | Not exceed 0.3 |
| Ap | 60 | 1.4 and 3.5 | 15 | Not exceed 4 | Not exceed 0.75 | Not exceed 0.3 |
| Bp | 40 | | | | | |
| Cp | 35 | | | | | |
| P | - | - | - | - | - | - |

b) Color

The color of the guard fence should be as defined below.

A. In principle, the color of the guard fence should be white. However, a zinc coated guard fence may be able to be used without painting.

B. Any color can be used for the guard fence to prevent crossing by pedestrians.

c) Anti-Corrosive Treatment

1) Beam, pipe, bracket and paddle

Beams, pipes, brackets and paddles used for the guard fence should be hot-dipped zinc coated, and then painted at the factory. In this case, surface treatment, such as the phosphate treatment, is necessary to increase the adhesive efficiency of the paint.

The minimum weight of zinc coating for the material used for the guard fence should be 381 g/m². The paint used on the guard fence should be the thermosetting acryloylresin paint or equivalent and the minimum paint thickness should be 20μ.

2) Supporting post

The zinc coating and the painting of the supporting post should follow the process described above. However, after zinc coating, it is necessary to use an oil varnish paint on the lower part of the supporting post to be planted.

3) Bolts, nuts and joints

Bolts, nuts and joints used for the guard fence should be hot-dipped zinc coated.

4) Guard fence without painting

When guard fence is used without painting, the minimum weight of zinc coating should be 550 $g/m^2$, as defined in TIS 248-2531.

d) Installation Method

The guard fence should be installed in order to achieve the functions based on the road condition survey result.

A. When two or more road sections, with similar road and traffic conditions, are closely located, the same type and class of guard fence should be installed.

B. The guard fence should be installed continuously at a road section with same road and traffic conditions throughout the whole section, except in unavoidable cases.

C. When there is any small structure, such as short span bridge, within a road section constructed on earth works, the same guard fence installed on the earth works section should also be installed on the structure.

D. At road sections where it is necessary to install guard fence, it is necessary to extend the installation length of guard fence 20m beyond each end of the road section.

E. The supporting post of the guard fence should be installed vertically.

F. A guard rail should be installed at the edge of road reserve where it is possible to provide the allowable run-off distance.

G. The end of the guard fence facing oncoming vehicles should be aligned away from the edge if the road as much as possible.

H. The end of the guard fence should be installed having consideration for the geometric design of the road, such as a median opening, an intersection with an approach road, etc.

I. The median guard fence should be installed at the center of the median.

J. The maximum extent of the guard cable should be 500m.

e) Inspection

It is desirable to carry out routine inspection of the guard fence at least once every two months. In addition to the routine inspection, it is desirable to carry out an inspection after a natural disaster, such as a typhoon, together with an inspection of road structure. The necessary inspection items are as follows.

1) Guard fence

- Condition of the join between the supporting post and the horizontal component.
- Subsidence, tilting and bending of the supporting post.
- Dirt and condition of paint.
- Deformation and damage of horizontal component of the guard rail and the guard pipe.
- Damage on the join part of the beam and paddle of the box beam guard fence.
- Condition of cable slackening of guard cable.

2) Shoulder and slope

- Condition of the shoulder and slope.
- Condition of the drainage facility.

f) Maintenance

| |
|---|
| 1) Maintenance<br><br>If any damage or deformation on the guard fence is found during inspection achieve the function of the guard fence is impaired, it is necessary to rectify it as soon as possible.<br><br>2) Cleaning<br><br>It is desirable to carry out cleaning of the guard fence monthly along an unpaved road and once or twice a year along a paved road.<br><br>3) Painting<br><br>When the paint surface is removed by damage or deterioration, it is necessary to repaint as soon as possible. |

g) Record

| |
|---|
| When the guard fence is damaged, it is necessary to record the damaged extent, the road condition at the damaged location and cause of the damage. |

## 8.2.11 Pavement Treatment

### (1) Technical Guideline

| |
|---|
| The characteristics of the pavement surface will influence its trafficability. The trafficability is classified into riding quality, traffic safety and comfortability. In addition, it is also necessary to consider environmental aspects at the same time. The environmental aspect usually covers noise, air pollution and vibration. To secure trafficability and environmental conditions, the recommended target value for the characteristics of the pavement surface are as shown in Tables 8.16 and 8.17. |

Table 8.16 Recommended Target Value for Pavement Rehabilitation (Asphalt Pavement)

| Item / Road Classification | Rutting Depth (mm) | Bump(mm) | | Skid Resistance Coefficient | Longitudinal Roughness (mm) | Pot Hole Diameter (cm) |
|---|---|---|---|---|---|---|
| | | Abutment | Culvert Box | | | |
| Express Highway | 25 | 20 | 30 | 0.25-0.3** | 90 (PrI cm/km) (8m Profile meter) 3.5(σ) (3m Profile meter) | 20 |
| Highway with Heavy Traffic | 30-40 | 30 (60)* | 40 (60)* | 0.25-0.3** | 4.0-5.0(σ) (3m Profile meter) | 20 |
| Other Highways | 40 | 30 (60)* | - | - | - | 20 |

Note : * (σ) Soft ground with heavy displacement, suburb of Bangkok.
** Measuring speed on Express Highway 80 km/h, on Highway 60 km/h.

Table 8.17 Recommended Target Value for Rehabilitation (Cement Concrete Pavement)

| Item / Road Classification | Rutting Depth (mm) | Bump (mm) | Skid Resistance Coefficient | Longitudinal Roughness (mm) |
|---|---|---|---|---|
| Express Highway | 25 | 10 | 0.25-0.3** | 90 (PrI cm/km) (8m Profile meter) 3.5(σ) (3m Profile meter) |
| Highway with Heavy Traffic Vol. | 30-40 | 15 | 0.25-0.3** | 5.0(σ) (3m Profile meter) |
| Other Highways | 40-50 | - | - | - |

Note : * (σ) Soft ground with heavy displacement, suburb of Bangkok.
** Measuring speed on Express Highway 80 km/h, on Highway 60 km/h.

### 8.2.12 Other Facilities

(1) Vehicle Detector

a) Technical Guideline

A. It is desirable to install vehicle detectors for continual traffic surveys at most suitable locations for traffic data collection.

B. Vehicle detectors for traffic signal operation should be installed at appropriate locations which have been designed under the traffic signal installation plan.

## (2) Road Information System

### a) Technical Guideline

| |
|---|
| If it is required to inform the latest and accurate information to road users, such as road, weather and traffic conditions, or traffic control, installation of apparatuses for traffic information is desirable in order to maintain a safe and smooth road traffic. |

## (3) Bus Stop Facility

### a) Technical Guideline

1) Size and location of bus stop facility

| |
|---|
| The determination of the size and location of bus stop facilities should depend on the type of bus and take into due consideration the needs of smooth stopping and acceleration. |

2) Bus bay

| |
|---|
| A. A bus bay should be provided on highways with a design speed of more than 80 km/h.<br><br>B. A bus bay should be provided on other types of highways, if necessary, when the stopping of a bus on the carriageway would disturb the main traffic flow, and/or reduce the traffic capacity to be less than the design traffic capacity. |

3) Bus stop

| |
|---|
| It is desirable to indicate the location of a bus stop by pavement markings at a bus stop without provision of a bus bay. |

### (4) Grade Separation at Railway Crossing

#### a) Technical Guideline

A. Road and railway crossing should be grade separated in principle, except in the following cases.

- "Traffic Movement" (T.M.) value, which is the value obtained by multiplying the ADT on DOH road and number of passing trains at railway crossing for 24 hours, is 100,000 or less.
- The location where provision of grade separation is economically unfeasible.
- Difficulty of grade separation due to site condition.
- Temporary railway crossing.
- Near a railway station, where the efficiency of roads or railway may reduced due to provision of grade separation.

B. For the planning of a grade separation, it is necessary to consider the future plan of both road network and railway. In addition, it is also necessary to consider the road network configuration in the area.

#### b) Engineering Specification

A. It is desirable to construct a grade separation of a railway crossing at a location where the horizontal and vertical alignments are good for both road and railway.

B. For design of a grade separation, it is necessary to pay attention to the railway structural profile (clearance), the sight distance, the drainage, safety facilities, the land use adjacent to the grade separation, etc.

# CHAPTER 9 TRAFFIC OPERATION PLAN

# CHAPTER 9 TRAFFIC OPERATION PLAN

## 9.1 TRAFFIC OPERATION SYSTEM

### 9.1.1 Principle of Traffic Operation

(1) Objectives of Traffic Operation

The DOH roads are the most important arteries of the national road network catering for majority of land transportation of goods and passengers. Therefore, they should be regarded as the most fundamental and essential infrastructure of the Kingdom. The traffic flow on these roads provides the basis on which national socioeconomic activities take place. On this context, the basic idea for traffic operation on DOH roads must be focussed on how best to utilize the existing road facilities.

From the standpoint of traffic operation, utilization of the DOH roads is commonly interpreted as the optimum control of traffic on them. The control will generally be done by means of various traffic control devices, road surface improvement works, provision of traffic information message to the road users, etc. The application and implementation of these means and measures shall be realized in systematic and rational manners for achievement of the objectives.

The overall objectives of traffic operation on the DOH roads based on above idea are summarized as;

A. Ensuring safe, comfortable and smooth trip

B. Preventing unexpected delay

C. Avoiding reduced traffic handling capability, and

D. Preventing transportation pollution.

(2) Methods Used in Traffic Operation

Road traffic operation often involves controlling motor vehicles. Typical motor vehicle control includes trip regulation under abnormal weather conditions, and the establishment of detours in the event of traffic congestion. Motor vehicle control thus lets drivers take either compelled or guided action to achieve the following:

A. Ensuring traffic handling capability

B. Providing traffic information

C. Adjusting traffic demand

D. Controlling traffic flow

Traffic handling capability at bottlenecks is ensured by improvement of road and traffic facilities. Traffic information is provided by traffic information system. Traffic demand is adjusted by improvement of DOH road use. Traffic flow is controlled by rationalization of traffic operation.

Figure 9.1 shows the principle scheme of traffic operation which is based on the objectives and methods of traffic operation mentioned above.

(3) Benefits of Traffic Operation

As already stated, traffic operation requests drivers to take either compelled or guided actions. Its benefits should be enjoyed not only by individual drivers but by society in general. The following summarizes the benefits obtained by proper traffic operation on DOH roads.

a) Direct Benefits

1) Social

- Improved traffic flow and elimination of localized traffic congestion.

- Accurate prediction of traffic situation.

- Making data available for traffic regulation and road administration.

- Reduced travel time, and reduced consumption of gasoline thank to elimination of slow-speed running.

2) Private (as enjoyed by drivers)

- Reduced travel time.

- Reliable road information services.

- Reduction in traffic accidents.

- Latest information on roads, traffic flow and traffic regulations.

- Being informed of occurrence of a traffic accident, disaster, etc.

- Can reach their destination smoothly.

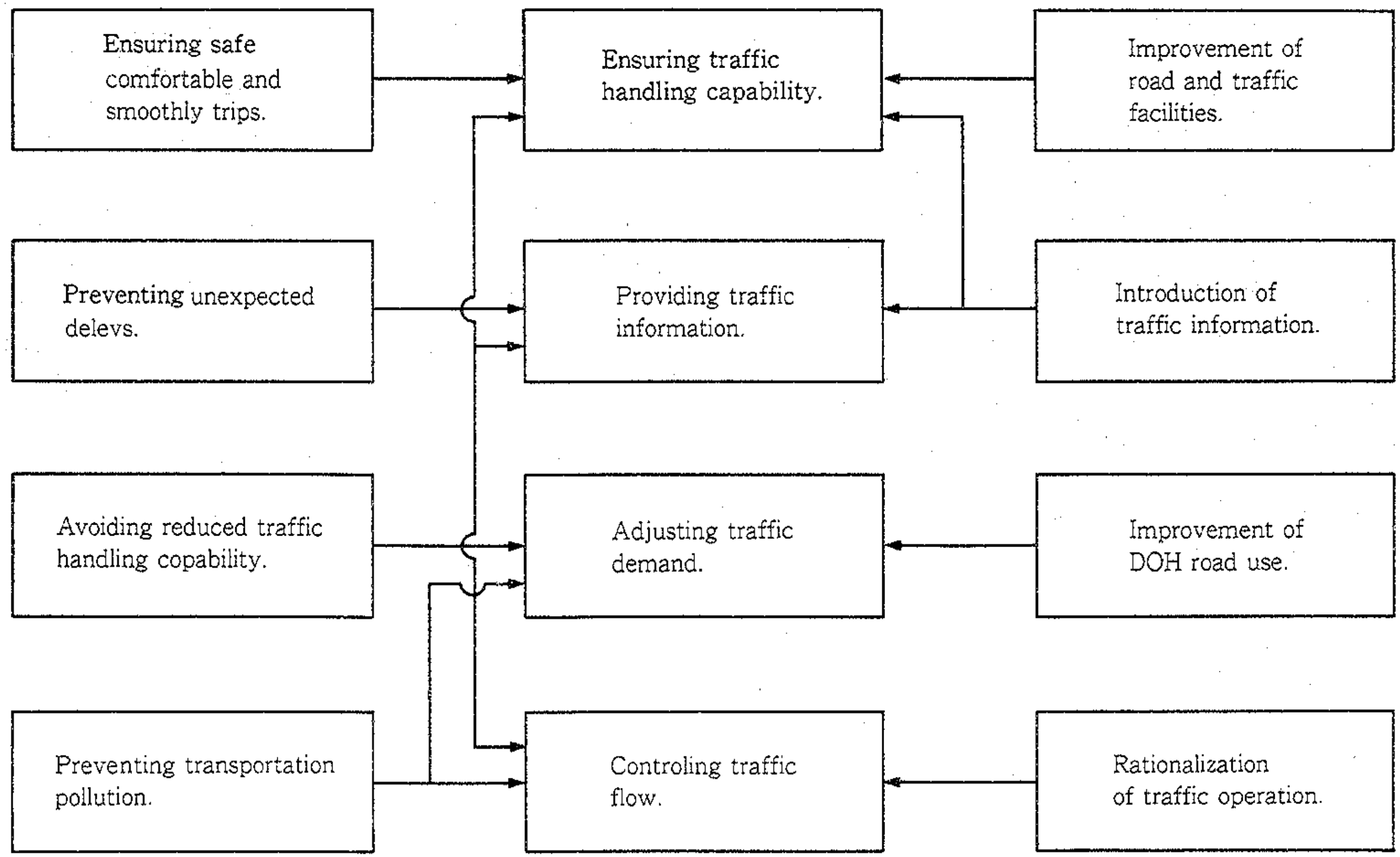



**Figure 9.1 Principle of Traffic Operation**

b) Indirect Benefits

A. Making more information available on traffic situations.

B. Helping to analyze traffic situations.

(4) Expansion of Traffic Operation System

Traffic operation is systematized and expanded in accordance with the needs by society in general, individual drivers or road administrators. In other words, traffic operation should be expanded to meet ever-changing needs of society in general, drivers and road administrators, on a recurring basis. Figure 9.2 shows the expansion of traffic operation conceptually.

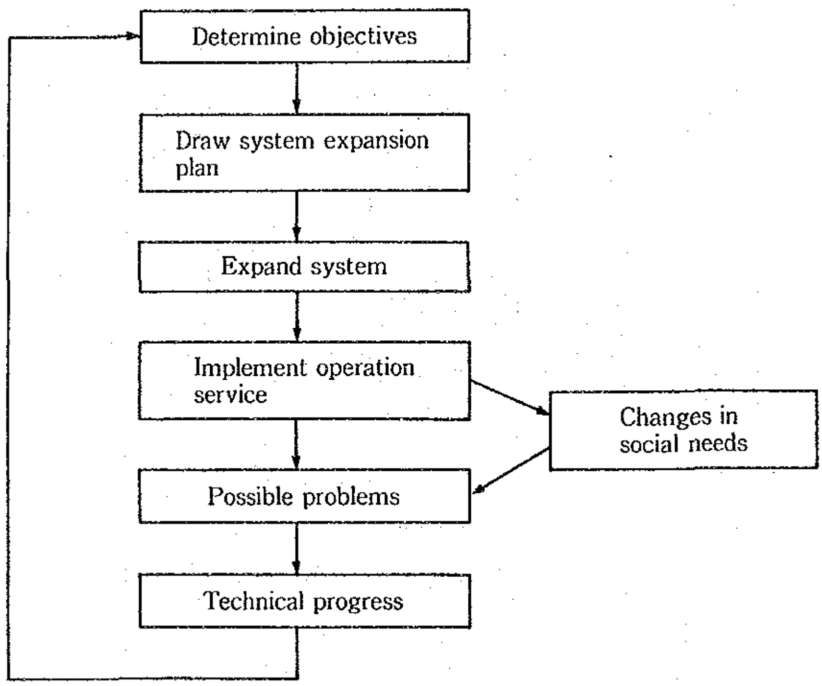



**Figure 9.2 Expansion of Traffic Operation System**

Before a traffic operation system is introduced (expanded) as motivated by society in general, drivers or road administrators, similar systems must be evaluated prior to introduction of the system by assessment from both technical and social viewpoints, and its objectives must be determined and its introduction (expansion) plan be drawn. The system that has been introduced (expanded) will undergo changes (updating its objectives, etc.) to accommodate changes in social needs and the technical progress shall be made after its initial introduction.

### 9.1.2 Major Scheme of Traffic Operation in DOH

(1) Traffic Obstacles in Thailand

This undertaking is concerned with DOH roads. DOH roads and related roads seem to have the following obstacles to traffic:

A. Traffic accidents

B. Road disasters

C. Road improvement work

D. Abnormal weather

E. Traffic congestion

Accidents, disasters and improvement work represent traffic obstacles common to all roads,not limited to DOH roads. Abnormal weather poses a traffic obstacle accompanied mostly by torrential rain, sometimes with fog. Traffic congestion is caused by the concentration of traffic in the metropolitan area of Bangkok and other major cities across the nation at morning and evening peak hours. The traffic congestion is observed as a constant occurrence.

(2) Traffic Operation Measures

The main objectives of the traffic operation for countermeasures to the traffic obstacles mentioned above on DOH and related roads are as follows:

A. Easing of traffic congestion

B. Securing traffic handling capability in a state of traffic obstacles

C. Effective road use

Easing traffic congestion is to prevent or reduce traffic congestion. Securing traffic handling capability is to utilize detours to cope with traffic obstacles such as traffic accident. Effective road use is aimed at proper distribution of traffic volume on road network so as to avoid a localized concentration of traffic volume.

These objectives should be achieved by application of the traffic operation methods mentioned in section 9.1.1 (2). Figure 9.3 shows the basic scheme for the proposed traffic operation.

(3) Traffic Operation System

The basic considerations in implementing the proposed traffic operation may be systematized in Figure 9.4.

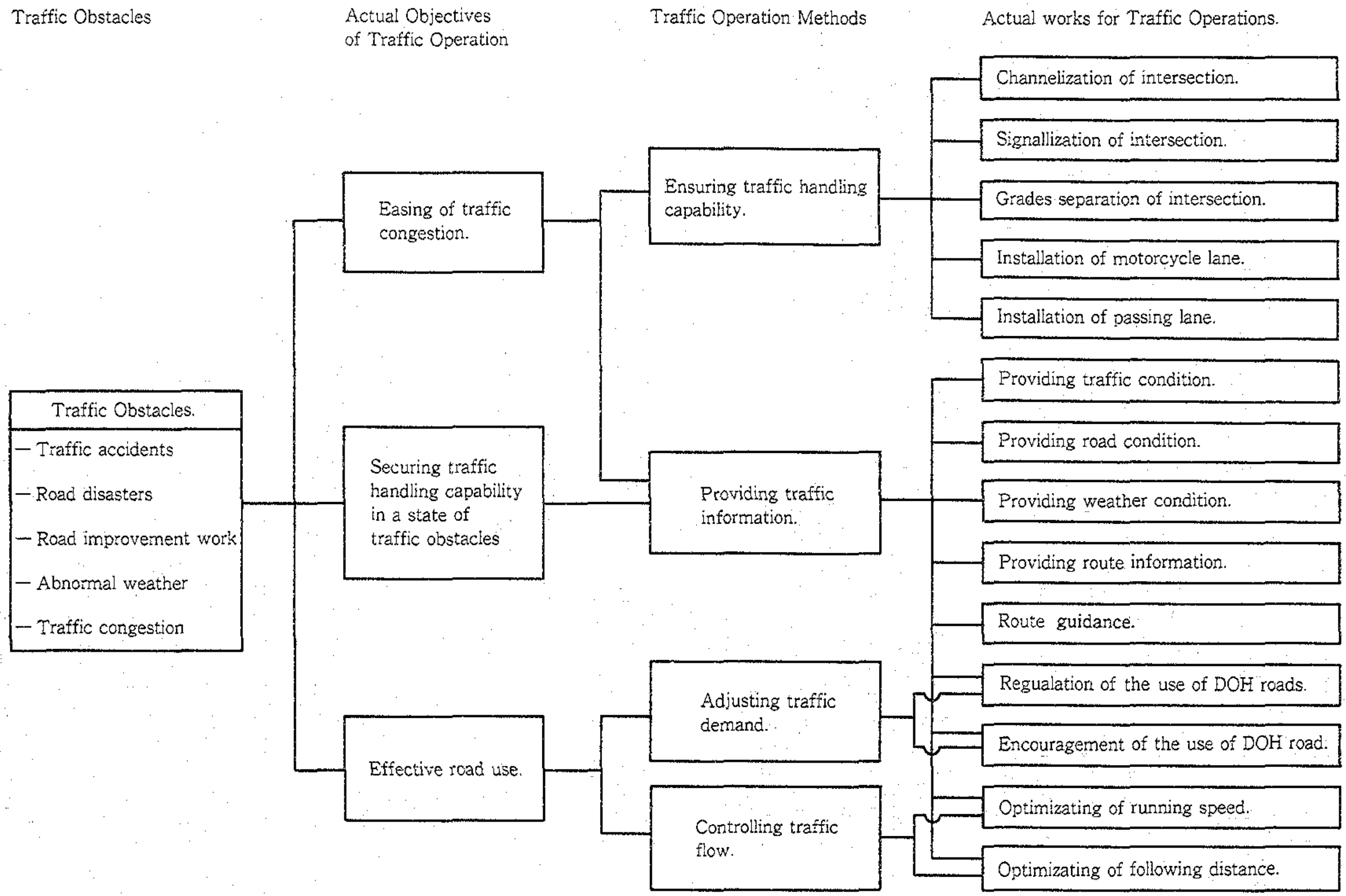



**Figure 9.3 Major Scheme for Traffic Operation**

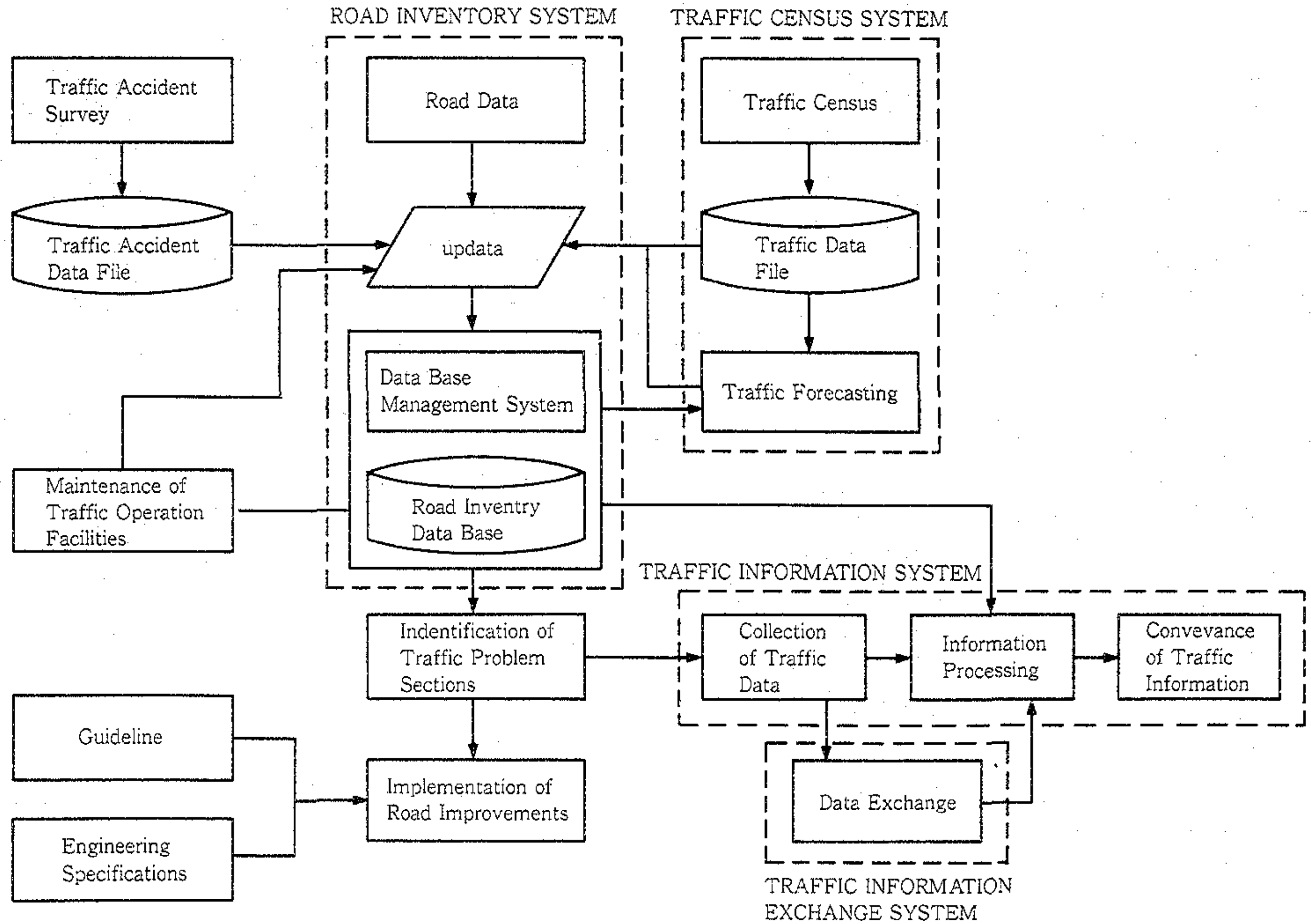



**Figure 9.4 Traffic Operation System**

## 9.2 TRAFFIC OPERATION PLAN

### 9.2.1 Definition of Traffic Operation Plan

(1) Basic Concept of Traffic Operation Plan

There is no established definition as to traffic operation plan for achievement of safe, efficient and convenient travel of motor vehicles. The definition shall varies according to the purposes of the plan. In a broad sense, the plan for traffic operation is not only to formulate the direct and immediate measures and applications for traffic control by means of various devices, but also shall include the improvement of all the existing traffic functions comprising all the road facilities, traffic regulations and organizations, etc.

In the Study, however, the scope of traffic operation plan is defined in Chapter 1, 1.2.2 (Definition of Traffic operation Plan and System), and is discussed on those physical measures to be applied on road facilities, such as motorcycle lane, passing lane and grade separated intersection, and traffic information system, which shall be implemented in a certain time span.

It is also to be mentioned that this report does not aim to present a plan itself, but the information needed for formulation of a traffic operation plan, and indication of the process to work out a plan through case study. From the planning period, the plan can be classified into two types, namely; masterplan with the time span of about five to ten years, and action plan with shorter planning period with detailed scheme of implementation. The Study deals with a macroscopic masterplan on traffic operation.

(2) Masterplan on Traffic Operation

A masterplan will generally be developed so as to determine the basic policy and strategy to traffic operations on entire DOH roads, taking into consideration of the effective and economic measures, financial resources and the effects of investment from the engineering viewpoint.

The masterplan should therefore set forth a goal or target of traffic operations together with approximate amount of investment and quantity of works planned out as the measures which may be drawn out macroscopically.

Within the framework of masterplan, a fairly concrete plan with a medium time span can be worked out so as to identify the road sections having serious traffic problems among those selected in the longer time span, which need speedy implementation of adequate measures. This plan requires more realistic implementation and related investment schedule, since it has somewhat a nature of action plan.

As this medium term plan needs substantial amount of detailed data including field information on the road sections which require traffic operational measures, and possible investment amount as well as DOH's policy, it can be prepared only by those who have the best access to the necessary data and information.

In this report, therefore, only the concept to select high priority road sections requiring operational measures is introduced.

### 9.2.2 Method for Development of Traffic Operation Plan

(1) Procedure

There are two basic approaches for DOH to formulate a traffic operation plan from road engineering practices for achievement of its objective to ensure safe, efficient and convenient travel of motor vehicles. The one is to mobilize DOH district engineers and have them find out the road sections or locations having traffic problems. Then, these engineers shall work out adequate measure work plans for those selected sections or locations together with quantities of the required works and related cost estimations. DOH Traffic Engineering Division shall then collect and integrate all the measure work plans prepared by the district engineers to be a certain form of traffic operation plan. The plan thus made can be directly put into implementation, since it consists of specific work items at the specific road sections or locations.

This approach, however, requires the district engineers' well experienced in traffic operations and other related traffic engineering expertises. Otherwise, the plan tends to be subjective depending upon the available capacity of each engineer, and is apt to lack of uniformity both in accuracy and level of improvements, even though each measure plan is worked out based on the guidelines and specifications issued by the DOH headquarters.

On the other hand, the other approach is to prepare a traffic operation plan macroscopically and systematically at the DOH headquarters utilizing the data and information from the district engineers. In this approach, the road sections or locations which require certain improvement works as the traffic operational measure can be screened and determined by appropriate and practical identification methods discussed in Chapter 3, and the applicable measures can be easily worked out, referring to standardized guidelines and specifications on traffic operations which are discussed in Chapter 8 of this report.

This approach will be more effective when applied in combination with the former approach, that is, firstly to prepare a traffic operation plan macroscopically, and then, to monitor or seek for creative comments on the plan from the district engineers, and to finalize it with adequate modifications and revisions, if deemed necessary.

The process and steps to formulate a traffic operation plan macroscopically are described as follows;

A. To select road sections or locations having traffic problems by identification methods with criteria by congestion degree and accident rate.

B. To classify the selected section or locations by road patterns and measure types.

C. To prepare standardized improvement measures corresponding to road patterns.

D. To apply each standardized measure to each classified road sections or locations, and to map out a macroscopic improvement plan for traffic operation.

E. To quantify the volume of the unit work for each type of improvement plan, and to estimate the cost required for implementation of the plan.

F. To sum up each type of improvement plan and to integrate to be a complete traffic operation plan.

G. To evaluate the formulated plan for traffic operation from the engineering viewpoint as well as from economic viability such as net benefit and benefit/cost ratio, together with the available financial resources.

As to the evaluation on the effectiveness of the formulated plan, it is possible to a certain extent to convert the benefit accrued from the investment such as saving of travel time, reduction in vehicle operation cost, saved life, prevented injury and property damage, etc., to monetary values, but it would be advisable to make a final decision in consideration of other factors like national policy and interest, development and improvement policy and strategy of road transportation and also DOH's policy and strategy for encouragement of traffic operations.

For formulation of a traffic operation plan, it is also important to verify the quantity and conditions of the existing traffic control and safety devices, and to work out the budget needed for replacement, repair and maintenance of such devices.

(2) Determination of Locations for Traffic Operation Plan

The road sections or locations having traffic problems to be incorporated to the traffic operation masterplan are to be determined by the identification methods which are discussed in Chapter 3, (Identification of Problem Sections on DOH Roads), in which the criteria for identification are traffic congestion rate and accident rate. The identification methods are only applicable to those roads where traffic volume and accident data, and other traffic and road condition data are available. Also, the road sections or locations identified by the aforesaid methods shall be endorsed by the district engineers of DOH to be determined as those requiring improvement measures.

It is to be mentioned that because of the reason that the Phase I Study identified and selected the road section which required remedial measures for traffic safety on all the DOH roads, this study regarded as its Phase II selected the road locations and sections which had not been selected in Phase I Study in order to avoid duplication.

(3) Macroscopic Improvement Works Planning

After the road locations and sections requiring improvement work for traffic operations are selected and determined, they are to be classified into a certain number of road patterns like roadway, intersection or a certain unit of road network, for each of which a certain improvement work for traffic operation can be effectively applicable.

In the Study, there are four (4) types of improvement works or macroscopic remedy works are proposed, namely; installation of motorcycle lane, passing lane, grade separated intersection and provision of traffic information system. Therefore, the classified road patterns are to be sorted out to fit into these four types of macroscopic improvement works, by which the planning process is to be standardized and simplified.

The improvement work planning shall include quantity of work, estimated cost and anticipated effects after implementation.

It is to be mentioned that when certain devices for traffic operation are used in the improvement plan, they are effective when properly installed, operated and maintained. Therefore, for cost estimation, in addition to the initial costs, the operation and maintenance expenditures should also be incorporated in the plan.

(4) Effectiveness Evaluation

The effectiveness evaluation of the masterplan for traffic operation is commonly practiced by economic analysis as well as from engineering viewpoint such as reduction of traffic accident and travel time, etc. However, this evaluation is regarded as complicated and controversial because of the difficulties to estimate the effectiveness of improvement works for traffic operation. However, when available fund for traffic operation is limited, an evaluation on a traffic operation plan is unavoidable to attain the best use of allocated budgets. Although there are no universal methods, undernoted are possible and practical methods to evaluate a traffic operation plan, namely;

a) Reduction in Number of Traffic Accident

In this method, the effectiveness is evaluated either on the number of traffic accident or related number of casualties to be reduced by implementation of the traffic operation plan in question.

It is the simplest way of effectiveness evaluation, and the greater the number in reduction, the more effective the plan is.

b) Driving Smoothness and Reduction in Travel Time

In this method, the effectiveness is evaluated by driving smoothness in a certain length of road section without interruption of vehicle travelling, which is commonly measured by reduction of travel time after implementation of the traffic operation plan.

In the foregoing section, the reduction in travel time was incorporated in the case study for macroscopic masterplan on traffic operation.

c) Benefit/Cost Evaluation

In this method, the effectiveness evaluation is to be made by comparative assessment of the expected benefits to be derived from the implementation of the traffic operation plan and the costs to be required for the said plan. For application of this method, the benefits stand for the monetary values of the reduced travel time, saved life and prevented injury on accident. The effectiveness in this method is judged by the value of the net benefit (B - C) and benefit/cost ratio (B/C).

(5) Traffic Operation Masterplan

A masterplan for traffic operation shall consist of the objective and target of the plan which shall be within the framework of the overall socio-economic development plan of the country, and in line with the road traffic improvement policy and strategy set forth by DOH and other related governmental agencies. Also, this masterplan shall include tabulation of the quantity of improvement works required for the plan and related financial need and resources.

It can be said that the more the improvement works are implemented, the more the objective or target can be achieved, but the proportional effect can not be expected. It is the general rule that the greater the target is, the more the cost and expense are needed for implementation of the masterplan.

The financial need for the masterplan can be estimated from the quantity of each type of improvement works and related prevailing unit cost for each work, which is to be integrated into the total investment amount of the masterplan. The financial resource for the masterplan shall also be reviewed carefully and secured for, however, this aspect is not discussed in this study because it is an internal issue of the concerned government.

9.2.3 <u>Case Study for Masterplan</u>

(1) Objective of Case Study

In the preceding section, a macroscopic method to prepare a masterplan for traffic operation is discussed and presented. In this section, a case study for preparation of traffic operation masterplan for DOH roads is attempted, applying this method, to provide and furnish the DOH officials with information and guidance for their actual practice of planning of the masterplan. The general flow chart for the case study is shown in Figure 9.5.

For formulation of the nationwide road traffic operation masterplan, a variety of accurate information and data, and judgments by concerned engineers and officials are needed, in addition to related national policy and strategies. The case study in this study has been carried out with limited data and information, and based on a number of judgments and assumptions made by the Study Team. Therefore, the objective of the case study is to demonstrate the macroscopic method for masterplan formulation, but not to propose a conclusive masterplan.

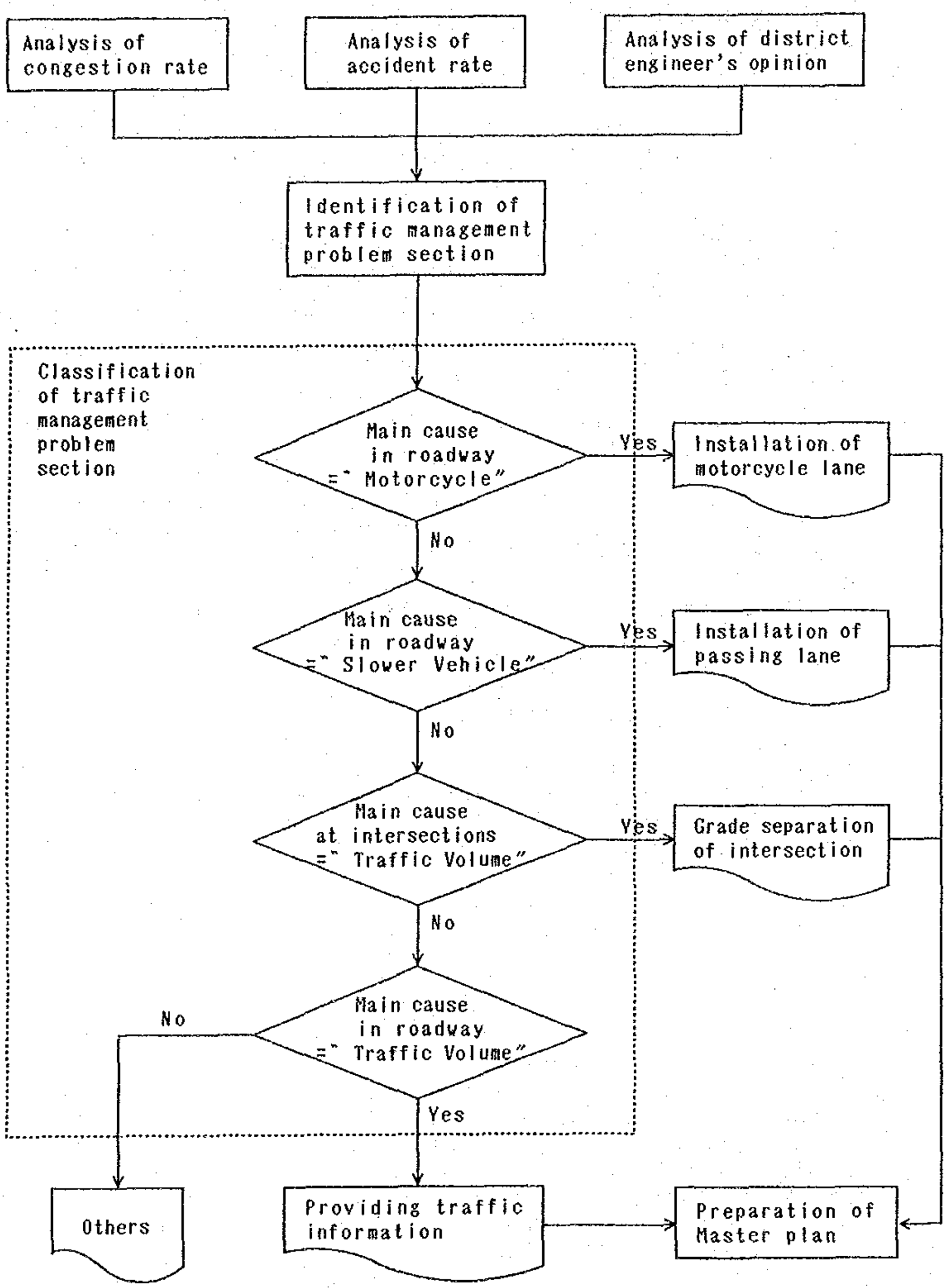



**Figure 9.5 Selection Flow for Macroscopic Remedy Works**

(2) Determination of Improvement Locations

In this case study for the masterplan, the road sections or locations having traffic problems and requiring improvement works on traffic operation, are selected by the identification methods which have been established in Chapter 3, in such a way to select problem locations in terms of traffic congestion and accident.

As shown in Figure 9.4; Traffic Operation System, the identification methods presented in Chapter 3 require the following data;

A. Traffic accident data discussed in Chapter 4 on Case Studies and Experimental Works for Traffic Control Measures, and Section 2.4.2.

B. Traffic data discussed in Chapter 5 on Traffic Census System.

C. Data on traffic information system discussed in Chapter 6 on Traffic Information System.

D. Road Inventory data discussed in Chapter 7 on Road Inventory System.

By application of the identification methods with the main criteria being traffic congestion rate and accident rate to the existing DOH roads, the study selected 64 locations which have traffic problems and require improvement works from the standpoint of traffic operation. The number of these problem locations by DOH's Highway Field Division and by the type of improvement work is shown in Table 9.1. Also the locations of these selected road sections are indicated on the road maps presented in Appendix 9.1.

It is to be mentioned that the length of road sections or locations which require improvement works for macroscopic masterplan was assumed in the case study to be 2km for provision of motorcycle lane, 20km each for installation of passing lane and provision of traffic information system, and 500m for grade separated intersection. However, at time of actual implementation of the improvement work, the length shall be determined according to the conditions of the road section or location and its environment, as well as traffic conditions.

(3) Macroscopic Improvement Work Planning

In order to draw out a masterplan for traffic operation systematically and macroscopically, 64 selected road sections have been classified into four typical road patterns by road and traffic conditions for which four

Table 9.1 Location of Remedy Works

| | Motorcycle Lane | Passing Lane | Traffic Information System | Grade Separation of Intersection |
|---|---|---|---|---|
| 1.Songkhla | 2 | 1 | 1 | 1 |
| 2.Nakhon Si Thammarat | 5 | 0 | 1 | 1 |
| 3.Prachuap Khan | 4 | 1 | 1 | 2 |
| 4.Bangkok | 0 | 0 | 4 | 5 |
| 5.Chachoengsao | 0 | 1 | 3 | 6 |
| 6.Lop Buri | 0 | 5 | 0 | 1 |
| 7.Phitsanulok | 1 | 1 | 0 | 0 |
| 8.Chiang Mai | 2 | 1 | 2 | 1 |
| 9.Phrae | 2 | 0 | 0 | 0 |
| 10.Nakhon Ratchasima | 1 | 4 | 0 | 0 |
| 11.Khon Kaen | 1 | 1 | 0 | 0 |
| 12.Ubon Ratchathani | 2 | 0 | 0 | 0 |
| Total | 20 | 15 | 12 | 17 |

types of standardized improvement measures can be effectively adopted respectively.

As described in the preceding sections, there are four types of improvement work proposed in the Study;

A. Installation of motorcycle lane

B. Installation of passing lane

C. Provision of grade separated intersection

D. Provision of traffic information system

Therefore, the criteria for classification of road sections having various traffic problems to fit into four types of improvement work on traffic operation have been set forth as the following:

A. Congestion rate exceeding 0.50

B. Hazardous section selected by statistical method

C. Type of Traffic problem to be congestion

D. Cause of traffic problem by ;

- Motorcycle .............Motorcycle lane
- Slower vehicle .........Passing lane
- Heavy traffic volume at intersection.........Grade separation
- Heavy traffic volume on road network ........Traffic information system

E. Degree of problem to be very high endorsed by district engineers of DOH.

F. Number of lane to be 1 lane each for both directions in cases of motorcycle and passing lanes.

G. The selected road section is on roadway or the road section between intersections, for traffic information system.

With aforesaid criteria, 64 selected problem sections have been classified and fit into four types to which four proposed improvement works are to be adopted, namely; 20 sections for installation of motorcycle lane, 15 sections for installation of passing lane, 12 sections for provision of traffic information system, and 17 sections for provision of grade separated intersections.

The number of classified road sections by improvement work type with classification criteria is shown in Table 9.2 and the details of each road section with location number, route number, control section number, number of lane, traffic volume per PCU, vehicular compositions of motorcycle and heavy vehicle, number of fatality and injury are presented in Appendix 9.2.

Table 9.2 Identification and Classification Method for Macroscopic Remedy Works

| Type of Remedy Works | Criteria | No. of Location |
|---|---|---|
| Installation of Motor-cycle Lane | (1) Congestion Rate > 0.50<br>(2) Hazardous Section<br>(3) Type of Problem = "Traffic Congestion"<br>(4) Cause of Problem = "Motorcycle"<br>(5) Degree of Problem = "Very High"<br>(6) Number of Lane = "2" | 20 |
| Installation of Passing Lane | (1) Congestion Rate > 0.50<br>(2) Hazardous Section<br>(3) Type of Problem = "Traffic Congestion"<br>(4) Cause of Problem = "Slower Vehicle"<br>(5) Degree of Problem = "Very High"<br>(6) Number of Lane = "2" | 15 |
| Providing Traffic Information System | (1) Congestion Rate > 0.50<br>(2) Hazardous Section<br>(3) Type of Problem = "Traffic Congestion"<br>(4) Cause of Problem = "Traffic Volume"<br>(5) Degree of Problem = "Very High"<br>(6) Location is in Roadway | 12 |
| Grade Separation of Intersection | (1) Congestion Rate > 0.50<br>(2) Hazardous Section<br>(3) Type of Problem = "Traffic Congestion"<br>(4) Cause of Problem = "Traffic Volume"<br>(5) Degree of Problem = "Very High"<br>(6) Location is at Intersection | 17 |

(4) Cost Estimation

After determination of the number of road sections by four types of road patterns each of which requires proposed improvement measures as described in the preceding paragraph, cost estimation including installation cost and operating/maintenance cost has been carried out with the following procedures.

A. Determination of the unit cost of each improvement work; motorcycle lane, passing lane, traffic information system and grade separated intersection.

B. Determination of service life of equipment and devices required for four types of improvement works, for clarification of their replacement time.

C. Estimation of installation cost of each improvement work by multiplying the unit cost by the number of road sections, and obtain the total installation cost of the master plan.

D. Estimation of replacement cost and operating/maintenance cost of the masterplan.

The unit costs of four types of improvement works are based on the market prices of 1989, and the estimated total installation cost and that of replacement and operating/maintenance cost were converted to economic costs by deduction of taxes and duties, which are shown in Table 9.3.

Table 9.3 Unit Cost for Remedy Works

Unit : Million Baht

| Type of Remedy Works | Unit | Unit Cost | |
|---|---|---|---|
| | | Construction | Maintenance |
| Motorcycle Lane | Location | 1.09 | 0.03 |
| Passing Lane | Location | 12.84 | 0.39 |
| Traffic Information System | Location | 60.00 | 3.00 |
| Grade Separation of Intersection | Location | 37.50 | 0.38 |

a) Installation Cost

The total economic cost for installation required for improvement works at 64 road sections proposed in the masterplan for traffic operation amounts to 1,571.9 million Baht, of which 21.8 million Baht is for motorcycle lane at 20 road sections, 192.6 million Baht for passing lane at 15 road sections, 720.0 million Baht for traffic information system at 12 sections and 673.5

million Baht for grade separated intersection at 17 locations.

b) Replacement and Operating/Maintenance Cost

In order to ensure the original effectiveness and function of the equipment and devices to be used for improvement works on traffic operation, they should be properly operated, maintained and periodically replaced. The masterplan should include the expenditure for these operation, maintenance and replacement. In the Study, implementation of the masterplan has been assumed to be carried out over the period of 10 years from 1990 to 1999 with the progress rate of 5 percent for the first year, through 40 percent in 1994, to 100 percent in the last year as indicated in Table 9.4. Taking into account of this progress rate of masterplan implementation, total economic cost for replacement and operating/maintenance cost amount to about 235.0 million Baht.

**Table 9.4 Progress Rate of Implementation**

| Fiscal Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| Rate % | 5.00 | 11.50 | 19.50 | 29.00 | 40.00 | 51.33 | 63.00 | 75.00 | 87.33 | 100.0 |

Table 9.5 summarizes the estimated investment cost, while the summary of yearly investment schedule of the masterplan for 10 years period has been tabulated in Table 9.6., in which the total financial requirement amounts to about 1,800 million Baht, when distribution in accordance with the implementation schedule.

**Table 9.5 Estimation of Investment Cost**

Unit : Million Baht

| Type of Remedy Works | No. of Location | Unit Cost | | Cost | |
|---|---|---|---|---|---|
| | | Construction | Maintenance | Construction | Maintenance* |
| Motorcycle Lane | 20 | 1.09 | 0.03 | 21.80 | 0.60 |
| Passing Lane | 15 | 12.84 | 0.39 | 192.60 | 5.85 |
| Traffic Information System | 12 | 60.00 | 3.00 | 720.00 | 36.00 |
| Grade Separation of Intersection | 17 | 37.50 | 0.38 | 637.50 | 6.46 |
| Total | | | | 1,571.90 | 48.91 |

Note : * -- Million Baht/Year

Table 9.6 Annual Investment Schedule

Unit : Million Baht

| Year | Fiscal Year | Investment | | |
|---|---|---|---|---|
| | | Construction Cost | Maintenance Cost | Total |
| 1 | 1990 | 78.59 | 2.45 | 81.04 |
| 2 | 1991 | 102.17 | 5.62 | 107.80 |
| 3 | 1992 | 125.75 | 9.54 | 135.29 |
| 4 | 1993 | 149.33 | 14.18 | 163.51 |
| 5 | 1994 | 172.91 | 19.56 | 192.47 |
| Sub-Total | | 628.76 (40%) | 51.36 | 680.11 |
| 6 | 1995 | 178.10 | 25.11 | 203.20 |
| 7 | 1996 | 183.44 | 30.81 | 214.25 |
| 8 | 1997 | 188.63 | 36.68 | 225.31 |
| 9 | 1998 | 193.82 | 42.71 | 236.53 |
| 10 | 1999 | 199.16 | 48.91 | 248.07 |
| Sub-Total | | 943.15 (100%) | 184.22 | 1,127.37 |
| Total | | 1,571.90 | 235.58 | 1,807.48 |
| 11 ¦ 20 | 2000 ¦ 2009 | 0.00 | 489.10 | 489.10 |
| Total | | 1,571.90 | 724.68 | 2,296.58 |

(5) Estimation of Benefit

As discussed in the preceding section, the direct benefit adopted in the Study consists of the monetary value of saving in travel time of the motor vehicles, saved life and prevented injury from traffic accident, on all the 64 road sections which shall be accrued by the plan implementation. There are other direct benefits such as saving in vehicle operating cost, saving from prevention of the property damage on traffic accident, etc. and also indirect benefits like better driving comfort and better environmental conditions, etc., but these are not included in the benefit calculation, because the savings in travel time, life and injury are assumed to be major factors in the economic evaluation.

a) Time Saving and Accident Reduction Rates

In order to evaluate the masterplan, expected saving in travel time and traffic accident reduction shall be projected. These saving and reduction have been examined in the experimental works through before- and after-surveys and through discussions with the DOH district engineers and other concerned officials. In case of passing lane, estimation of saving is reviewed by application of computer simulation model.

The outcome of this examination and simulation reveals as follows;

A. Installation of motorcycle lane can yield average time saving of 5 seconds per PCU with the saving rate of 5 percent and accident reduction rate of 50 percent.

B. As to the passing lane, it yields average time saving of 35 seconds with saving rate of 3 percent and accident reduction rate of 30 percent.

C. Traffic information system can accrue 95 seconds with the rate of 10 percent and accident reduction rate of 15 percent.

D. Grade separated intersection can yield 25 seconds per PCU and reduction rate of 100 percent.

The summary of time saving and accident reduction rates are tabulated in Tables 9.7 and 9.8.

**Table 9.7 Time Saving Rate**

| Type of Remedy Works | Time Saving Rate | Average of Time Saving | Remarks |
|---|---|---|---|
| Motorcycle Lane | 5% | 5 sec. | Before-After Survey |
| Passing Lane | 3% | 35 sec. | Estimation Using Simulation Model |
| Traffic Information System | 10% | 95 sec. | |
| Grade Separation of Intersection | - | 25 sec. | |

Table 9.8 Accident Reduction Rate

| Type of Remedy Works | Accident Reduction Rate | Remarks |
|---|---|---|
| Motorcycle Lane | 50% | Before-After Survey |
| Passing Lane | 30% | Estimation Using Simulation Model |
| Traffic Information System | 15% | |
| Grade Separation of Intersection | 100% | |

b) Estimation of Unit Value of Benefit

1) Travel time value

Estimation of an average value of travel time in monetary terms per PCU-hour at 1989 prices was attempted in reference to the Study on Road Improvement, Rehabilitation and Traffic Safety in Bangkok, March 1987 by JICA, in which the value stood at 22.1 Baht. The unit time value to be applied in the Study was derived by application of an average annual compound inflation rate of 5.0 percent for the duration of 2.5 years, which came at 25.0 Baht as shown in Table 9.9.

Table 9.9 Time Value

| | |
|---|---|
| Time Value | 25.0 Baht/PCU-hour |

2) Fatality and injury values

As to estimation of the values of the person saved from fatality and prevented from injury, if applicable data are available, value estimation based on such elements as wage lost, medical expenses, compensation for physical and mental pain, etc. can be made. Since there has been no reliable statistics and studies on above elements available, the estimation was made with the data by Automobile Subcommittee of the General Insurance Association of Thailand and Royal Automobile Association of Thailand.

The unit value of fatality and injury estimated by examination of the aforesaid data came at 0.5 million Baht per person on fatality and 0.05 million Baht per person on injury on average of whole Kingdom, as shown in Table 9.10. These unit values were cross-checked with the Phase I Study result, and these values are considered to be adequate when similarly estimated by application of inflation rate.

Table 9.10 Unit Value of Benefit

| | |
|---|---|
| Fatality | 0.50 Million Baht/Person |
| Injury | 0.05 Million Baht/Person |

c) Estimation of Benefit

Calculation of annual benefit derived from time saving was carried out based on the number of improvement road sections, traffic volume in vehicle per day, average time saving per second and the unit value of travel time, which came at 117.05 million Baht per year, as shown in Table 9.11.

Table 9.11 Estimation of Benefit in Smoothness

| Type of Remedy Works | No. of Location | Traffic Volume (Veh./Day) (1) | Average of Time Saving (sec.) (2) | Saving Time (Hour) (3) | Benefit in Smoothness (Million Baht) (4)=(3)x(5)x365 |
|---|---|---|---|---|---|
| Motorcycle Lane | 20 | 149,860 | 5 | 208.14 | 1.90 |
| Passing Lane | 15 | 146,702 | 35 | 1,426.27 | 13.01 |
| Traffic Information System | 12 | 183,001x2 | 95 | 9,658.39 | 88.13 |
| Grade Separation of Intersection | 17 | 221,055 | 25 | 1,535.10 | 14.01 |
| Total | | | | | 117.05 |

Note : (5) Time Value = 25 Baht/Hour

Similarly, annual benefit calculation for accident reduction was made based on the number of improvement road sections, number of fatality in persons per year, number of injury in persons per year, accident reduction rate, and unit values of fatality and injury which came at 104.79 million Baht per year, as shown in Table 9.12.

Therefore, when the masterplan for traffic operation is fully implemented, the total annual benefit is estimated to amount about 220 million Baht per year. However, because of the reason that this masterplan is assumed to be implemented in accordance with the aforesaid implementation schedule, yearly benefit amount to be yielded in the first year is estimated to be 11.09 million Baht, 88.73 million Baht in the fifth year and 221.83 million Baht in the 10th year, with the accumulated total benefits of 10 years for 1,068.49 and 20 years for 3,286.83 million Baht, respectively, as shown in Table 9.13.

## Table 9.12 Estimation of Benefit in Safety

| Type of Remedy Works | No. of Location | No. of Fatality (Person/Year) (1) | No. of Injury (Person/Year) (2) | Accident Reduction (%) (3) | Benefit in Safety (Million Baht) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Fatality (4)= (1)x(3)x(5) | Injury (5)= (1)x(3)x(7) | Total (6)=(4)+(5) |
| Motorcycle Lane | 20 | 22 | 106 | 50 | 5.5 | 2.65 | 8.15 |
| Passing Lane | 15 | 176 | 919 | 30 | 26.4 | 13.79 | 40.19 |
| Traffic Information System | 12 | 89 x 2 | 303 x 2 | 15 | 13.35 | 4.55 | 17.90 |
| Grade Separation of Intersection | 17 | 62 | 151 | 100 | 31.00 | 7.55 | 38.55 |
| Total | | | | | 76.25 | 28.54 | 104.79 |

Note : (7) Unit Value -- * Fatality = 0.50 Million Baht
* Injury = 0.05 Million Baht

## Table 9.13 Annual Benefit

Unit : Million Baht

| Year | Fiscal Year | Smoothness | Safety | | Total |
|---|---|---|---|---|---|
| | | | Fatality | Injury | |
| 1 | 1990 | 5.85 | 3.81 | 1.43 | 11.09 |
| 2 | 1991 | 13.46 | 8.77 | 3.28 | 25.51 |
| 3 | 1992 | 22.83 | 14.87 | 5.56 | 43.26 |
| 4 | 1993 | 33.95 | 22.11 | 8.27 | 64.33 |
| 5 | 1994 | 46.82 | 30.50 | 11.41 | 88.73 |
| Sub-Total | | 122.91 | 80.06 | 29.96 | 232.93 |
| 6 | 1995 | 60.08 | 39.14 | 14.64 | 113.87 |
| 7 | 1996 | 73.74 | 48.04 | 17.97 | 139.76 |
| 8 | 1997 | 87.79 | 57.19 | 21.40 | 166.38 |
| 9 | 1998 | 102.22 | 66.59 | 24.92 | 193.73 |
| 10 | 1999 | 117.05 | 76.25 | 28.53 | 221.83 |
| Sub-Total | | 440.89 | 287.21 | 107.46 | 835.57 |
| Total | | 563.80 | 367.27 | 137.42 | 1,068.49 |
| 11 - 20 | 2000 - 2009 | 1,170.55 | 762.49 | 285.30 | 2,218.34 |
| Total | | 1,734.35 | 1,129.76 | 422.72 | 3,286.83 |

(6) Effectiveness Evaluation

In the Study, the masterplan for traffic operation was evaluated by economic analysis in terms of net benefit (B - C) and benefit/cost ratio (B/C). In particular, it was made by the comparative assessment of the accrued total benefit by implementation of the masterplan in accordance with the implementation schedule spread over the period of 10 years, against the required installation cost and operating/maintenance cost distributed yearly according to the implementation schedule.

The conditions and assumptions for this evaluation were set as follows;

A. Evaluation period is assumed to be 20 years from the viewpoint of nature of the plan, its scale in work volume and cost, and the time required for completion.

B. The calculation was practiced with the constant prices at 1989 for costs and benefits with the assumption that price escalation rate is same for both costs and benefits. Also, for practical convenience, costs and benefits calculation was made without application of discount rate to achieve the net benefit and benefit/cost ratio.

C. The traffic volume and the number of casualties adopted for this evaluation was fixed at 1989 level for the practical convenience, although it might be possible to adopt those based on projection with annual increase for the plan period.

The economic evaluation reveals that by implementation of the masterplan for traffic operation, about 990 million Baht of net benefit (B - C) can be yielded with the benefit/cost ratio of 1.43 with the evaluation period of 20 years, justifying that this masterplan is economically feasible.

The result of economic evaluation from the first to 20th years are tabulated in Table 9.14.

Table 9.14 Summary of Economic Evaluation

Unit : Million Baht

| Year | F.Y. | Benefit | Cost | B-C | B/C |
|---|---|---|---|---|---|
| 1 | 1990 | 11.09 | 81.04 | -69.95 | 0.14 |
| 2 | 1991 | 36.60 | 188.84 | -152.24 | 0.19 |
| 3 | 1992 | 79.86 | 324.13 | -244.27 | 0.25 |
| 4 | 1993 | 144.19 | 487.64 | -343.45 | 0.30 |
| 5 | 1994 | 232.93 | 680.11 | -447.18 | 0.34 |
| 6 | 1995 | 346.79 | 883.32 | -536.53 | 0.39 |
| 7 | 1996 | 486.55 | 1,097.57 | -610.77 | 0.44 |
| 8 | 1997 | 652.92 | 1,322.88 | -669.96 | 0.49 |
| 9 | 1998 | 846.65 | 1,559.41 | -712.76 | 0.54 |
| 10 | 1999 | 1,064.49 | 1,807.48 | -738.99 | 0.59 |
| 11 | 2000 | 1,290.32 | 1,856.39 | -566.07 | 0.70 |
| 12 | 2001 | 1,512.16 | 1,905.30 | -393.14 | 0.79 |
| 13 | 2002 | 1,733.99 | 1,954.21 | -220.22 | 0.89 |
| 14 | 2003 | 1,955.82 | 2,003.12 | -47.30 | 0.98 |
| 15 | 2004 | 2,177.66 | 2,052.03 | 125.63 | 1.06 |
| 16 | 2005 | 2,399.49 | 2,100.94 | 298.55 | 1.14 |
| 17 | 2006 | 2,621.33 | 2,149.85 | 471.48 | 1.23 |
| 18 | 2007 | 2,843.16 | 2,198.76 | 644.40 | 1.29 |
| 19 | 2008 | 3,064.99 | 2,247.67 | 817.32 | 1.36 |
| 20 | 2009 | 3,286.83 | 2,296.58 | 990.25 | 1.43 |

(7) Summary of Traffic Operation Masterplan

a) Amount of Investment

The total amount of investment required for the masterplan for proposed traffic operation has been estimated at approximately 1,800 million Baht at 1989 prices, comprising 1,570 million Baht for installation/construction and 230 million Baht for replacement and operating/ maintenance. This estimation was made on the condition that the masterplan were to be implemented over the period of 10 years from 1990 to 1999.

There are four types of improvement works proposed in the masterplan, namely; motorcycle lane would be installed at 20 road section, passing lane be installed at 15 sections, 12 traffic information systems would be provided at the selected road sections and 17 grade separated intersections be provided at the selected locations.

b) Implementation Schedule

The implementation schedule of the masterplan was macroscopically set forth in this case study with application of proportional progress rate starting from 5 percent of the investment amount for the first year, and 40 percentile in the 5th year up to 100 percentile in the 10th year, without giving priority to a certain type of improvement work. Therefore, it is recommended that at time of formulation of the action plan or implementation plan of traffic operation, policy and strategies of the traffic operation shall be set up, and priority of either the type of improvement works or the selected road sections shall be placed.

It is also recommended that economic evaluation for each road section shall be attempted in order to verify the feasibility, which can lead to determination of the order of priority to be incorporated in the implementation schedule.

c) Financial Resources

Regarding the scale of investment for the masterplan on traffic operation, a brief review was attempted from the viewpoints of national and DOH's budgets. With an assumption that the national budget and DOH's budget will increase with a rate of 5 percent per annum from 1990 to 1999, it was estimated that the total amounts of national and DOH's budgets for 10 years will amount to approximately 3,770.5 billion Baht and 155.8 billion Baht, respectively. The share of DOH's budget against the national budget will remain about 4.1 percent. Assuming also that the share of maintenance budget of DOH will be about 25 percent of total DOH's budget, the total of DOH's maintenance budget for the same period of 10 years will be about 39 billion Baht.

Now, the investment amount proposed in the traffic operation masterplan in the case study amounting to 1.8 billion Baht shares about 4.6 percent. When reviewed on the first 5 years of the implementation schedule, the share of the investment amount of the masterplan for the first 5 years is calculated to be about 4.0 percent of the DOH's maintenance budget, and similarly the same share for the latter 5 years is estimated to be about 5.2 percent. Therefore, it can be said that the investment amount required for the masterplan is well in the framework of the national and DOH's budgetary schemes. Also assuming that the budget for the proposed traffic operation masterplan shall be in the range of about 5 to 6 percent of the DOH's maintenance budget, it comes to 1.95 to 2.34 billion Baht.

## 9.3 TRAFFIC OPERATION ORGANIZATION

### 9.3.1 Review on Present DOH's Organization

In this section, the present status of the DOH's organization and the existing problems related to the traffic operation aspects are reviewed.

(1) Organization of DOH

According to the Royal Decree issued in 1973, DOH is allowed to have 16 Divisions with 18 Highway Field Divisions and 93 Highway Districts and 8 Construction Centers. The present organization chart of DOH is shown in Figure 9.6. Highway Field Divisions and Highway Districts are responsible for construction and maintenance of the highways, except in the case of construction or rehabilitation projects financed by foreign loan which is implemented by Construction Centers.

The present organization of DOH is considered to be functioning well. However, DOH still has functions to construct and maintain highway under the direct management. To consider the future organization to be, it is desirable to strengthen divisions in responsible for the planning and the operation.

Divisions under control of the Deputy Director General for Engineering are mainly responsible for the establishment of the long term and annual highway development plan, and preparation of the design standard of highway at present. In addition to these functions, it is desirable to carry out other important roles, such as the planning and supervision of inter-city expressways and toll highways, which is formulating the national highway network, the roadside development and environment improvement planning, and the traffic management planning. In order to carry out these tasks, it is desirable to establish new divisions, such as the National Highway Division, the Provincial Highway Division, etc. by reforming the Location and Design Division, the Maintenance Division and the Construction Division. Under these new division, works related to the location and design are desirable to be mainly carried out, while works related to the construction should be transferred to Highway Field Divisions.

(2) Organization for Research and Materials

The Material and Research Division is an important division to mainly conduct the material testing, the soil testing and the pavement testing at present.

Other than these works, it is also necessary to conduct testing and research works related to new materials,

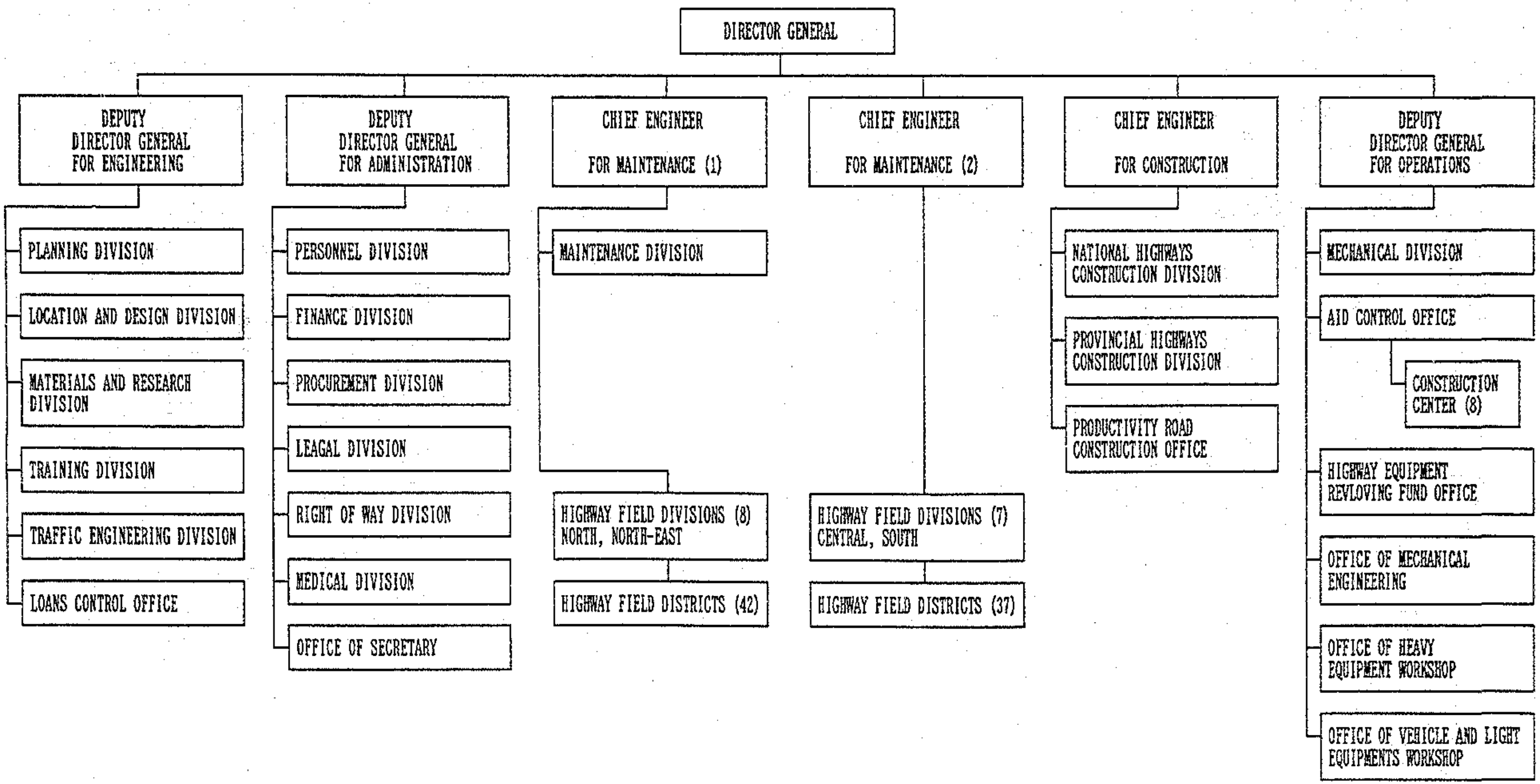



Figure 9.6 Present Organization Chart of DOH

such as compound materials, new metal materials, new ceramics, new high molecule substance, new soil stabilization materials and molecule substance material for pavement. It is also necessary to start research works related to the structures utilizing new materials and under new construction method. In addition, the progress of research works for the transport economics, the traffic flow, the safety, the information, etc. related to the traffic engineering have been rapidly progressed. Advanced safety apparatuses and information equipments have also been developed using the most modern electronic technologies. In order to apply these new technologies in Thailand, it is necessary to carry out research works individually. In addition, it is desirable to start research works related to the roadside landscaping and the environmental problems caused by traffic as the road administrator.

In order to appropriately manage these huge research works, a Laboratory should be established directory under DOH. In the Laboratory, not only testings for materials, soils and pavements, but also research works related to the traffic engineering, the road environment, the structure, etc. should be conducted. It is possible to consider the establishment of the research section as the research institute of the Ministry of Transport and Communications. However, for the time being, it is considered to be applicable to include the research section in the Laboratory under DOH.

(3) Organization for Traffic Engineering

The upgrading of the Traffic Engineering Office to the Traffic Engineering Division (TED) in 1989 is considered to be a very timely arrangement. The present DOH's organizational hierarchy related to the traffic operation is as follows.

TED under Deputy Director General for Engineering consists of five (5) Sections as follows:

| | | |
|---|---|---|
| | Division Director | 1 official |
| a. | Administrative Section | 8 " |
| b. | Traffic Survey Section | 17 " |
| c. | Traffic Analysis Section | 12 " |
| d. | Traffic Planning Section | 8 " |
| e. | Standard for Traffic Control Devices Section | 5 " |
| | Total | 51 officials |

In addition to 51 officials to be assigned to TED, there are 15 permanent employees for assistance to the officials, such as clerk, technician, driver and janitor, etc. Therefore, total number of staffs at TED accounts for 66 persons. However, at present there are 8 vacancies at the posts for 7 technicians and 1 statistician. In order to perform the assigned responsibility and enlarged function of TED, shortage of staffing seems to affect the volume and quality of the necessary works.

With regard to the function to properly introduce and implement the traffic operation system to all the DOH road network, TED shall assume the main responsibility, but shall need close and active cooperation from other divisions under Deputy Director General for Engineering and those divisions under other Deputy Director Generals. This attributes to the functional set-up of DOH, that the traffic operation plan shall be prepared by TED and this plan shall be submitted to Director General of DOH who when approve this plan assign the design works to Location and Design Division, and with allocation to required budget the actual implementation work is done by Highway Field District Office under Chief Engineer for Maintenance or Highway Construction Office under Chief Engineer for Construction, depending upon the nature of work for traffic operation. After completion of the work, TED is to monitor the improvement effect of traffic operation, which shall be the input information for further improvement of traffic operation plan.

Regarding budgetary arrangement for implementation of traffic operation plan, TED assumes the general administrative expenditure of its own division and some of administrative expenditure for engineering purposes, such as those costs for traffic surveys and analysis and for preparation of traffic operation plan. The cost for actual implementation work is being borne by respective division or field office where the work is done.

In TED, preparation of standards, establishment of the short/long term improvement plans, the statistical analyses, etc. related to the traffic safety, the traffic management and the traffic information should be strengthened.

In addition, it is desirable to newly establish or to strengthen the present division to handle the roadside development, including occupancies of road underground, environment improvement, transport economics, etc.

(4) Organization for Traffic Information

Other than organizations in DOH, the Highway Police Division established in 1961 under jurisdiction of the Police Dept., comes under the DOH for budgetary reason. Its duty is to supervise all vehicles on the highways, control traffic outside the metropolis and enforce law and regulation, so as to prevent accidents and promote welfare of the people as well as motorists traveling on the highways. The DOH coordinates with and gives guidance to the Highway Police Div. concerning its operation on highways. Presently, the Highway Police Division is composed of 7 sub-divisions. Each sub-division has 5 subsidiary police stations under its jurisdiction.

For the traffic operation, not only the traffic control but also the traffic information is very important. Concerning the traffic information, there is no nation-wide organization at present. Hence, in order to manage the traffic information in coordination with various agencies, it is necessary to establish the Traffic Information Center.

### 9.3.2 Traffic Operation Organization Improvement Plan

As described in the previous section, the problems regarding to the traffic operation organization cannot solely be solved by DOH. In this aspect, the communication and coordination with other relevant agencies, such as the Police Department, BMA, ETA, etc. are considered to be very important. In this Study, however, improvement plan of the traffic operation organization in DOH is only proposed under the assumption that the other agencies will be functioning as same as at present.

(1) Internal Organization Mainly Aimed at Traffic Operation

Proposed improvement plan for divisions under control of the Deputy Director General for Engineering is shown in Figure 9.7. Regarding TED, there are at present 51 officials and 15 permanent employees allocated to this division. But there are several shortage of staffing, and supplement of this shortage and some reshuffle from permanent employees to the official would be needed.

For TED, in order to accomplish the assigned responsibilities and functions, special facilities and apparatuses will be required, in addition to the usual administrative works, which are shown in Table 9.15.

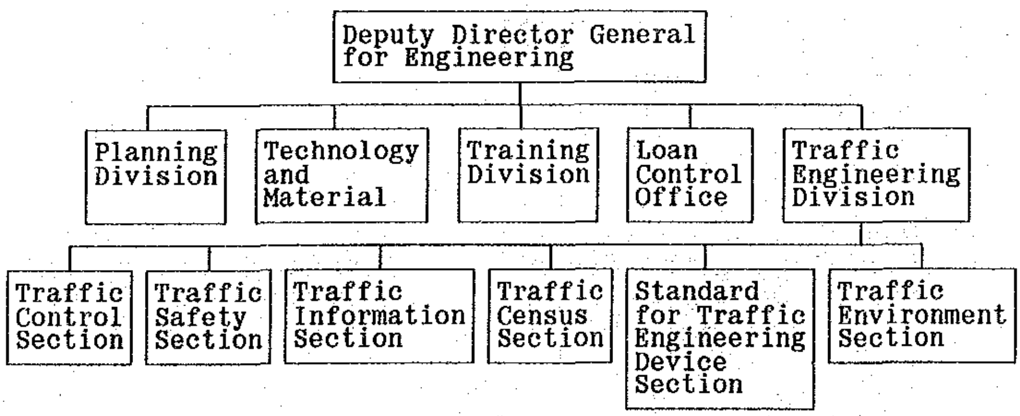



**Figure 9.7 Proposed Traffic Operation Organization**

Table 9.15 Recommended Facilities for Traffic Engineering Division

| Research Facilities Needed for Traffic Engineering Division |
|---|
| (1) Illumination Meter<br>(2) Luminance Meter<br>(3) Noise Meter<br>(4) Vibration Meter<br>(5) Vehicle Detector (speed, traffic volume and size)<br>(6) Vehicle Weighing Machine (portable type)<br>(7) Test Car for Traffic Drivability<br>(acceleration, deceleration, vibration, ridability)<br>(8) Test Car for Air Pollution<br>(9) Test Car for Road and Automobile Communication<br>(10) Test Car for Pavement Skid Resistance |

(2) External Organization

In order to cope with advanced and complicated technology as well as to aggressively respond to the social requirement, it is desirable to establish the Research Laboratory and the Traffic Information Center as external bodies of DOH.

a) Traffic and Highway Research Laboratory

In order to cope with the recent advanced technologies, it is necessary for some DOH staffs to concentrate into the testing tasks, various studies and research works in an external body separated from the administrative organization. Hence, the establishment of the Traffic and Highway Research Laboratory is proposed.

For the time being, it is desirable to include tasks presently performed by the Material and Research Division as well as the traffic engineering and the environment as additional. The organization chart of proposed Traffic and Highway Research Laboratory is shown in Figure 9.8. In addition, expansion of this organization is desirable to be done gradually.

Regarding the number of research staff, more than 15 staffs and 10 staffs are necessary for the Traffic Engineering Research Section and the Environment Research Section, respectively, at the beginning of the operation.

Facilities needed for the proposed Traffic and Highway Research Laboratory are shown in Table 9.16. As a reference, examples of research bodies related to traffic in Japan and France are attached in Appendix 9.4.

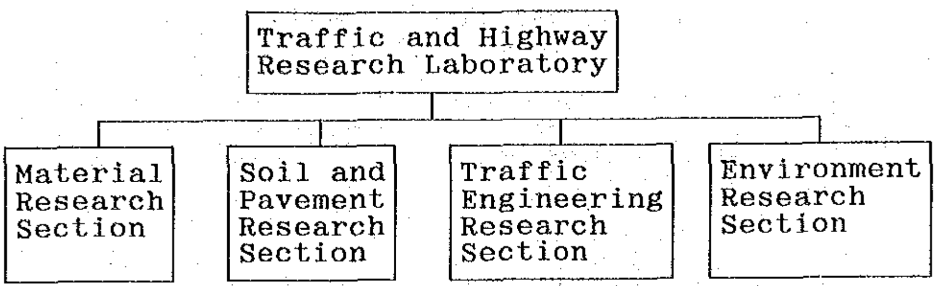



Figure 9.8 Organization Chart of Proposed Traffic and Highway Research Laboratory

Table 9.16 Recommended Facilities for Proposed Traffic and Highway Research Laboratory

| Research Facilities Needed for Proposed Traffic and Highway Laboratory |
|---|
| A. Environmental Research Section<br>(1) Diffusion Wind Tunnel (air pollution)<br>(2) Anechole Chamber<br>(3) Reverberation's Chamber |
| B. Traffic Engineering Research Section<br>(1) Testing Field for Visibility, Light and Drivability |

b) Traffic Information Center

At present, traffic information is provided to the general public through the broadcasting (radio, TV) as well as the roadside information board (by ETA). However, the request for the provision of traffic information will rapidly increase and the contents of information will become complicated and wide in the near future. On the other hand, information should be gathered from various agencies, such as DOH, Police Department, BMA, ETA, etc. and compiled. Hence, establishment of the Traffic Information Center as a juridical foundation is proposed in order to manage the traffic information provision in coordination with various agencies.

The organization chart of proposed Traffic Information Center is shown in Figure 9.9. According to increase of tasks in the future, the organization is necessary to be expanded. As references, the organization and information provision activities of the Traffic Information Center in Japan are attached in Appendix 9.5.

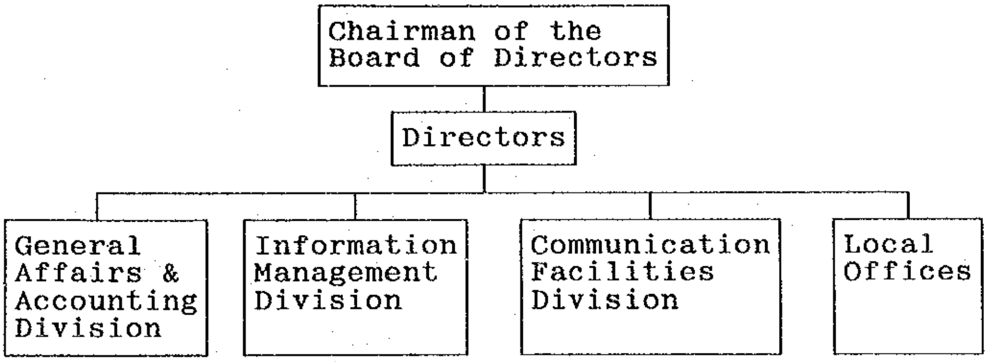
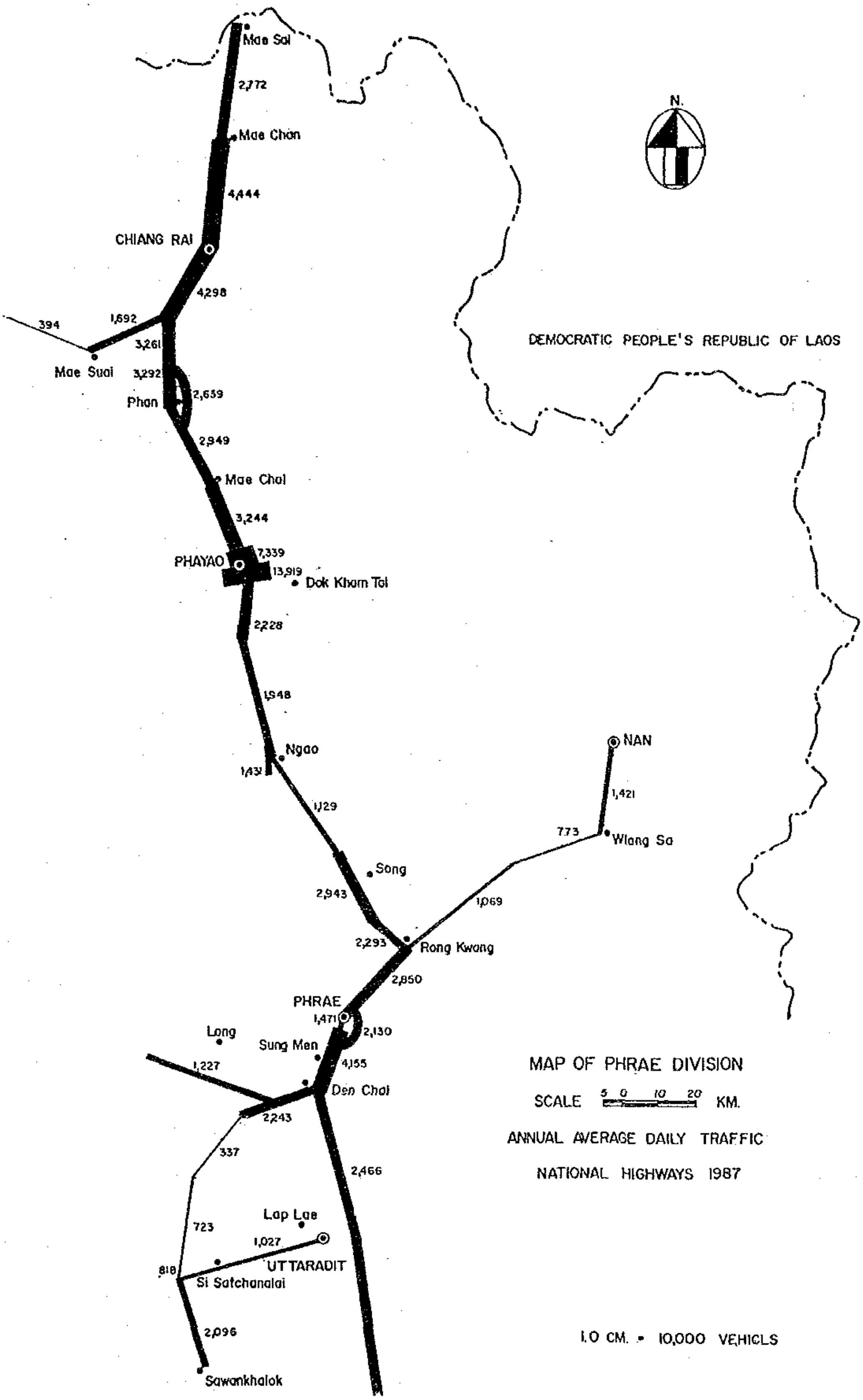



**Figure 9.9 Organization Chart of Proposed Traffic Information Center**

# APPENDICES



Mae Sai
2,772
Mae Chan
4,444
CHIANG RAI
4,298
394
1,692
3,261
Mae Suai
3,292
2,639
Phan
2,949
Mae Chai
3,244
PHAYAO
7,339
13,919
Dok Kham Tai
2,228
1,948
Ngao
1,431
1,129
Song
2,943
2,293
Rong Kwang
1,069
773
Wiang Sa
1,421
NAN
2,850
PHRAE
1,471
2,130
Long
Sung Men
1,227
4,155
Den Chai
2,243
337
2,466
Lap Lae
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1,027
UTTARADIT
818
Si Satchanalai
2,096
Sawankhalok
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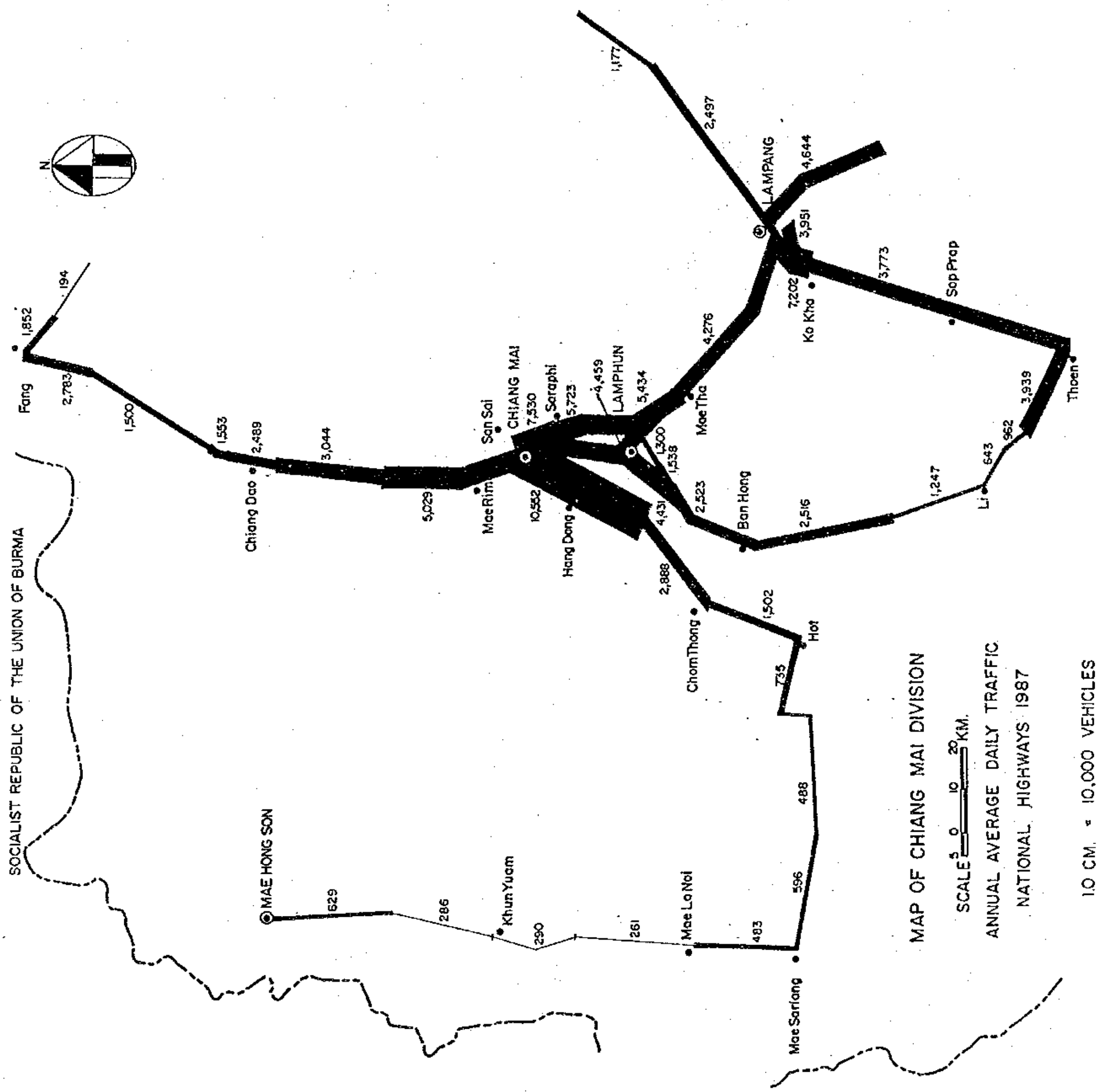
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Khun Yuam
Mae La Noi
Mae Sariang
Chom Thong
Hot
Hang Dong
Mae Rim
Chiang Dao
Fang
San Sai
CHIANG MAI
Saraphi
LAMPHUN
Mae Tha
Ban Hong
Li
Thoen
Ko Kha
Sop Prap
LAMPANG
629
286
290
261
483
596
488
735
1,502
2,888
4,431
10,552
5,029
3,044
2,489
1,553
1,500
2,783
1,852
194
7,530
5,723
4,459
5,434
1,300
1,538
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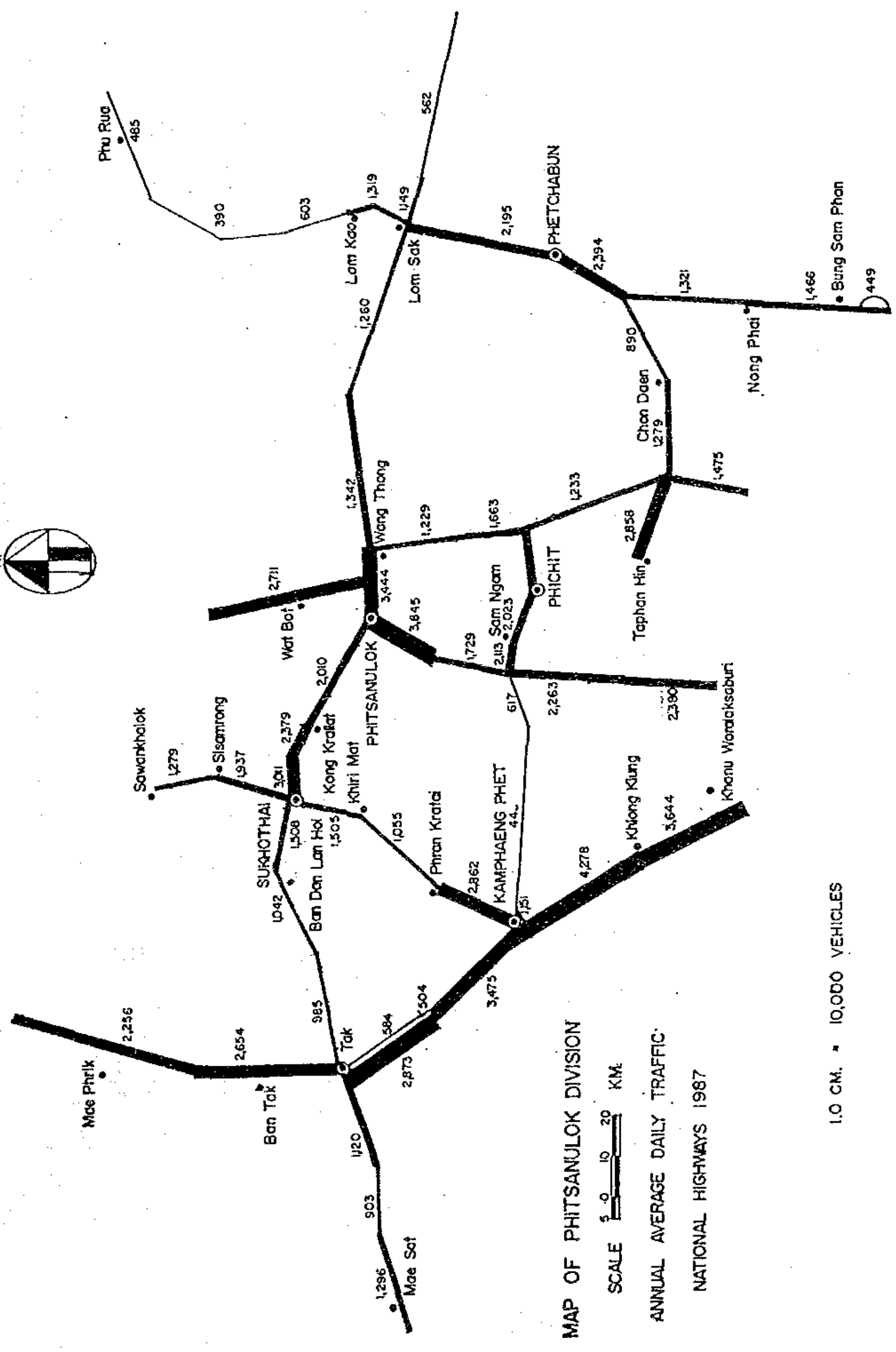
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Lom Sak
PHETCHABUN
Bung Sam Phan
Nong Phai
Chon Daen
Wang Thong
Taphan Hin
PHICHIT
Sam Ngam
Wat Bot
PHITSANULOK
Sawankhalok
Sisamrong
SUKHOTHAI
Kong Krailat
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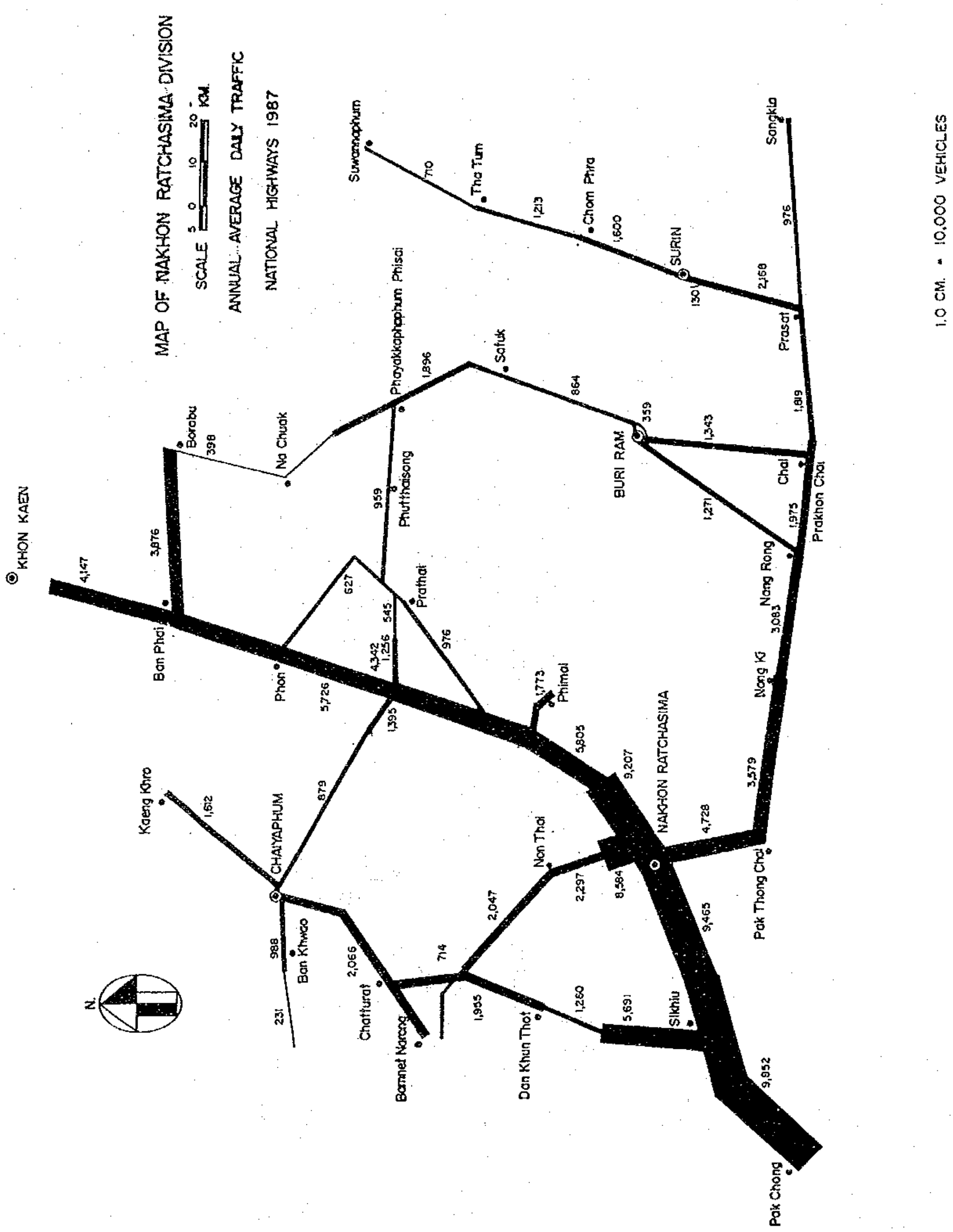
Mae Sot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Borabu
Na Chuak
Phayakkaphum Phisai
Satuk
Suwannaphum
Tha Tum
Chom Phra
SURIN
Sangkha
Prasat
BURI RAM
Chai
Prakhon Chai
Nang Rong
Nong Ki
Phutthaisong
Prathai
Phon
Phimai
NAKHON RATCHASIMA
Pak Thong Chai
Non Thai
Kaeng Khro
CHAIYAPHUM
Ban Khwao
Chatturat
Bamnet Narong
Dan Khun Thot
Sikhiu
Pak Chong
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398
1,896
864
710
1,213
1,600
1,301
2,168
976
359
1,343
1,819
1,271
1,975
3,083
959
627
545
4,342
1,256
976
5,726
1,395
1,773
5,805
9,207
3,579
4,728
1,612
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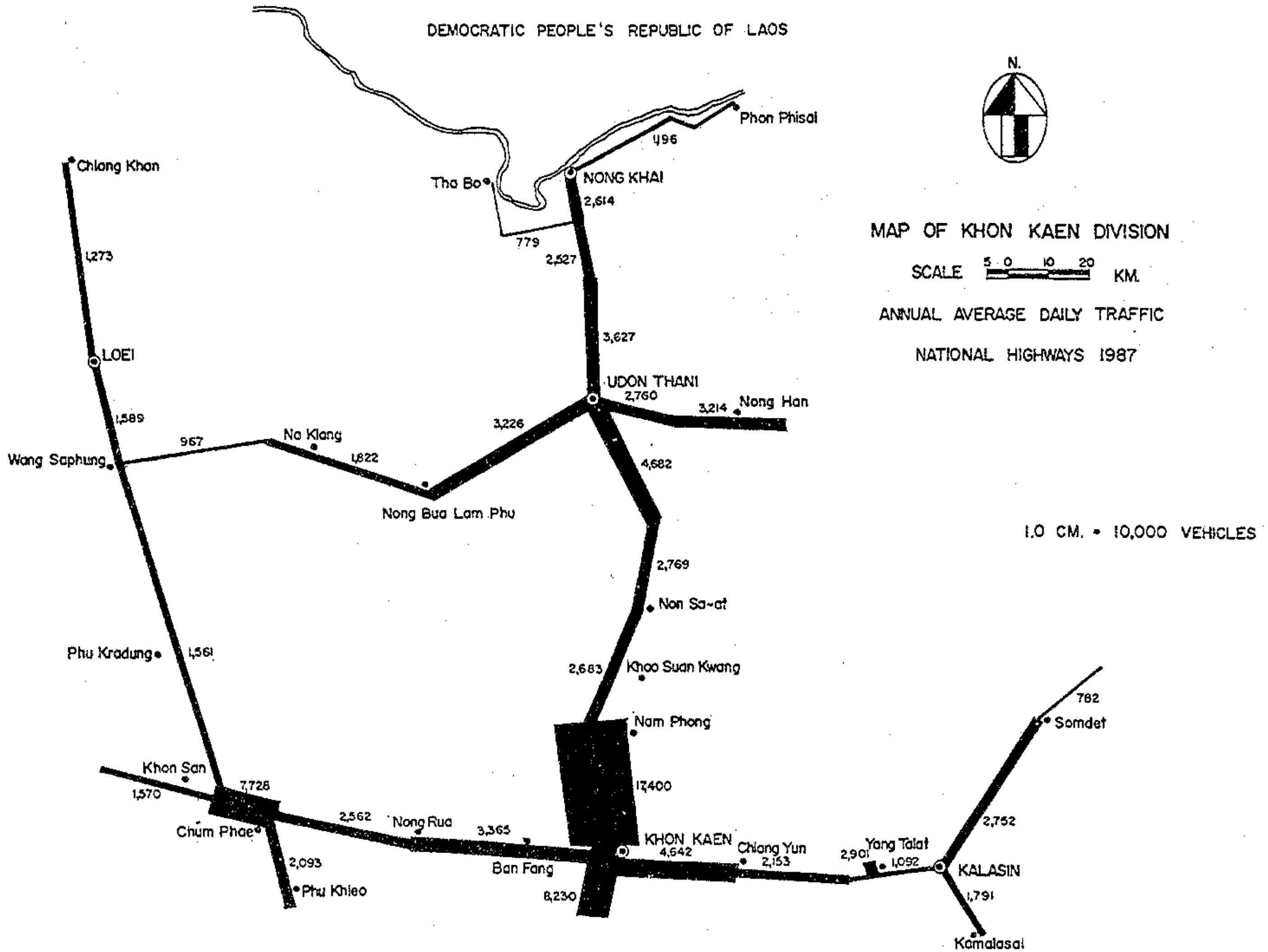
9,852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Tha Bo
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UDON THANI
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Nong Han
4,682
3,226
Chiang Khan
1,273
LOEI
1,589
Wang Saphung
967
Na Klang
1,822
Nong Bua Lam Phu
2,769
Non Sa-at
2,683
Khao Suan Kwang
Nam Phong
17,400
Phu Kradung
1,561
Khon San
1,570
7,728
Chum Phae
2,093
Phu Khieo
2,562
Nong Rua
3,365
Ban Fang
8,230
KHON KAEN
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Kamalasai
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Somdet
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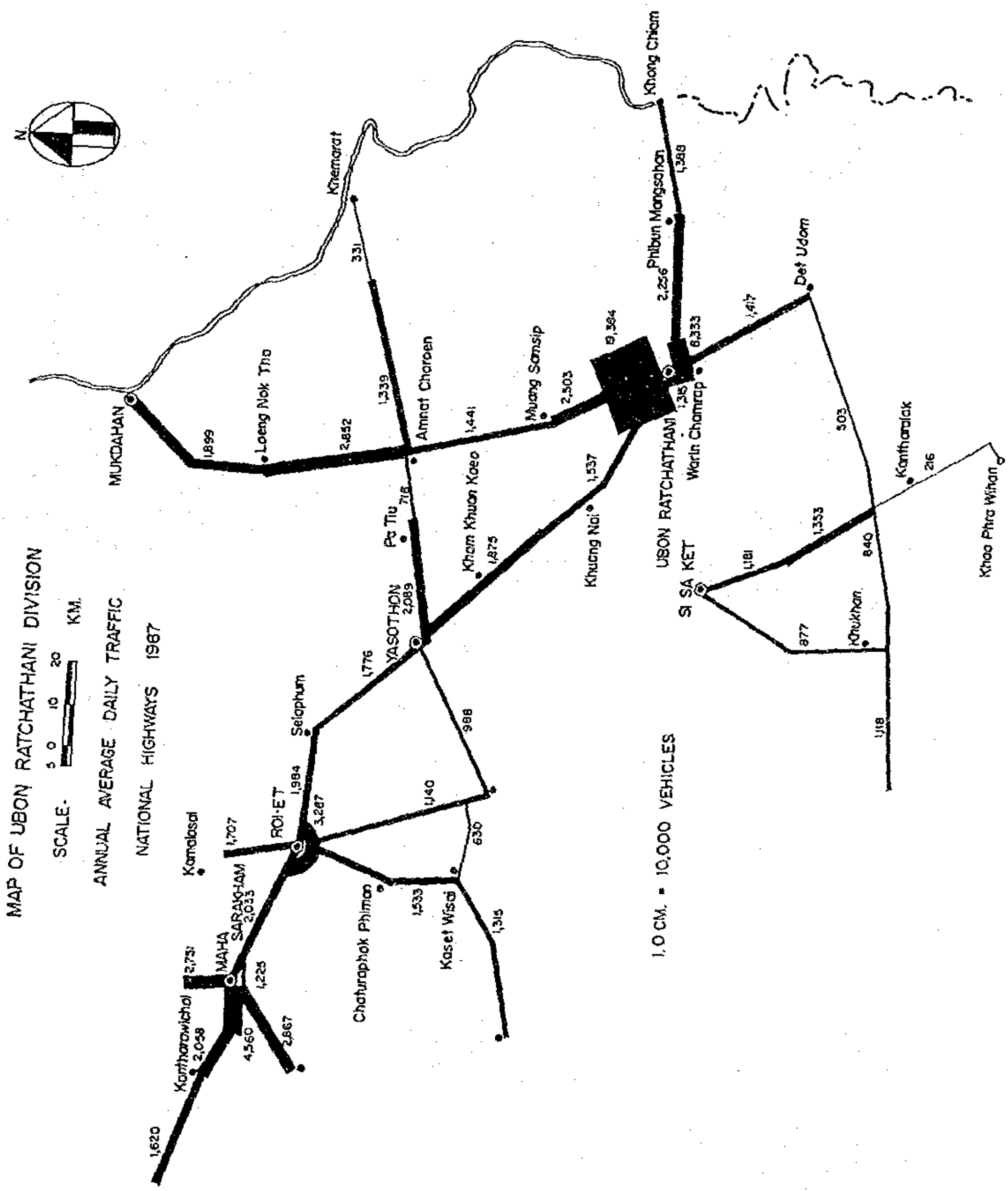
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Khemarat
Amnat Charoen
Muang Samsip
Khong Chiam
Phibun Mangsahan
Det Udom
UBON RATCHATHANI
Warin Chamrap
Kantharalak
Khao Phra Wihan
SI SA KET
Khukhan
Khuang Nai
Kham Khuan Kaeo
Pa Tiu
YASOTHON
Selaphum
ROI-ET
Kamalasai
MAHA SARAKHAM
Chaturaphak Phiman
Kaset Wisai
Kantharawichai
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1,353
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1,537
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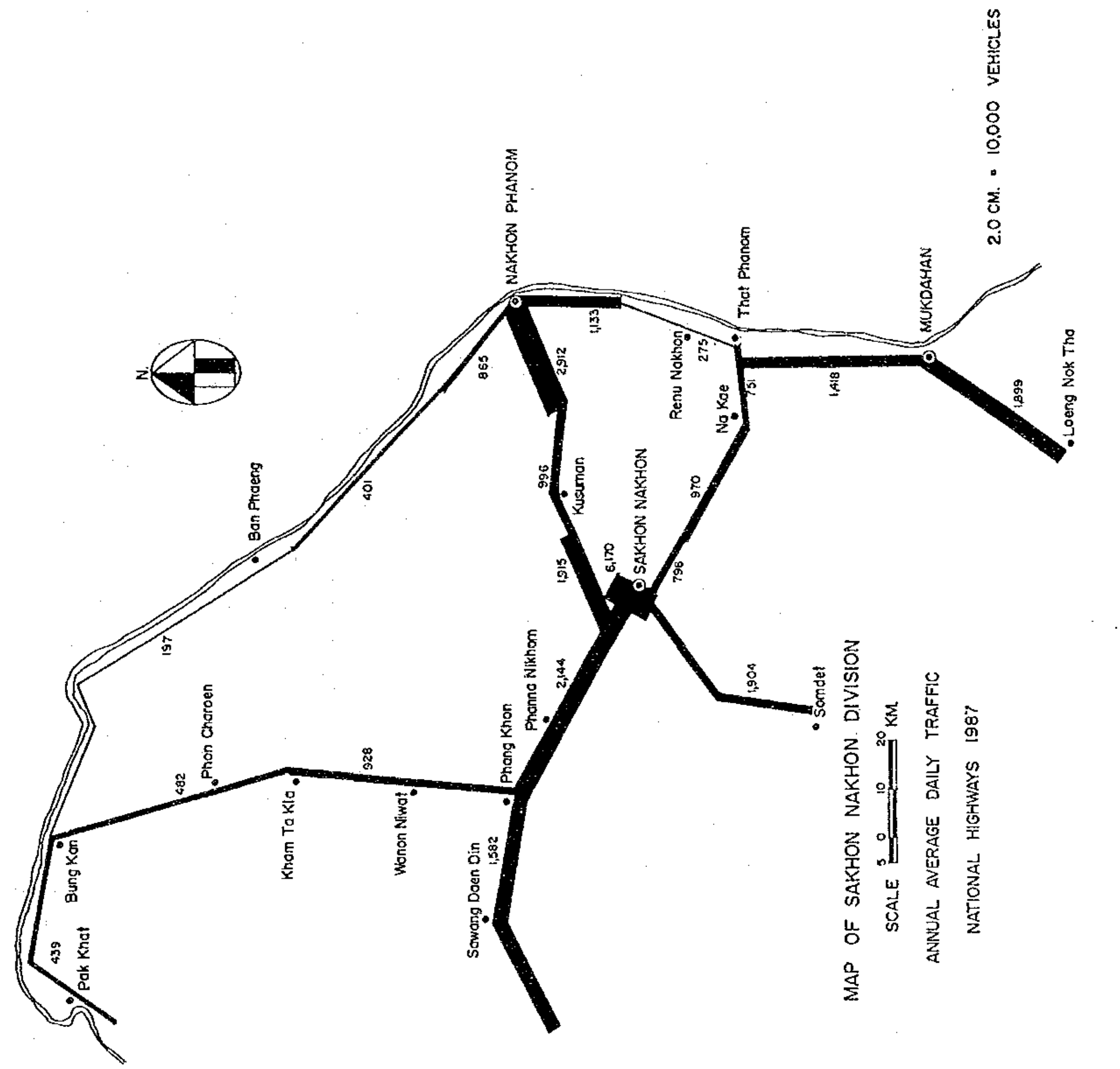
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That Phanom
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Loeng Nok Tha
Renu Nakhon
Na Kae
SAKHON NAKHON
Kusuman
Ban Phaeng
Phon Charoen
Bung Kan
Pak Khat
Kham Ta Kla
Wanon Niwat
Sawang Daen Din
Phang Khon
Phanna Nikhom
Somdet
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2,912
1,133
275
751
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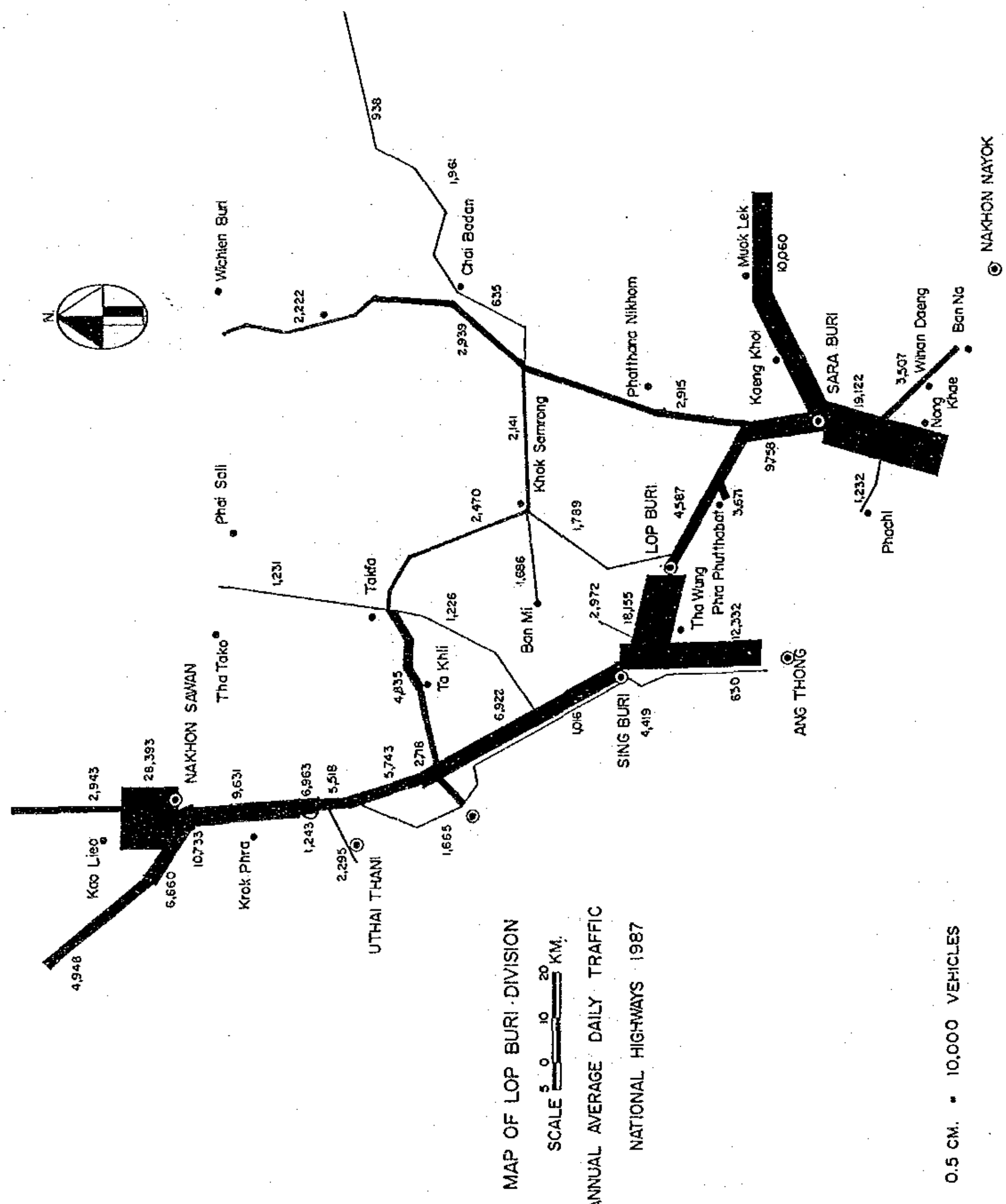
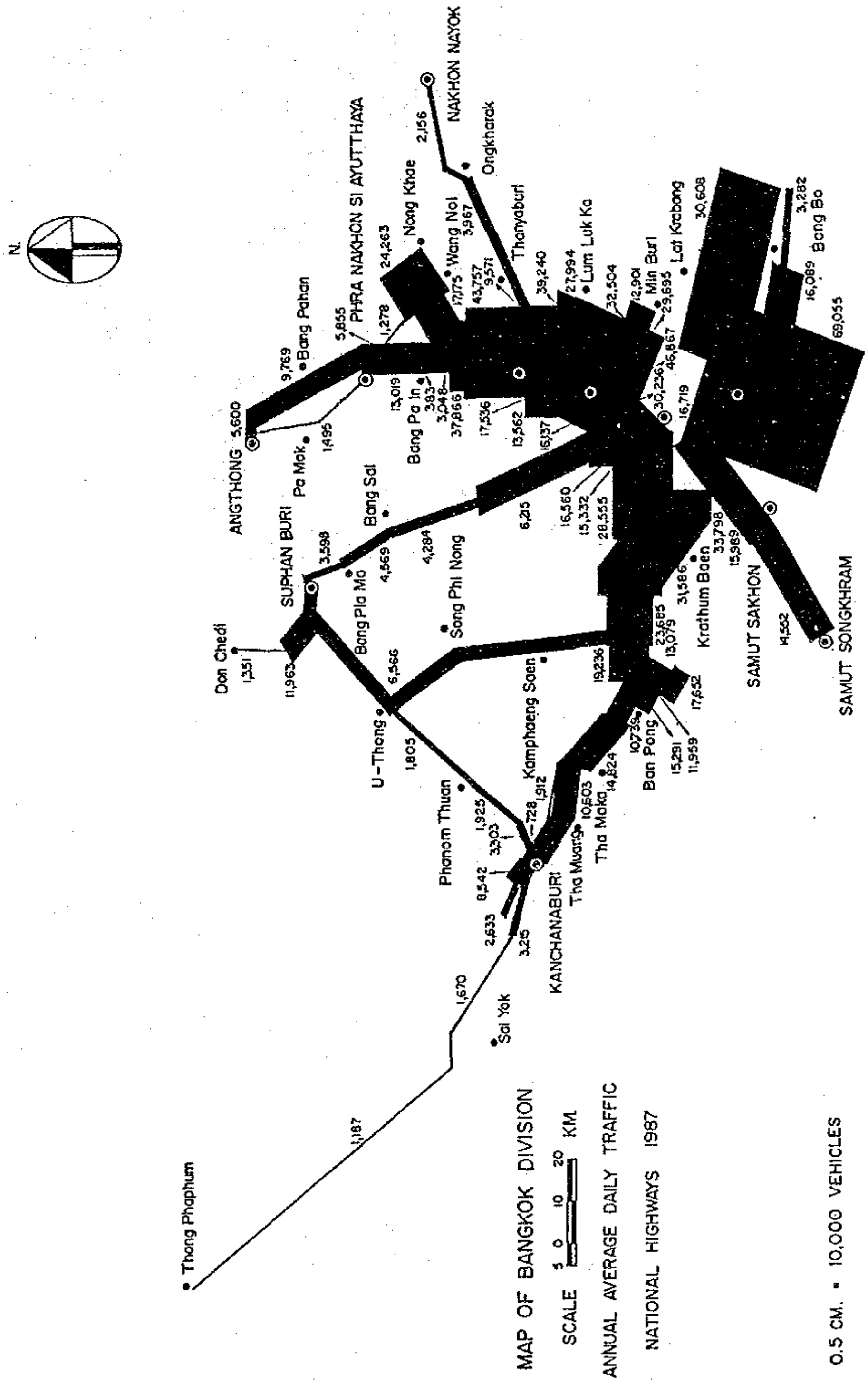
928
439
1,582




MAP OF LOP BURI DIVISION

ANNUAL AVERAGE DAILY TRAFFIC

NATIONAL HIGHWAYS 1987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NATIONAL HIGHWAYS 1987
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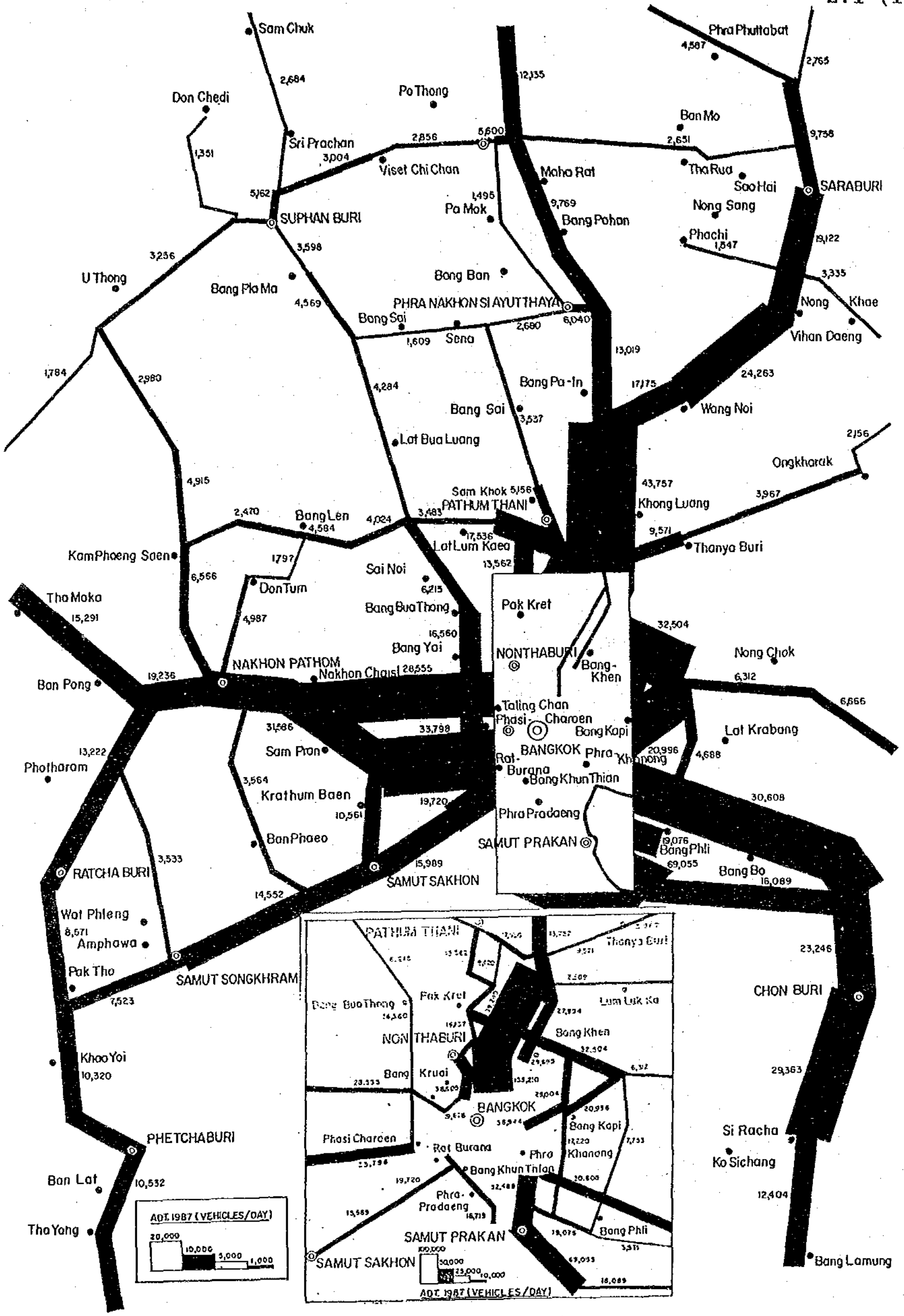
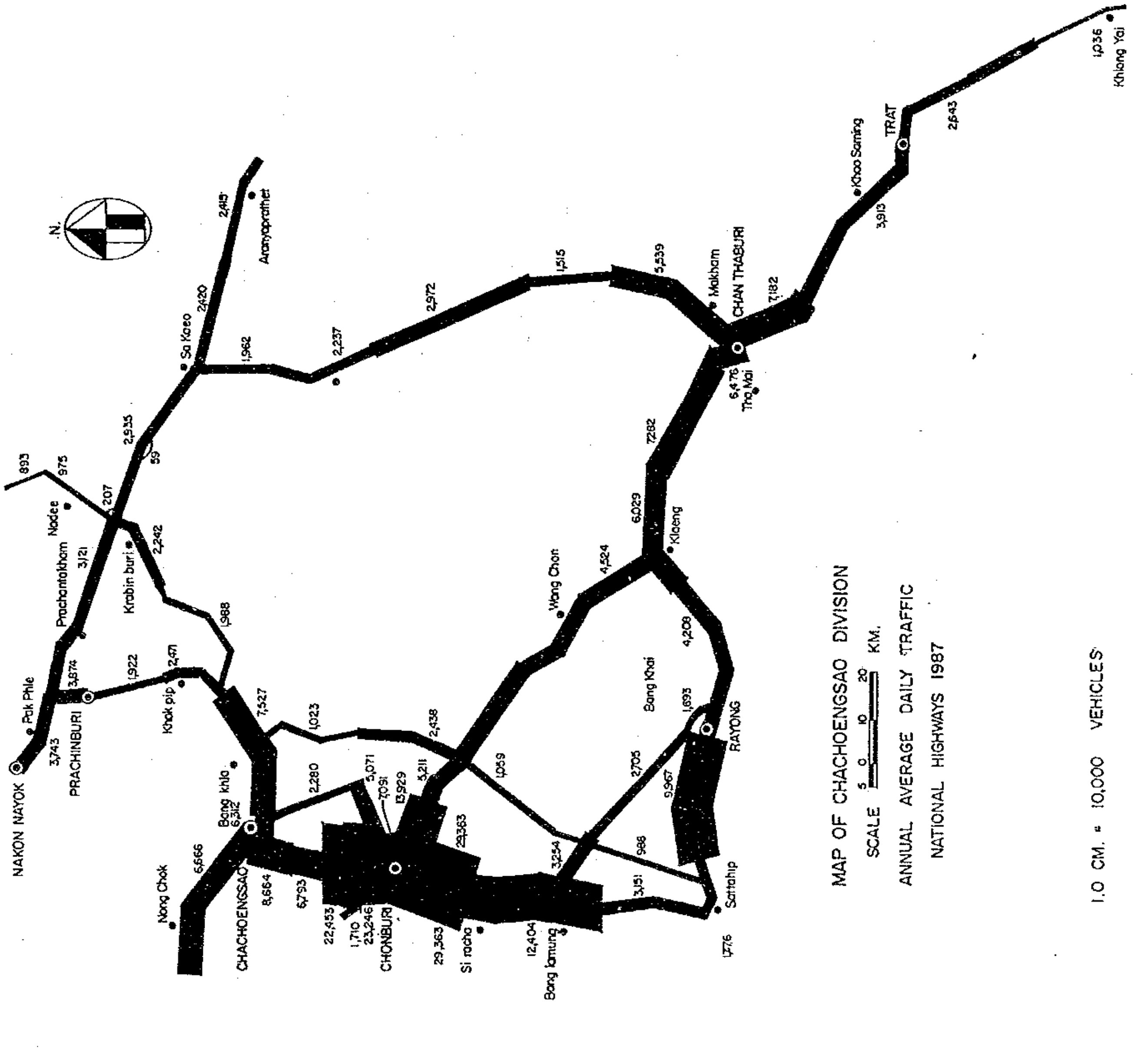
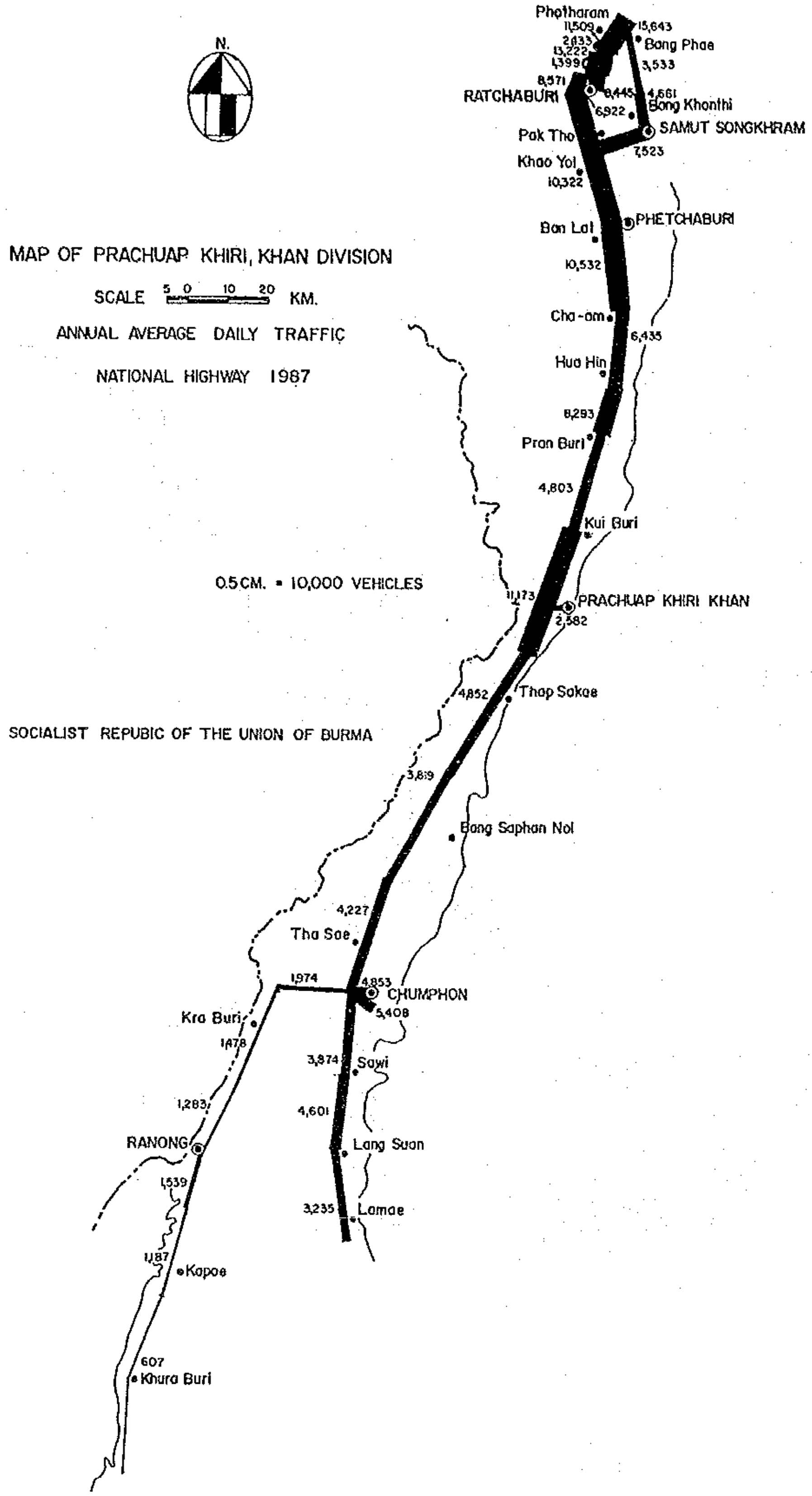
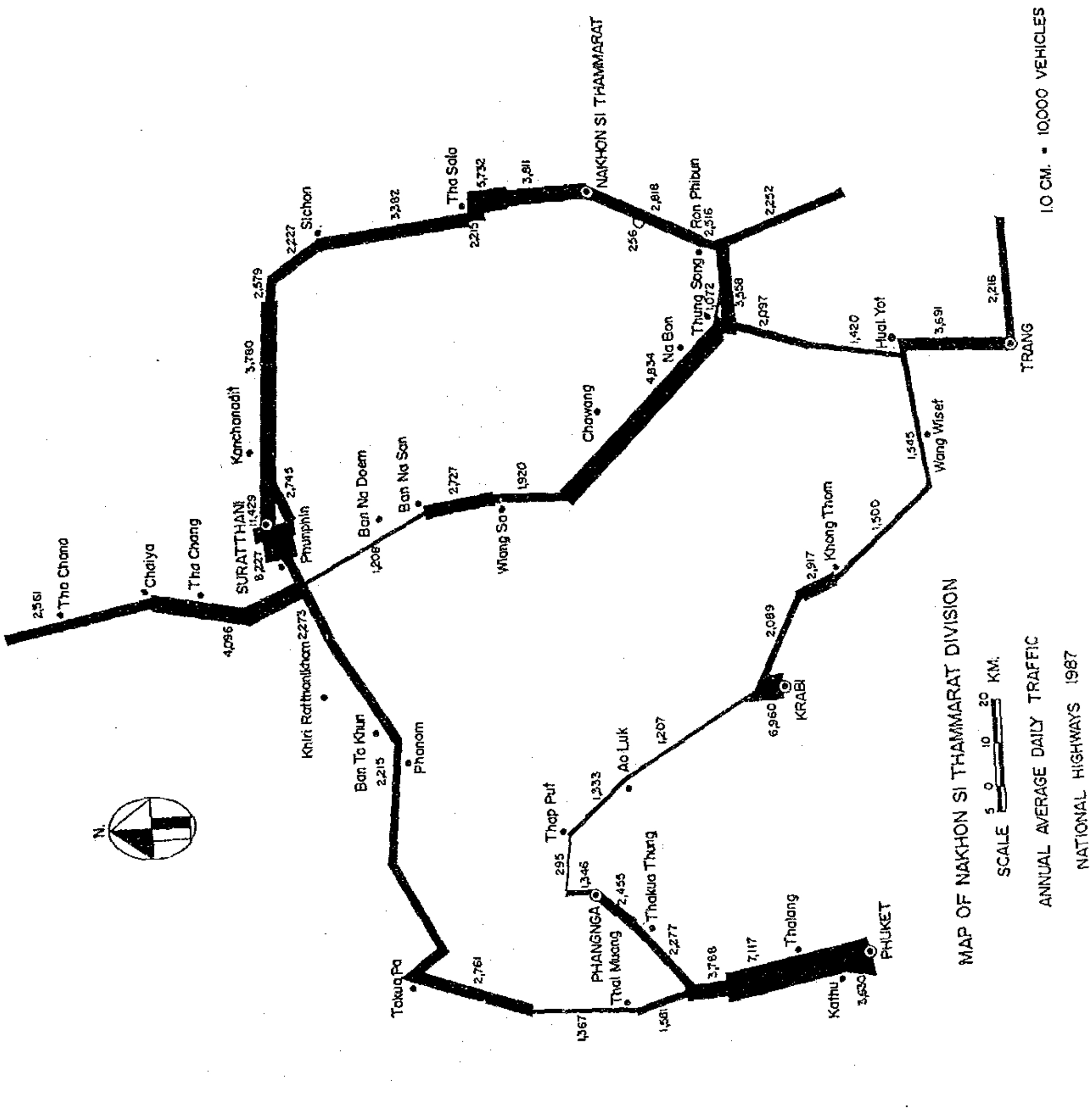
Thanyaburi
Lum Luk Ka
Min Buri
Lat Krabang
Bang Bo
Bang Pahan
ANGTHONG
Pa Mok
Bang Pa In
SUPHAN BURI
Bang Sai
Bang Pla Ma
Song Phi Nong
Don Chedi
U-Thong
Kamphaeng Saen
Krathum Baen
SAMUT SAKHON
SAMUT SONGKHRAM
Ban Pong
Tha Maka
Tha Muang
KANCHANABURI
Phanom Thuan
Sai Yok
Thong Phaphum


Sam Chuk
Don Chedi
Po Thong
Phra Phuttabat
Ban Mo
Sri Prachan
Viset Chi Chan
Maha Rat
Tha Rua
Sao Hai
SARABURI
SUPHAN BURI
Pa Mok
Bang Pahan
Nong Sang
Phachi
U Thong
Bang Pla Ma
Bang Ban
PHRA NAKHON SI AYUTTHAYA
Bang Sai
Sena
Nong Khae
Vihan Daeng
Bang Pa-In
Bang Sai
Wang Noi
Lat Bua Luang
Ongkharak
Sam Khok
PATHUM THANI
Khong Luang
Bang Len
Lat Lum Kaeo
Thanya Buri
Kam Phaeng Saen
Sai Noi
Don Tum
Tha Maka
Pak Kret
Bang Bua Thong
Bang Yai
NONTHABURI
Bang-Khen
Nong Chok
NAKHON PATHOM
Nakhon Chaisi
Ban Pong
Taling Chan
Phasi-Charoen
Bang Kapi
BANGKOK
Lat Krabang
Sam Phran
Rat-Burana
Phra Khanong
Photharam
Bang Khun Thian
Krathum Baen
Phra Pradaeng
Ban Phaeo
SAMUT PRAKAN
Bang Phli
RATCHA BURI
Bang Bo
SAMUT SAKHON
Wat Phleng
Amphawa
Pak Tho
SAMUT SONGKHRAM
CHON BURI
Khao Yoi
PHETCHABURI
Si Racha
Ko Sichang
Ban Lat
Tha Yang
Bang Lamung
ADT. 1987 (VEHICLES/DAY)
20,000
10,000
5,000
1,000
Bang Kruai
ADT. 1987 (VEHICLES/DAY)
100,000
50,000
25,000
10,000


MAP OF CHACHOENGSAO DIVISION
SCALE 5 0 10 20 KM.
ANNUAL AVERAGE DAILY TRAFFIC
NATIONAL HIGHWAYS 1987
1.0 CM. = 10,000 VEHICLES
N
NAKON NAYOK
Pak Phle
PRACHINBURI
Prachantakham
Nadee
Krabin buri
Sa Kaeo
Aranyaprathet
Khok pip
Bang khla
Nong Chok
CHACHOENGSAO
CHONBURI
Si racha
Bang lamung
Sattahip
RAYONG
Bang Khai
Wang Chan
Klaeng
Tha Mai
Makham
CHAN THABURI
Khao Saming
TRAT
Khlong Yai



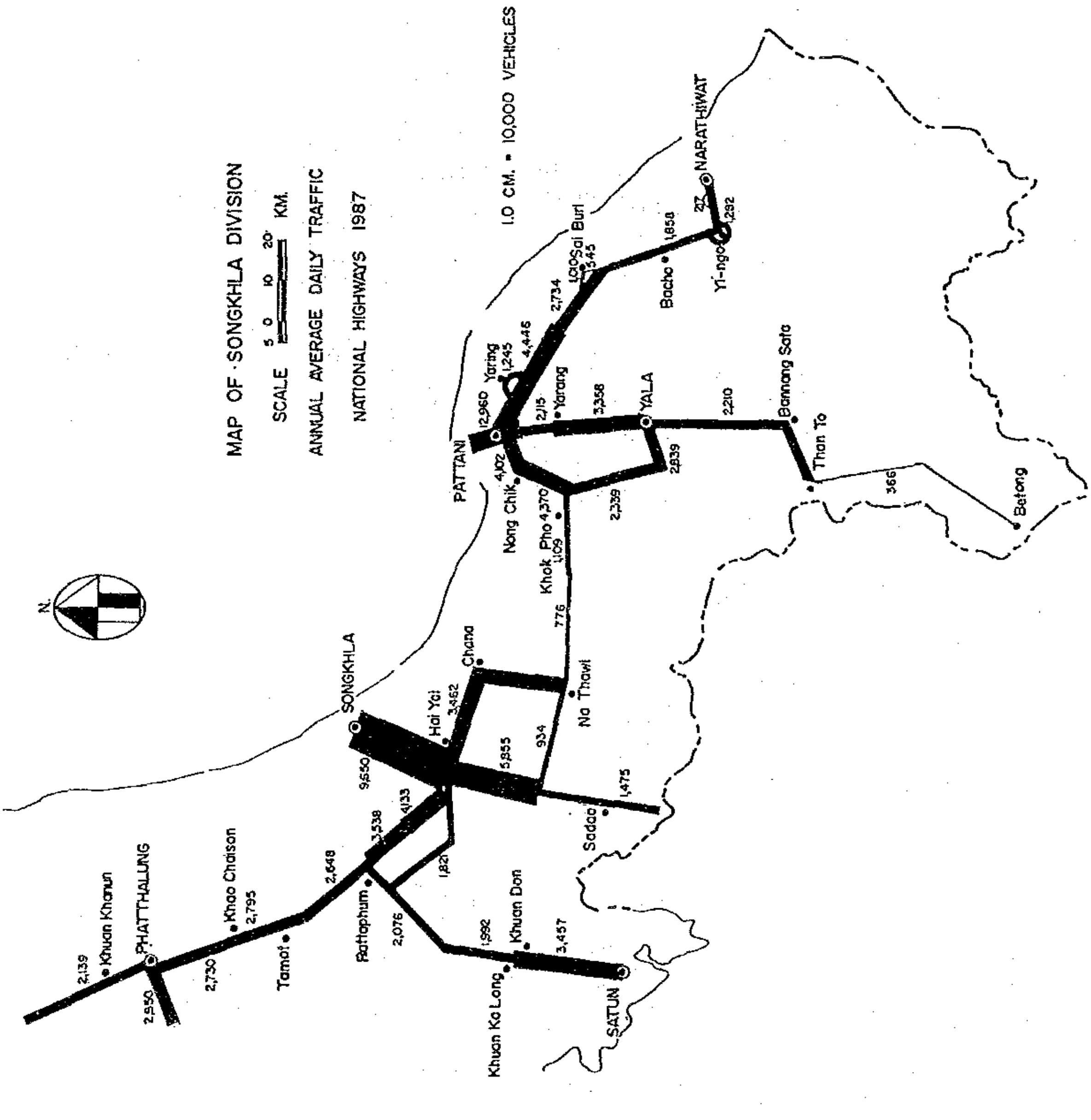
N.
MAP OF PRACHUAP KHIRI, KHAN DIVISION
SCALE 5 0 10 20 KM.
ANNUAL AVERAGE DAILY TRAFFIC
NATIONAL HIGHWAY 1987
0.5CM. = 10,000 VEHICLES
SOCIALIST REPUBIC OF THE UNION OF BURMA
Photharam
11,509
15,643
Bang Phae
2,833
13,222
1,399
3,533
8,571
RATCHABURI
8,445
4,661
Bang Khonthi
6,922
SAMUT SONGKHRAM
Pak Tho
7,523
Khao Yoi
10,322
PHETCHABURI
Ban Lat
10,532
Cha-am
6,435
Hua Hin
8,293
Pran Buri
4,803
Kui Buri
11,173
PRACHUAP KHIRI KHAN
2,582
4,852
Thap Sakae
3,819
Bang Saphan Noi
4,227
Tha Sae
1,974
4,853
CHUMPHON
5,408
Kra Buri
1,478
3,874
Sawi
1,283
4,601
RANONG
Lang Suan
1,539
3,235
Lamae
1,187
Kapoe
607
Khura Buri

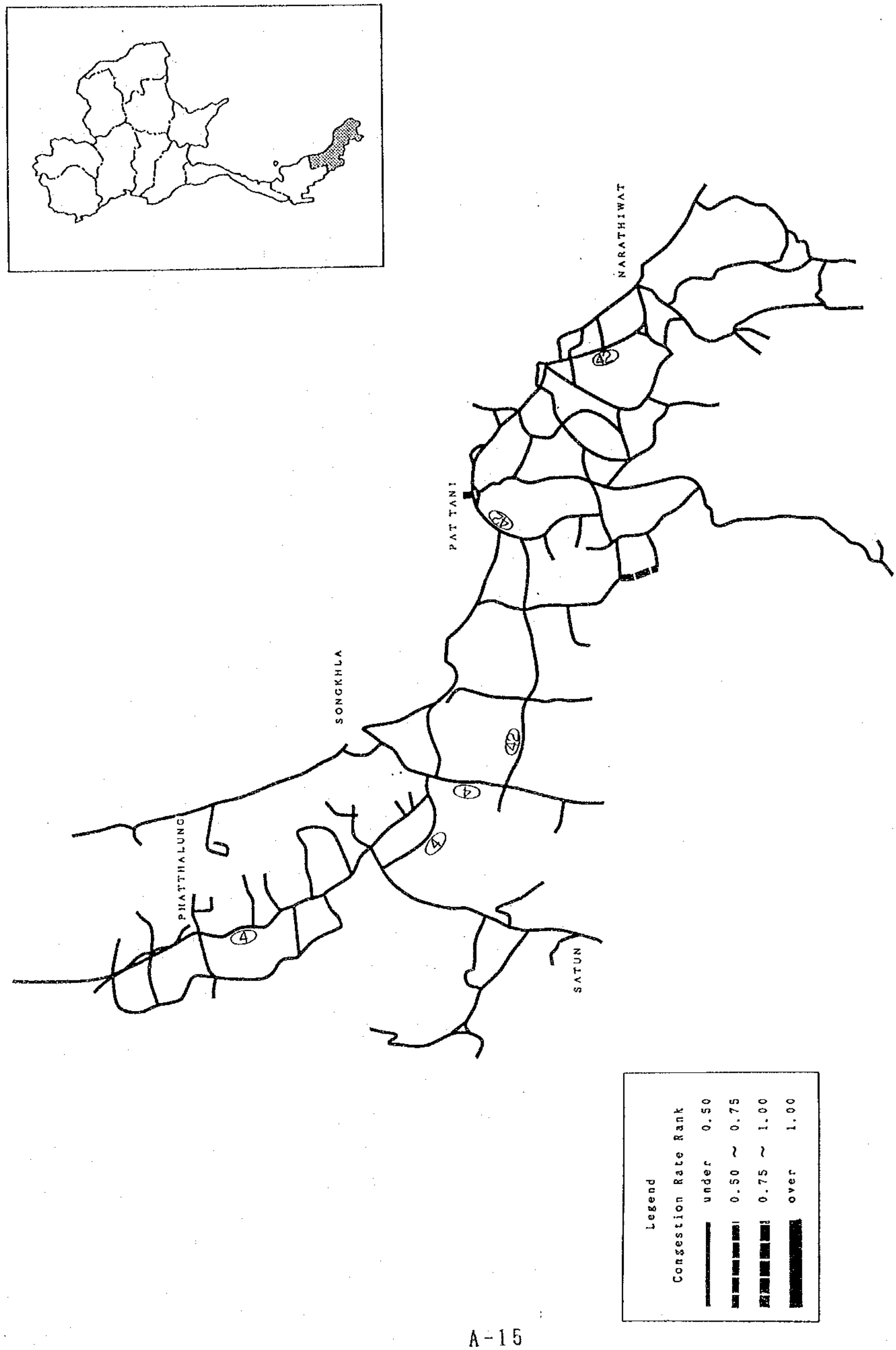



MAP OF NAKHON SI THAMMARAT DIVISION

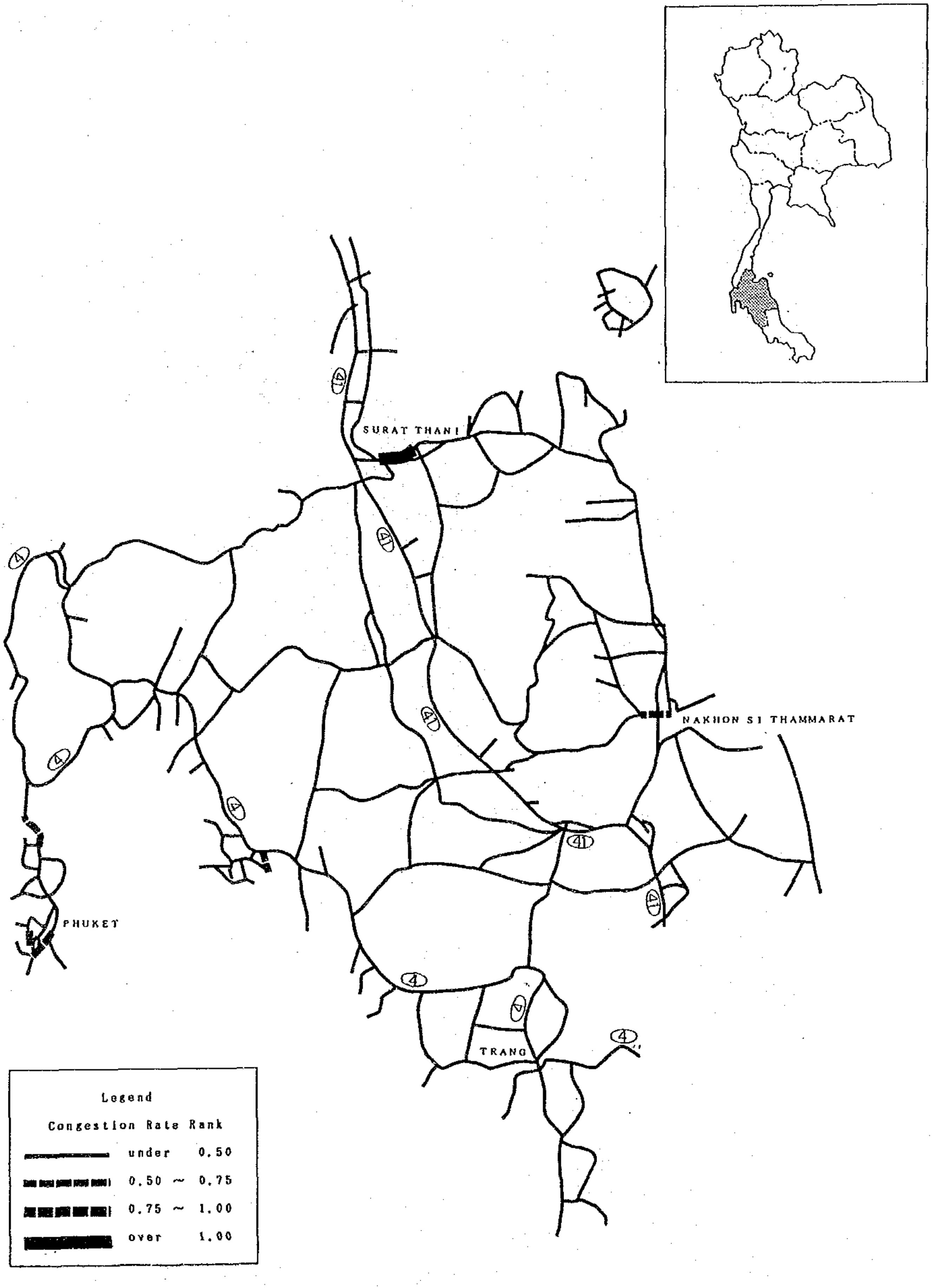
ANNUAL AVERAGE DAILY TRAFFIC

NATIONAL HIGHWAYS 1987


MAP OF SONGKHLA DIVISION
SCALE 5 0 10 20 KM.
ANNUAL AVERAGE DAILY TRAFFIC
NATIONAL HIGHWAYS 1987
1.0 CM. = 10,000 VEHICLES
N.
SONGKHLA
PATTANI
NARATHIWAT
YALA
SATUN
PHATTHALUNG
Khuan Khanun
Khao Chaison
Tamot
Rattaphum
Khuan Don
Khuan Ka Long
Hai Yai
Chana
Na Thawi
Sadao
Khok Pho
Nong Chik
Yaring
Yarang
Sai Buri
Bacho
Yi-ngo
Bannang Sata
Than To
Betong
2,139
2,950
2,730
2,795
2,648
3,538
4,133
9,650
1,821
2,076
1,992
3,457
3,462
5,855
934
1,475
776
1,109
4,370
4,102
12,960
2,115
3,358
2,839
2,339
2,210
366
1,245
4,446
2,734
1,100
3,45
1,858
27
1,292

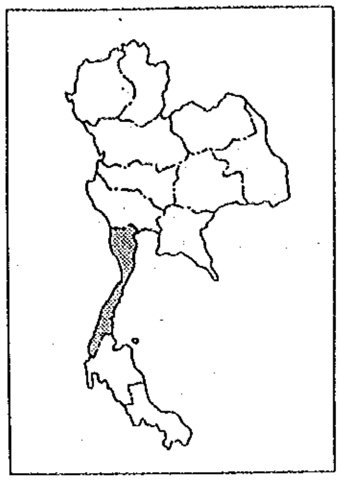


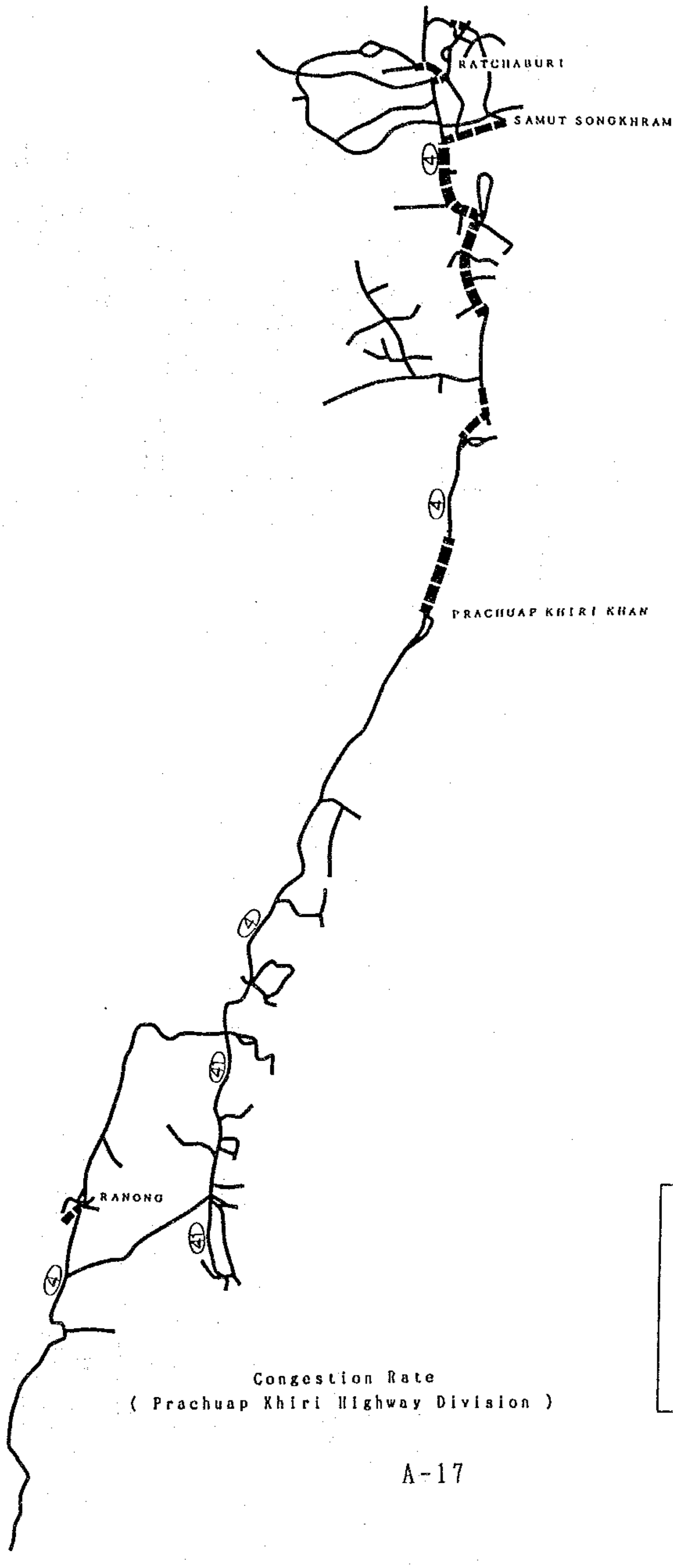

Congestion Rate ( Song Khla Highway Division )



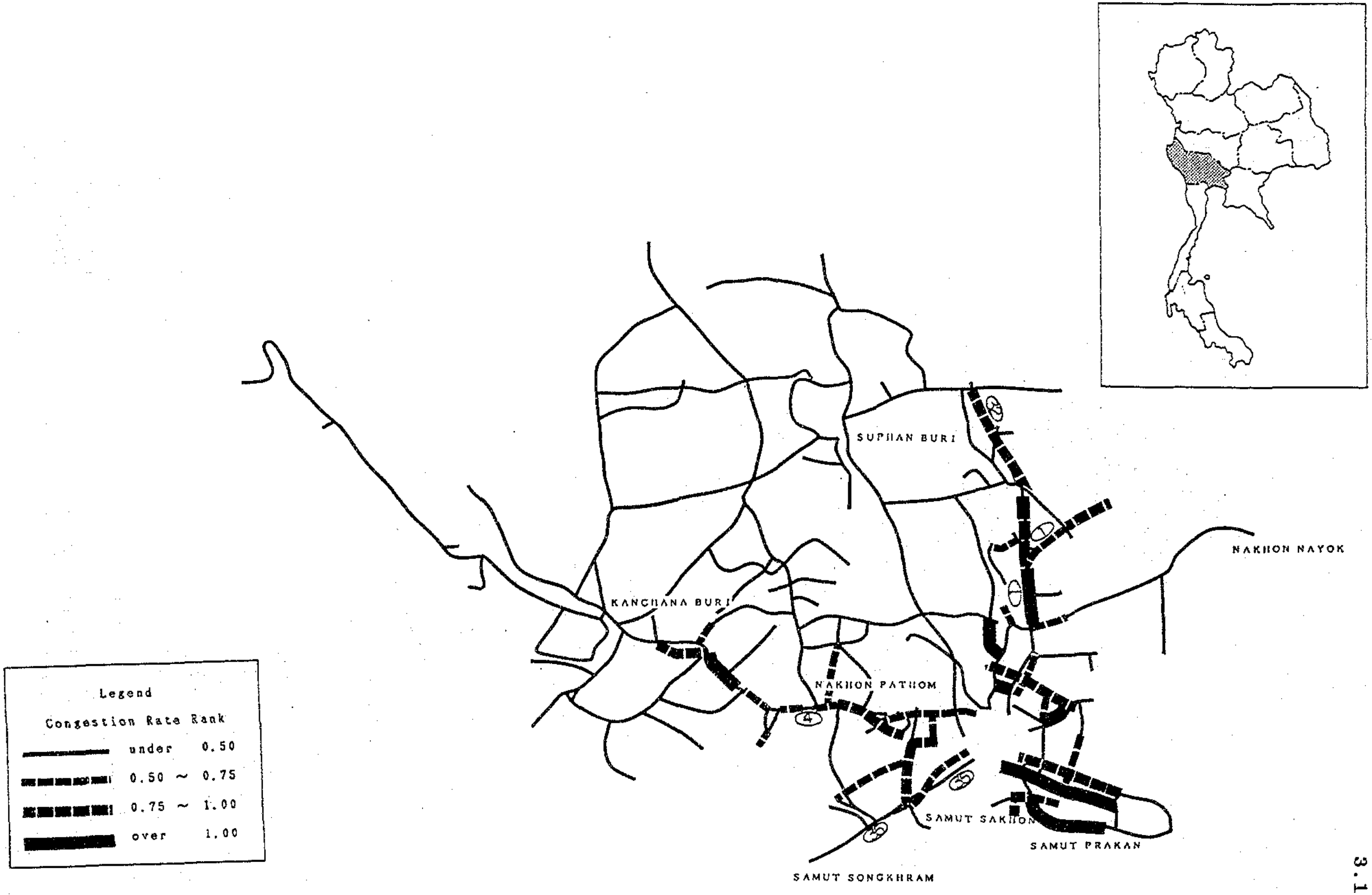

Congestion Rate ( Nakhon Si Thammarat Highway Division )

3.1 (3)

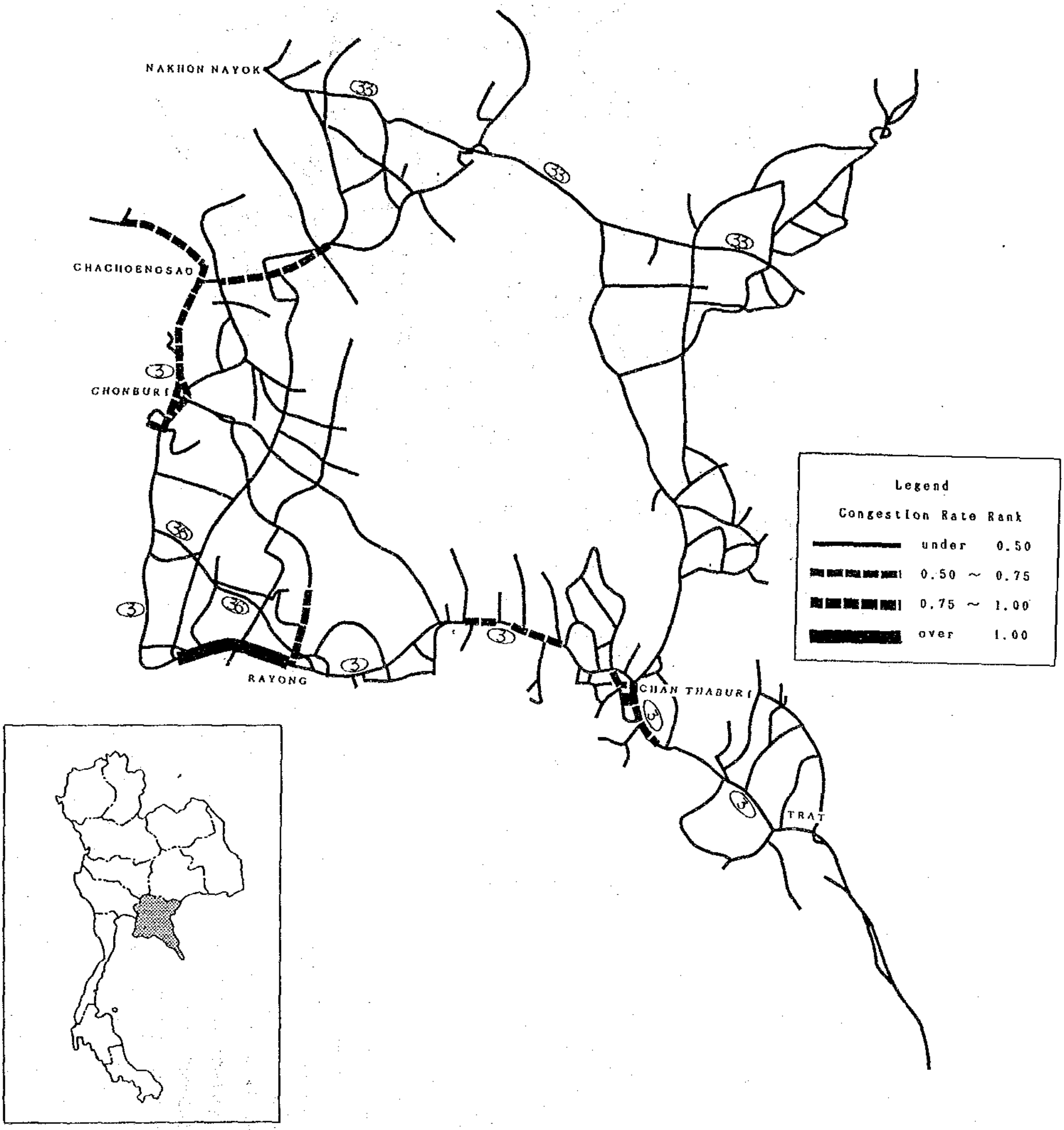




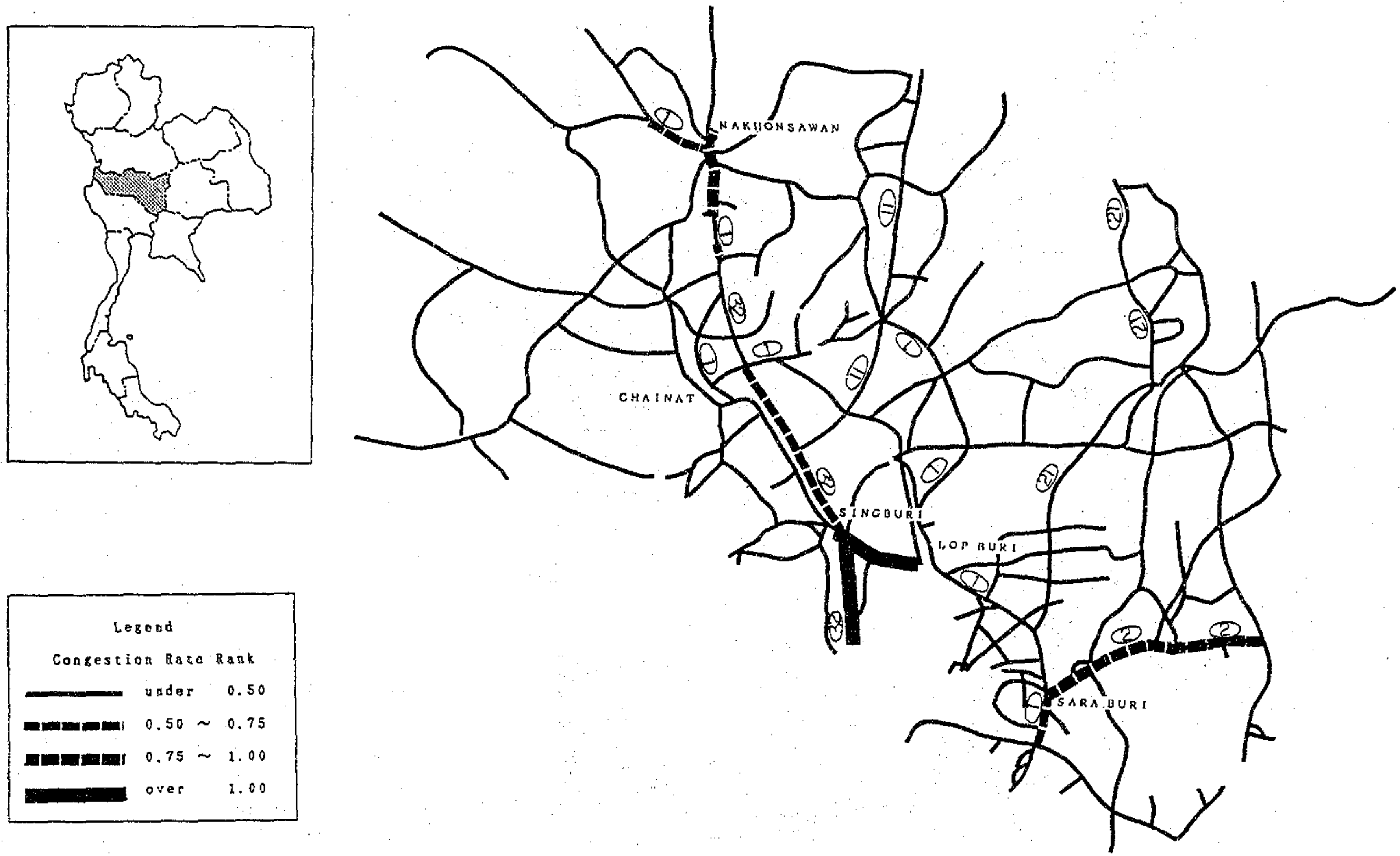

Congestion Rate
( Prachuap Khiri Highway Division )



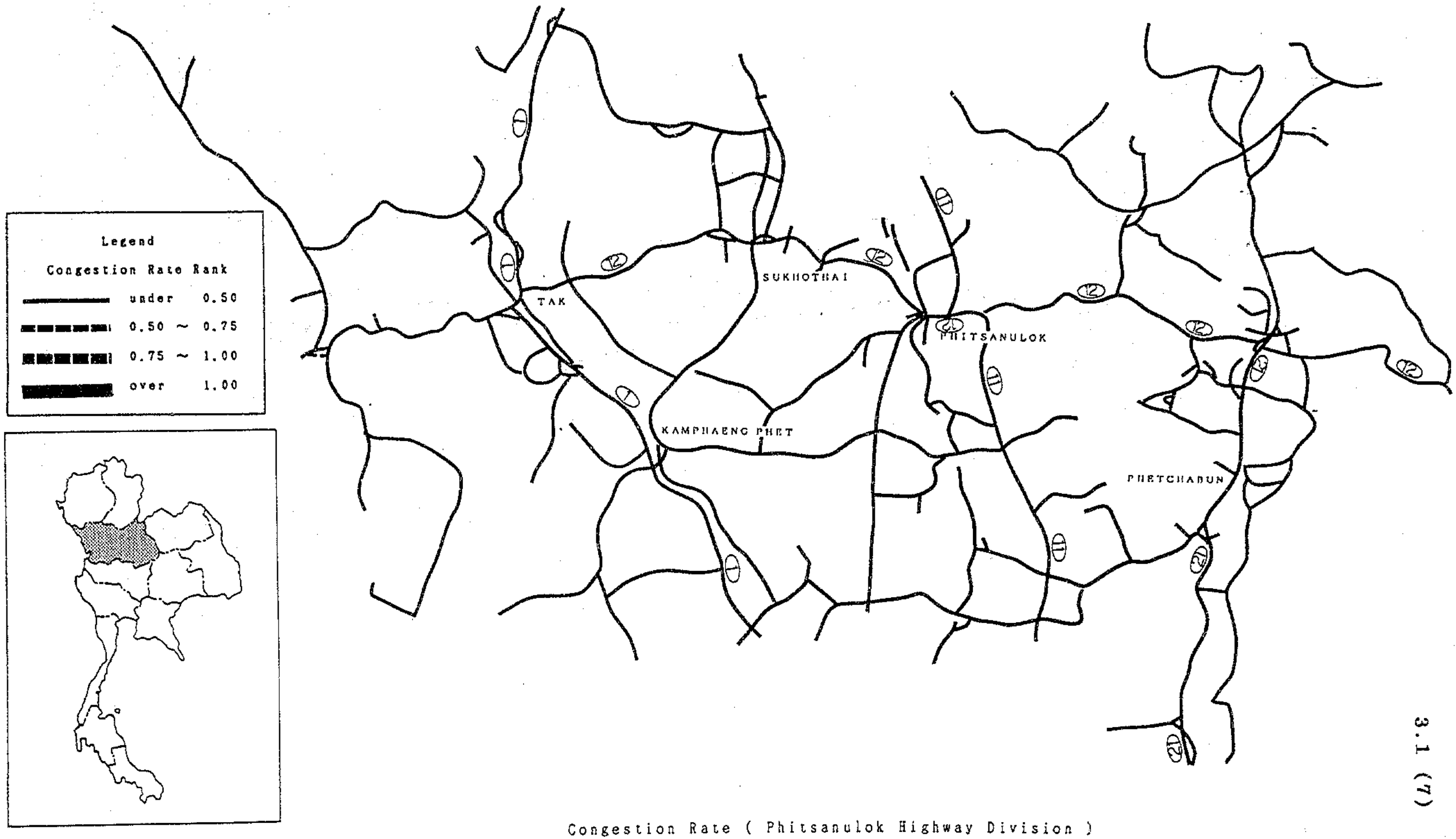

Congestion Rate ( Bangkok Highway Division )



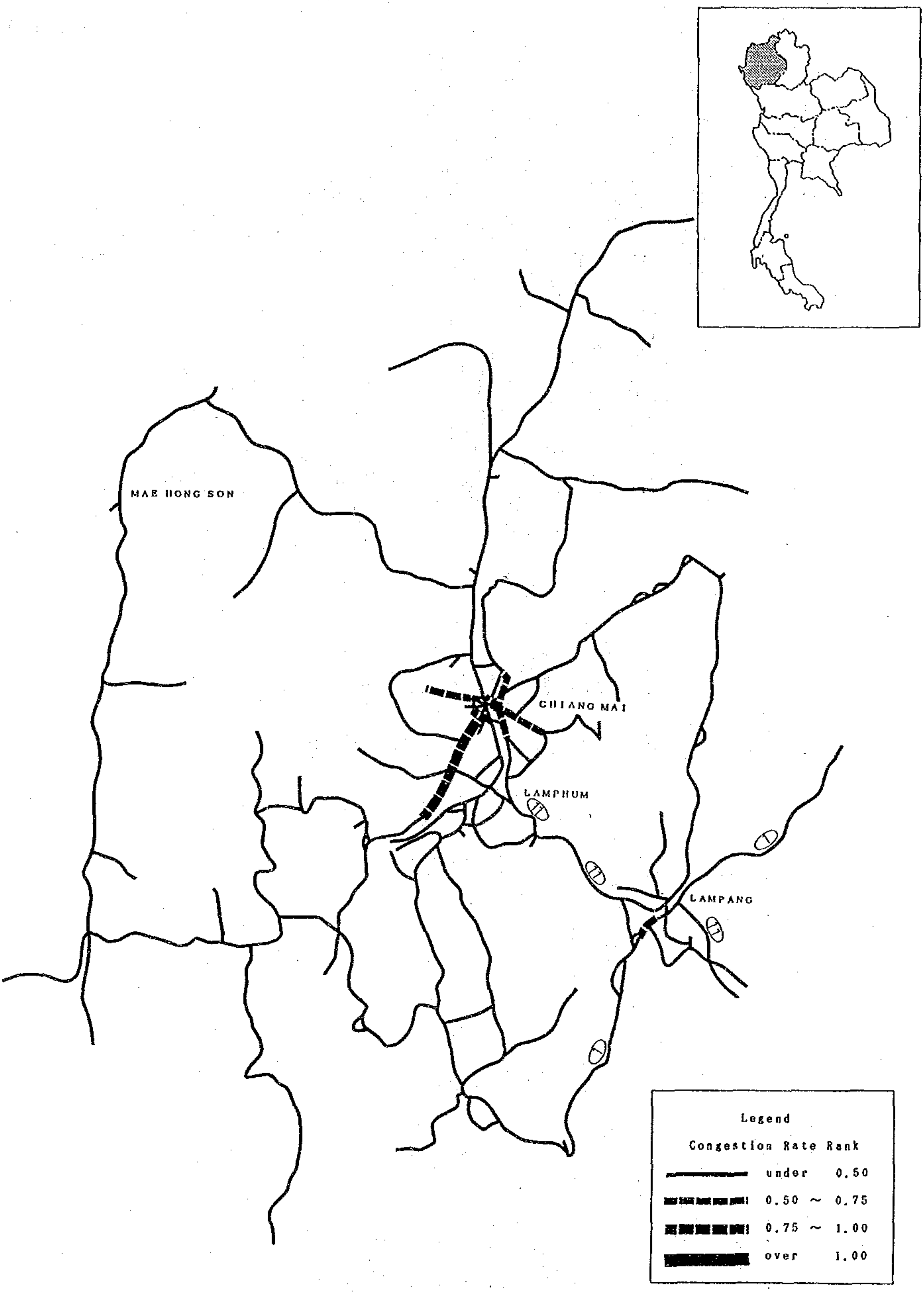

Congestion Rate ( Chachoengsao Highway Division )



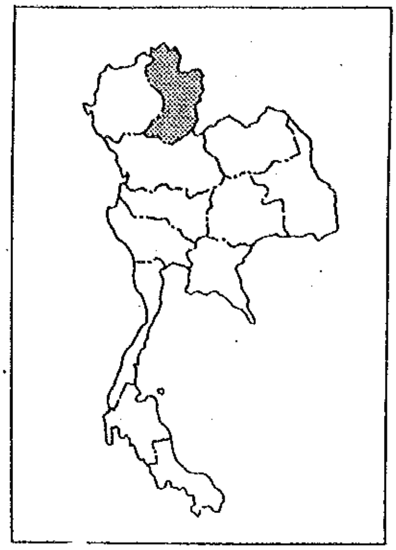

Congestion Rate ( Lop Buri Highway Division )

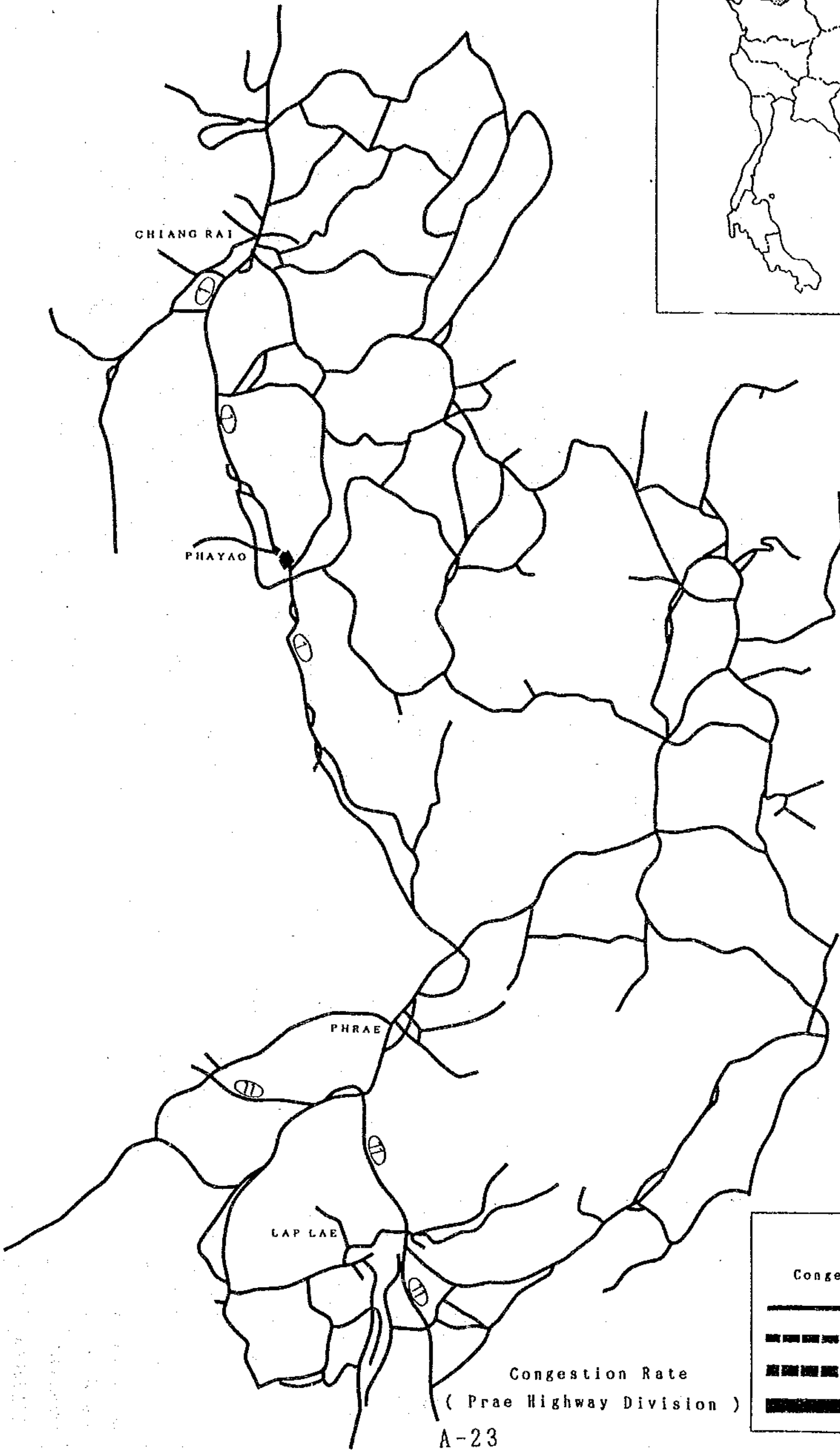



Congestion Rate ( Phitsanulok Highway Division )

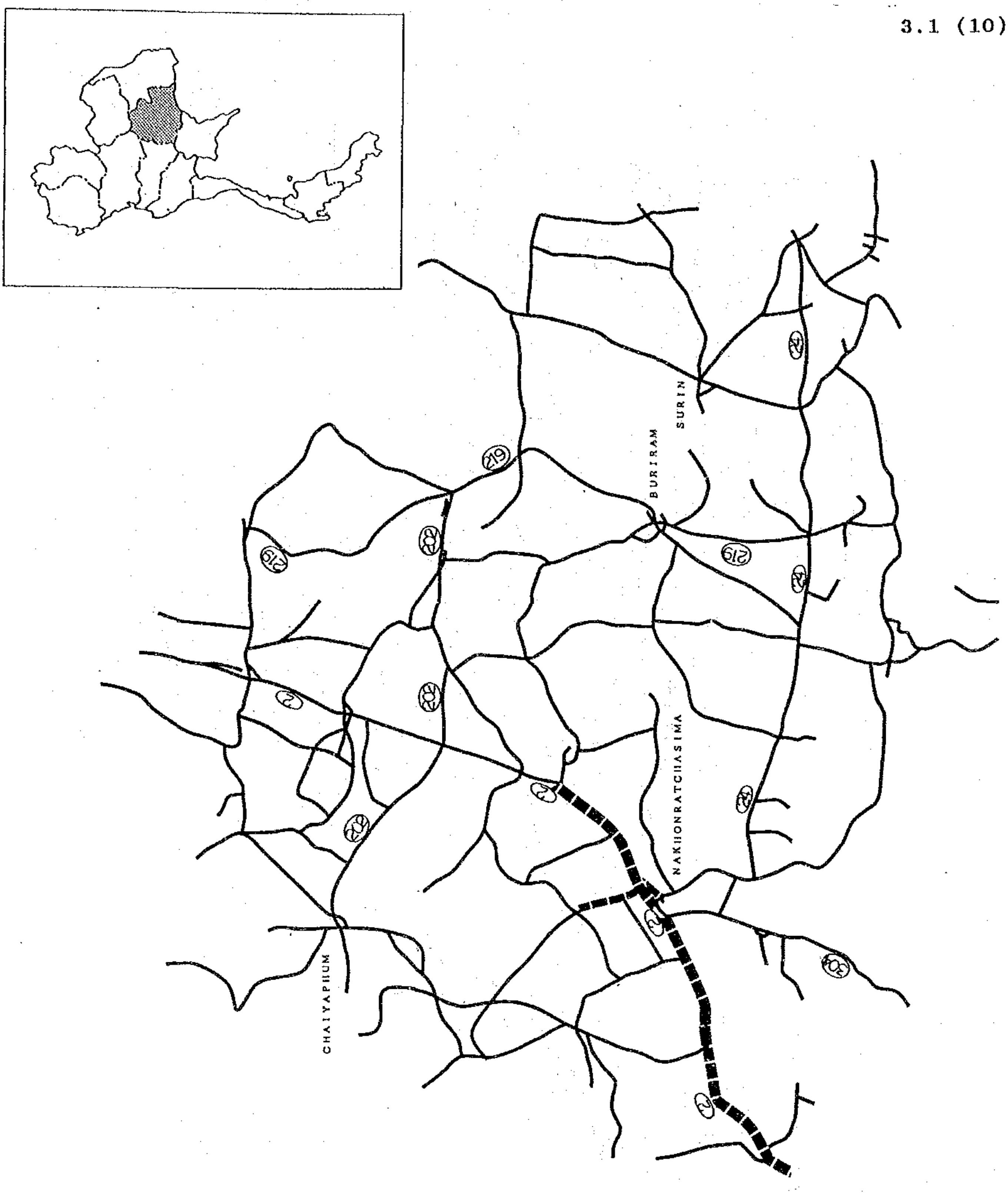


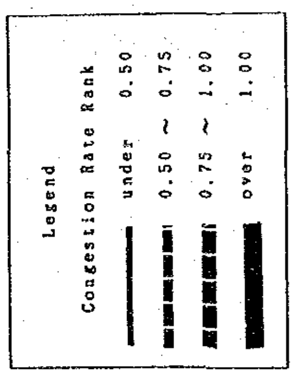

Congestion Rate ( Chang Mai Highway Division )



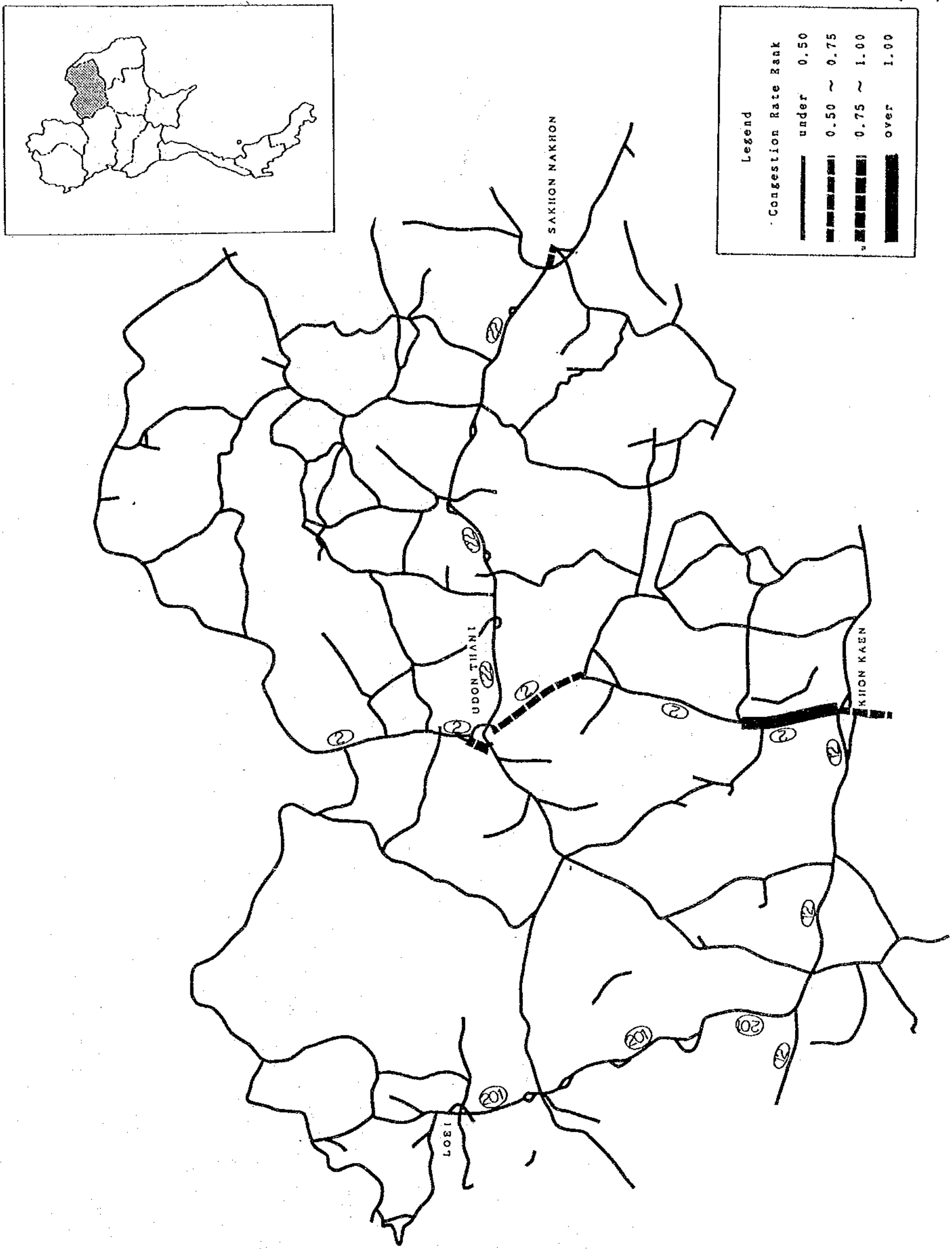



Congestion Rate
( Prae Highway Division )

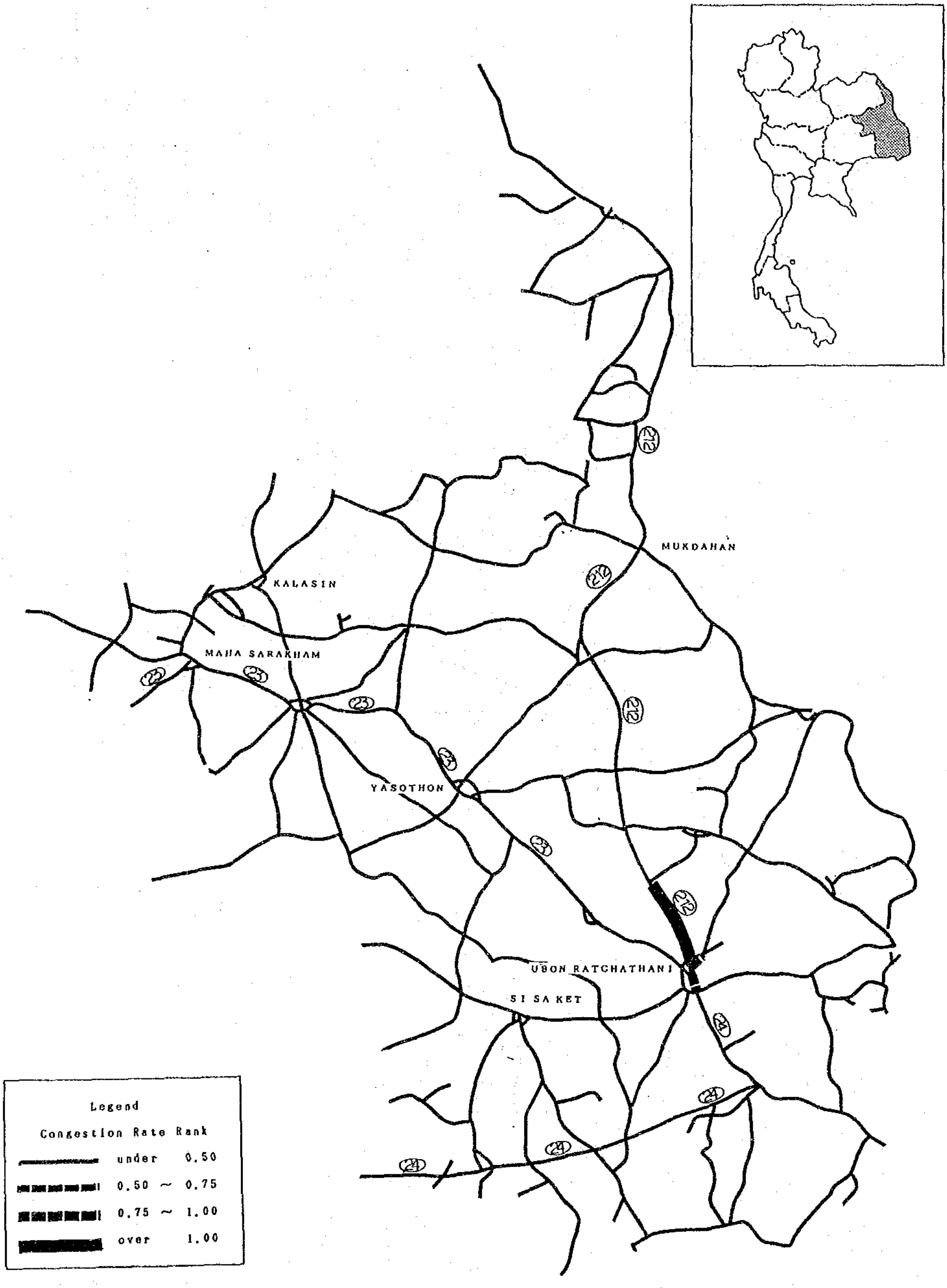



Congestion Rate ( Nakhon Ratchasima Highway Division )

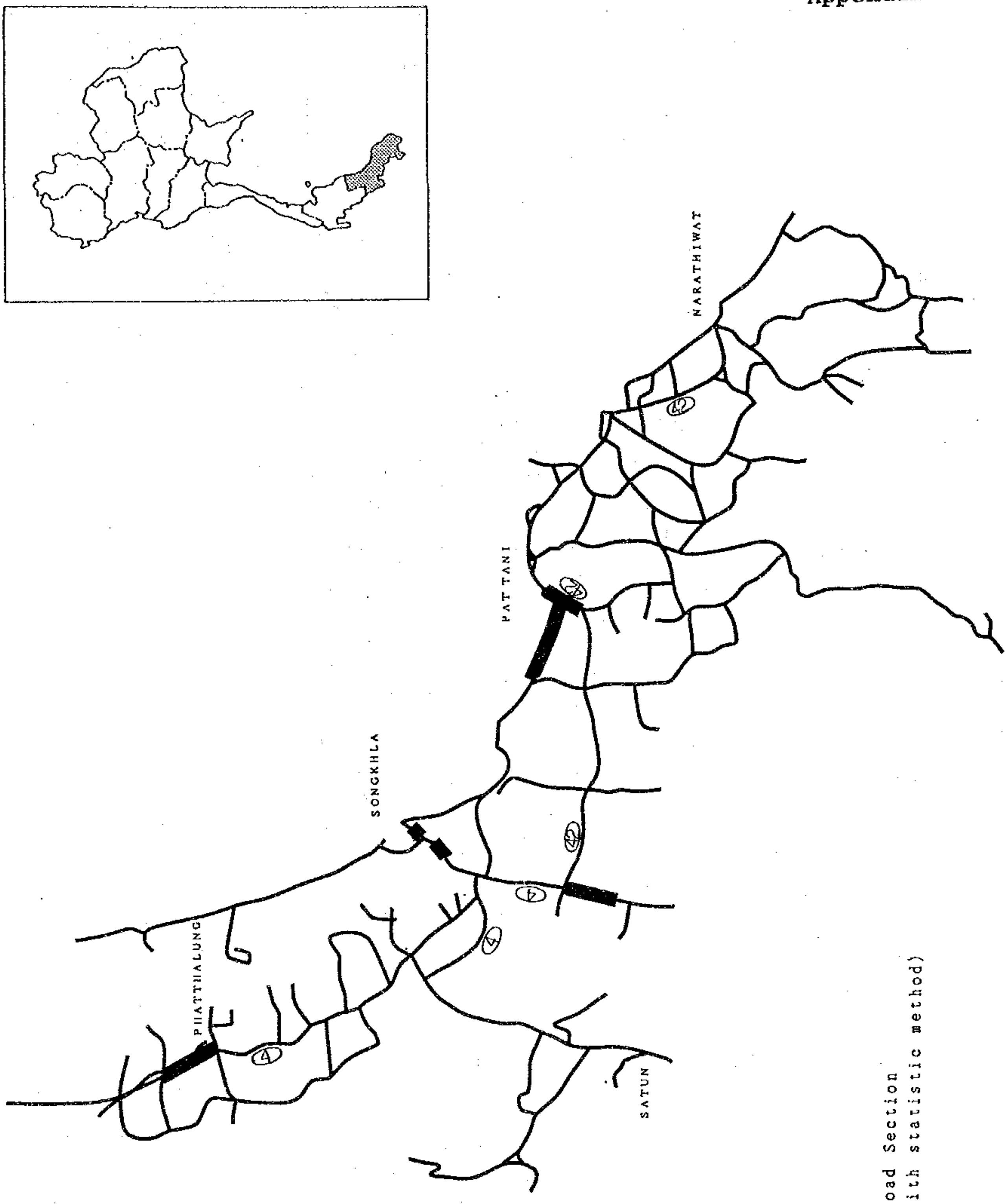



Congestion Rate ( Khon Kaen Highway Division )



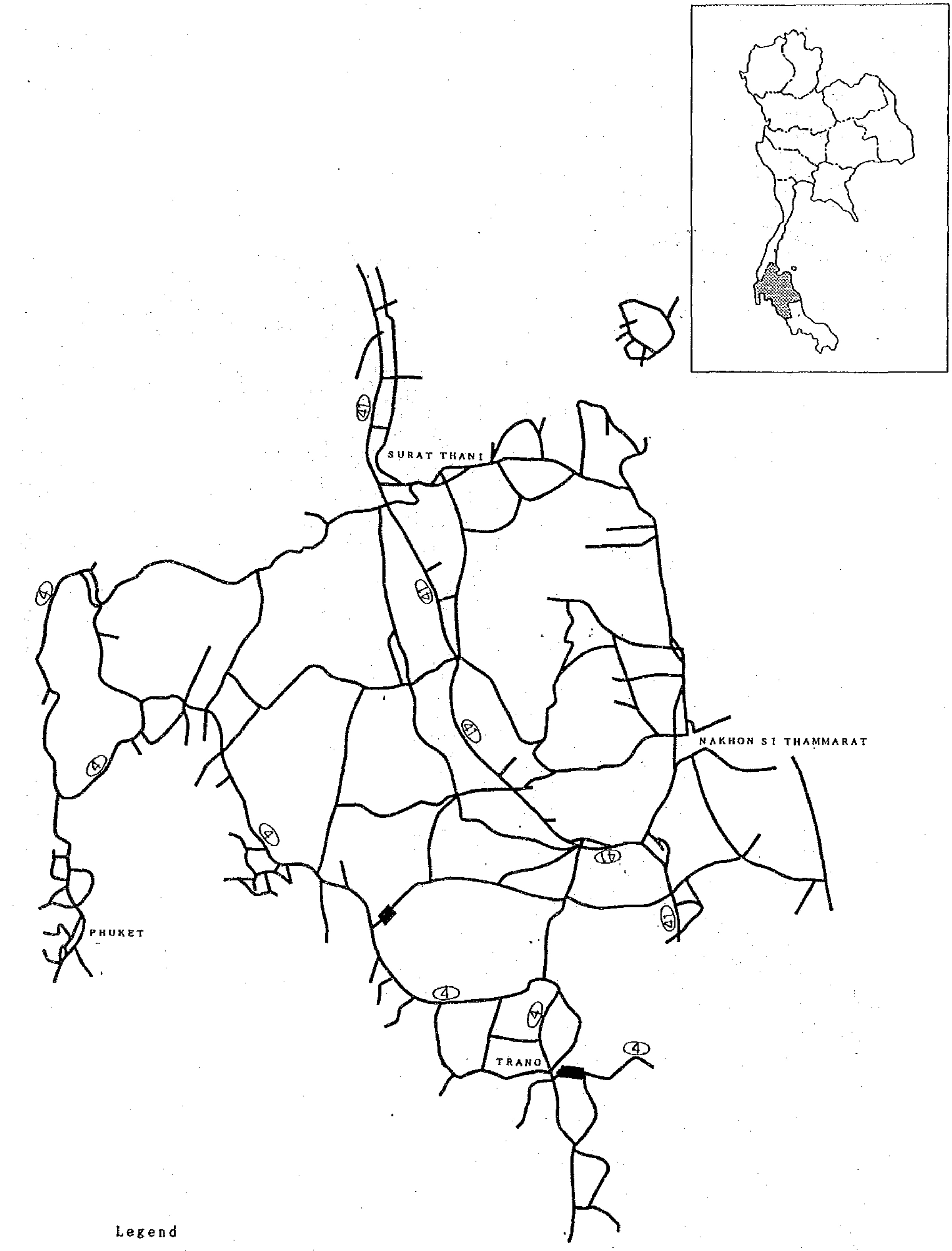

Congestion Rate ( Ubonratchathani Highway Division )

Hazardous Road Section ( Song Khla Highway Division )




Legend

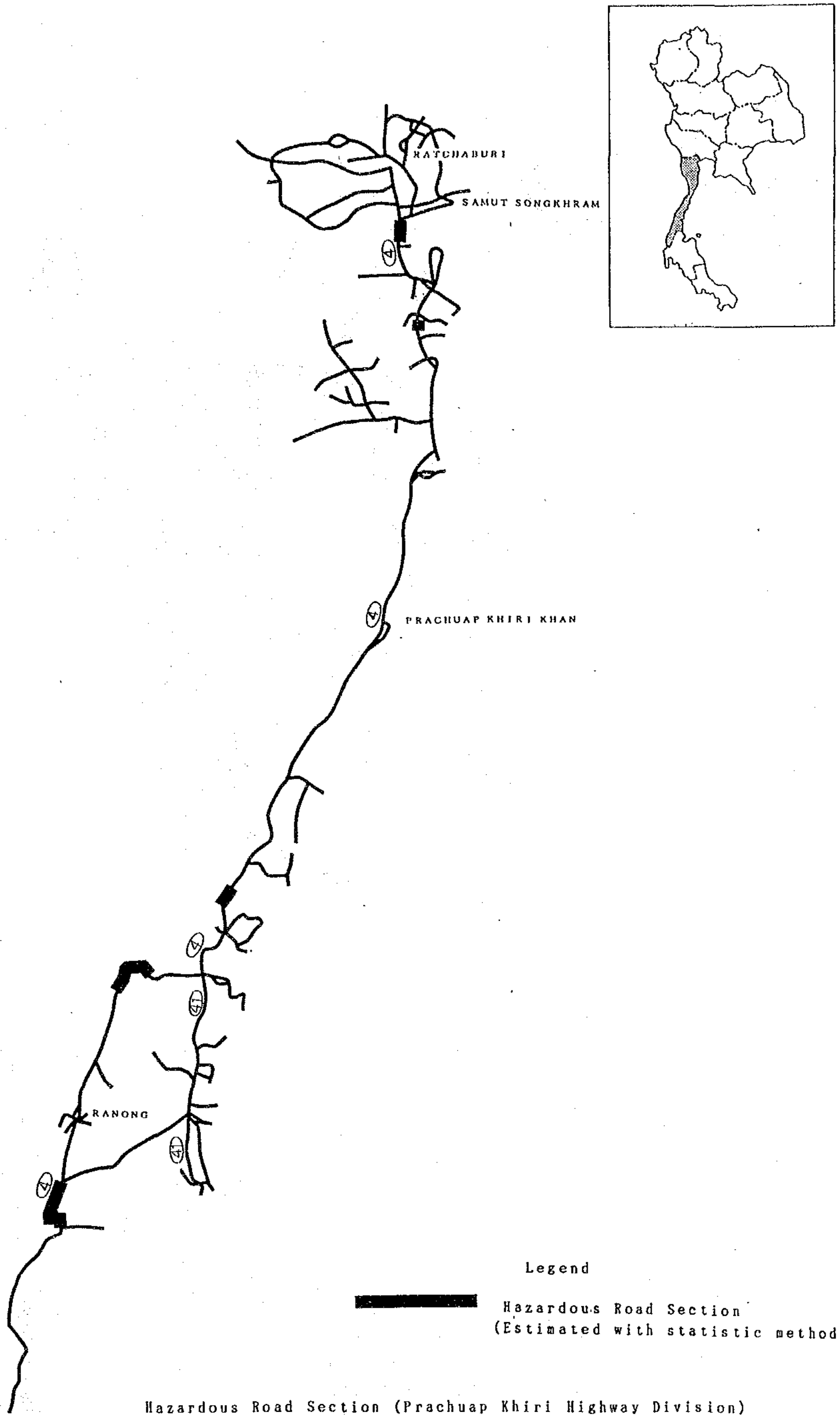
Hazardous Road Section
(Estimated with statistic method)




Legend

Hazardous Road Section
(Estimated with statistic method)

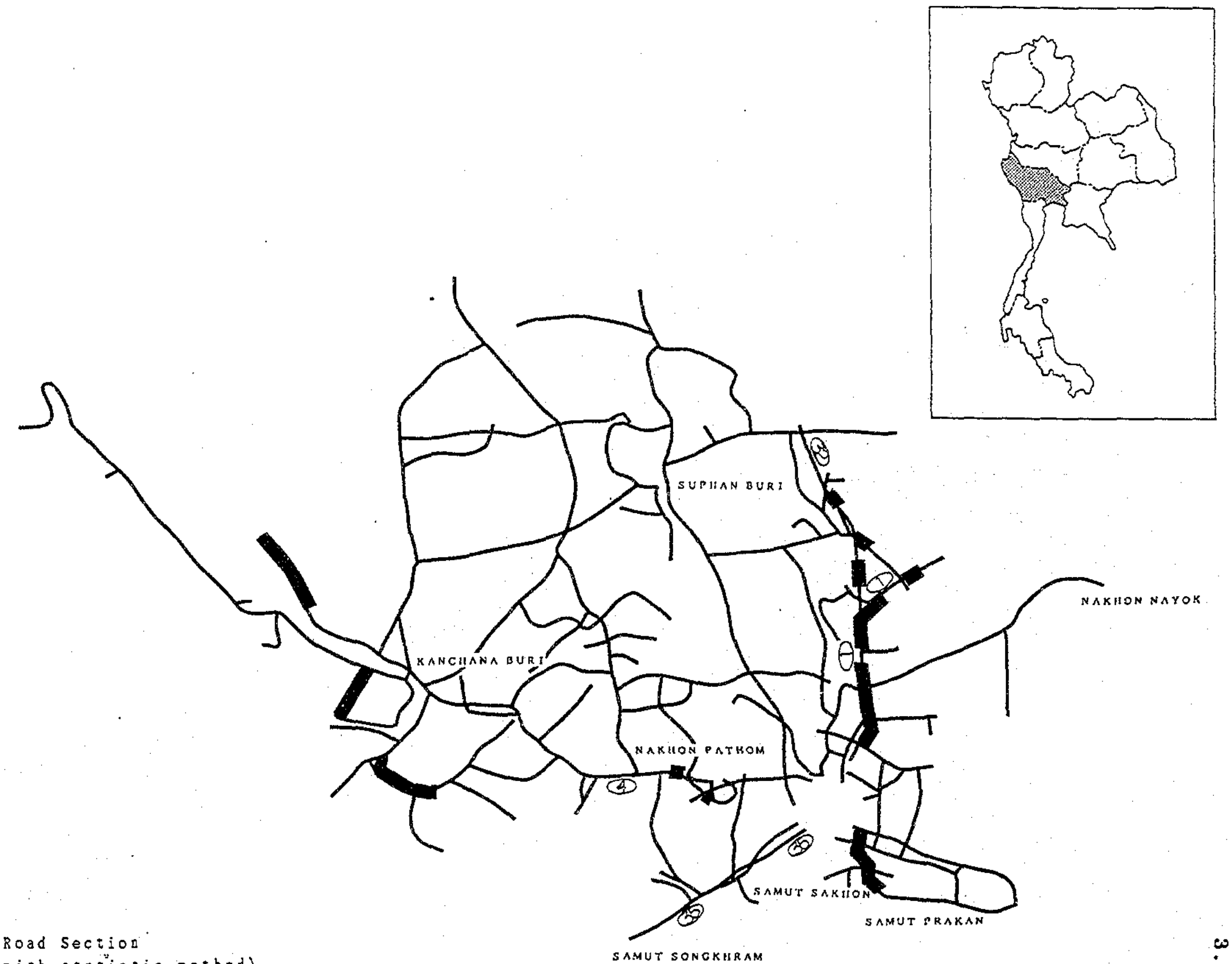
Hazardous Road Section
( Nakhon Si Thammarat Highway Division )




Legend

Hazardous Road Section
(Estimated with statistic method)

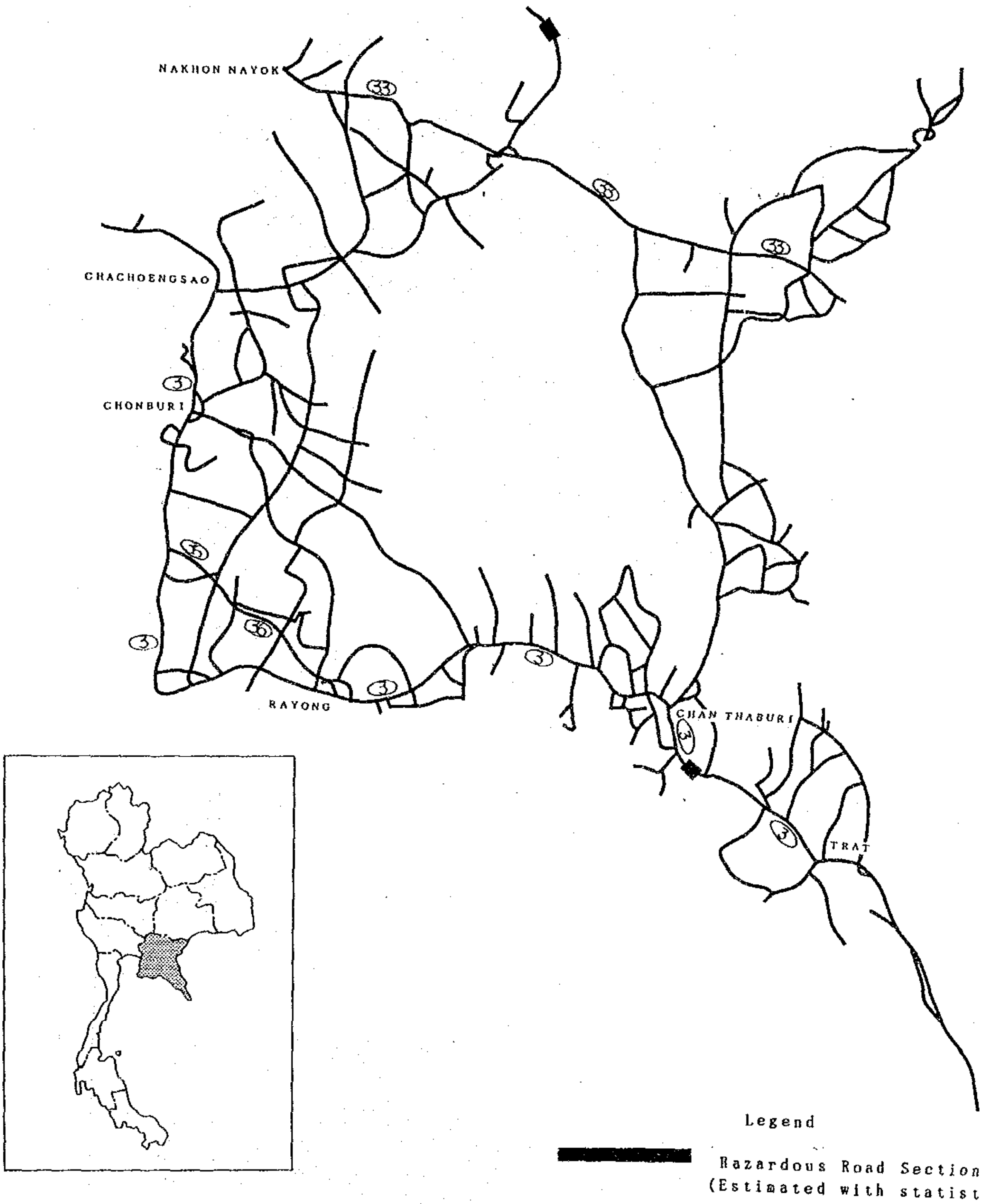
Hazardous Road Section (Prachuap Khiri Highway Division)




Legend

Hazardous Road Section
(Estimated with statistic method)

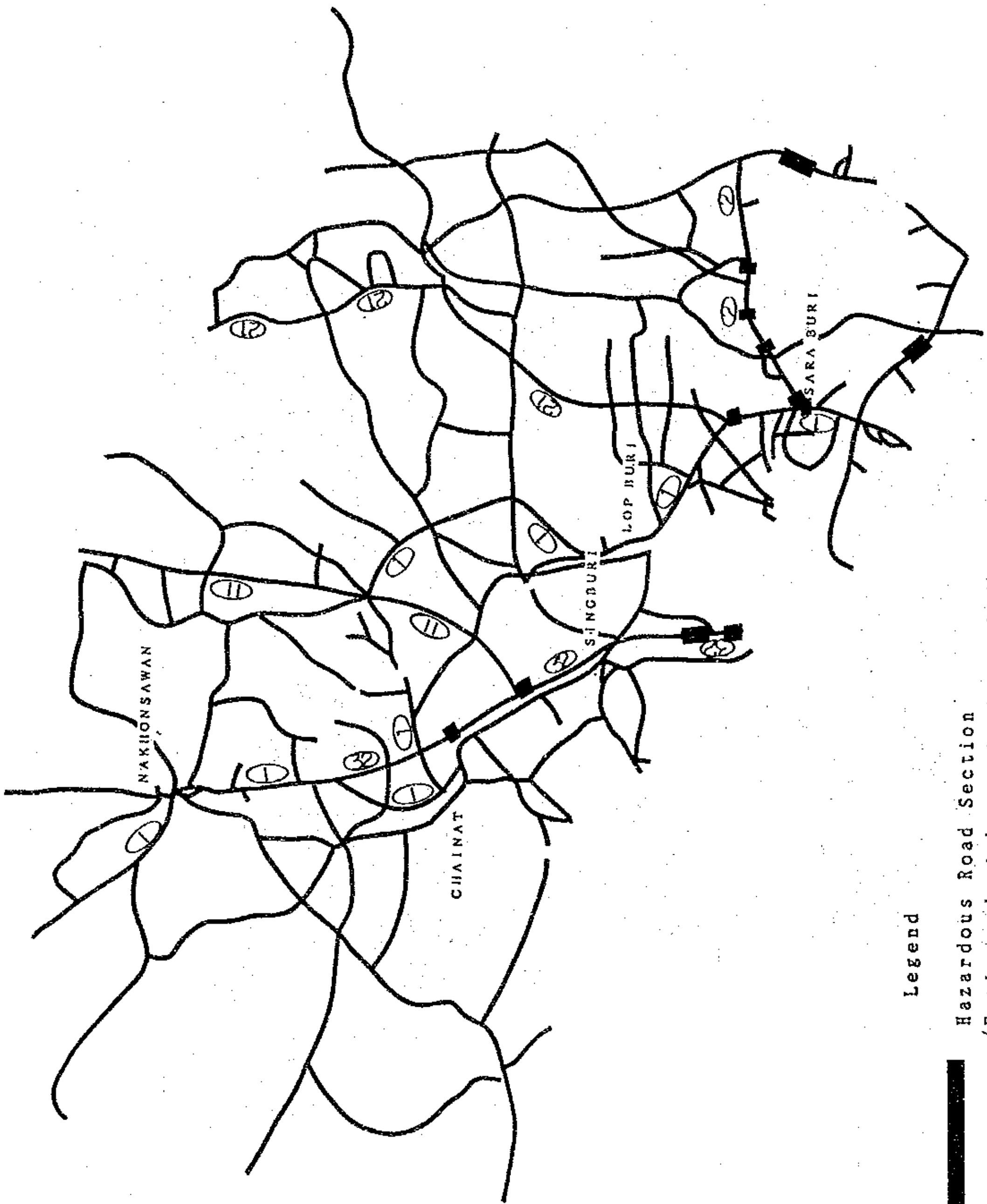
Hazardous Road Section( Bangkok Highway Division )




Legend

Hazardous Road Section
(Estimated with statistic method)

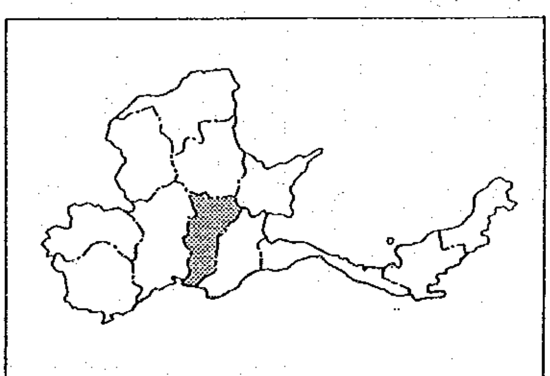
Hazardous Road Section ( Chachoengsao Highway Division )

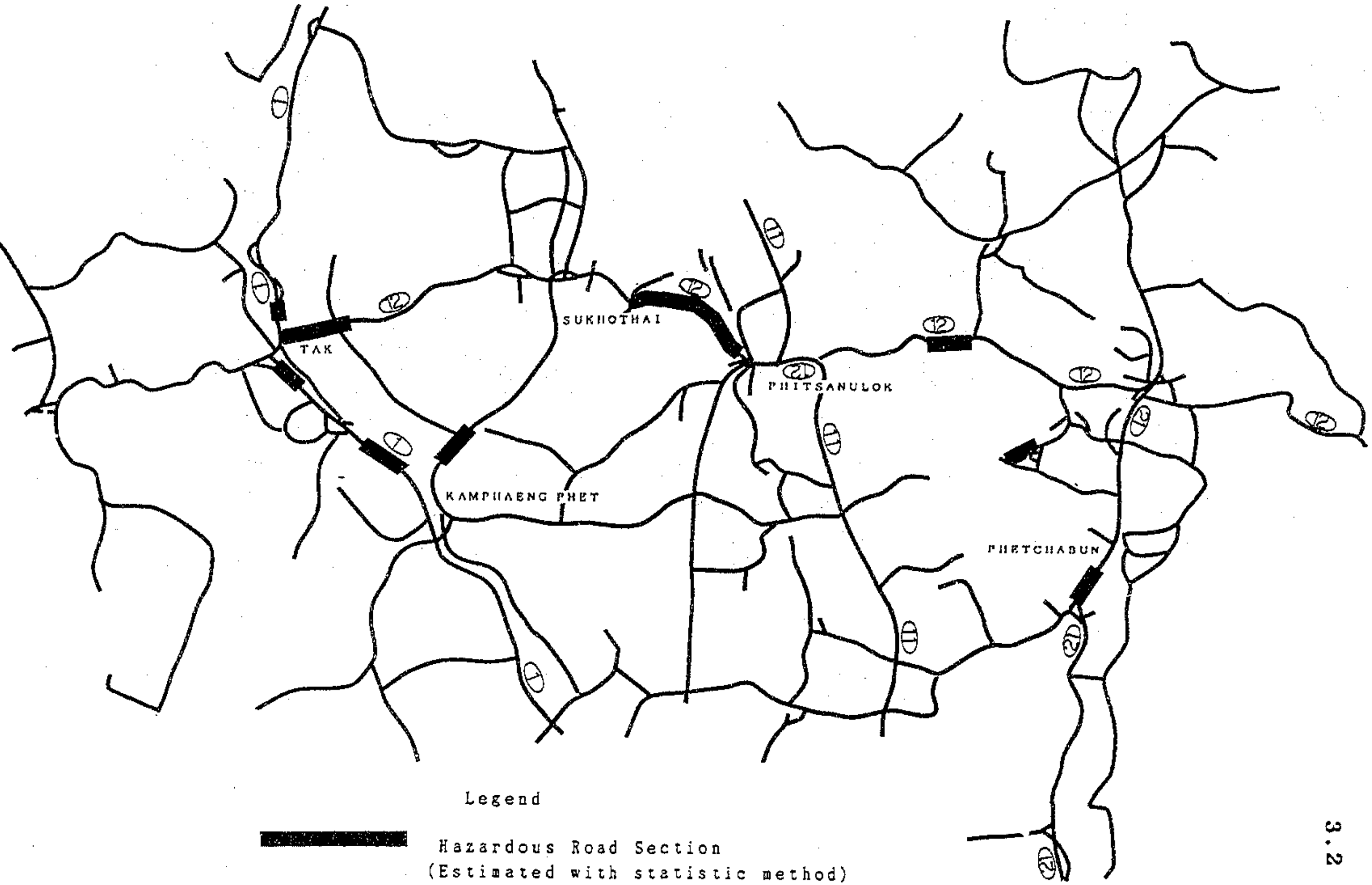



Legend

Hazardous Road Section
(Estimated with statistic method)

Hazardous Road Section ( Lop Buri Highway Division )

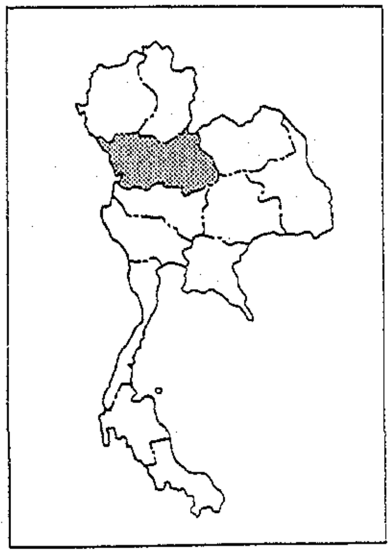


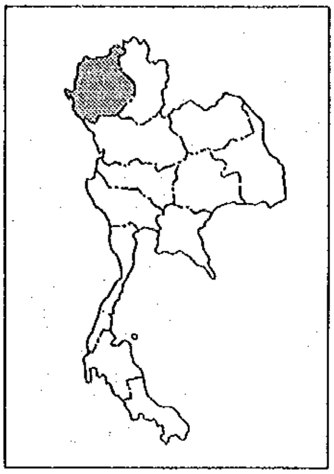



Legend

Hazardous Road Section
(Estimated with statistic method)

Hazardous Road Section ( Phitsanulok Highway Division )

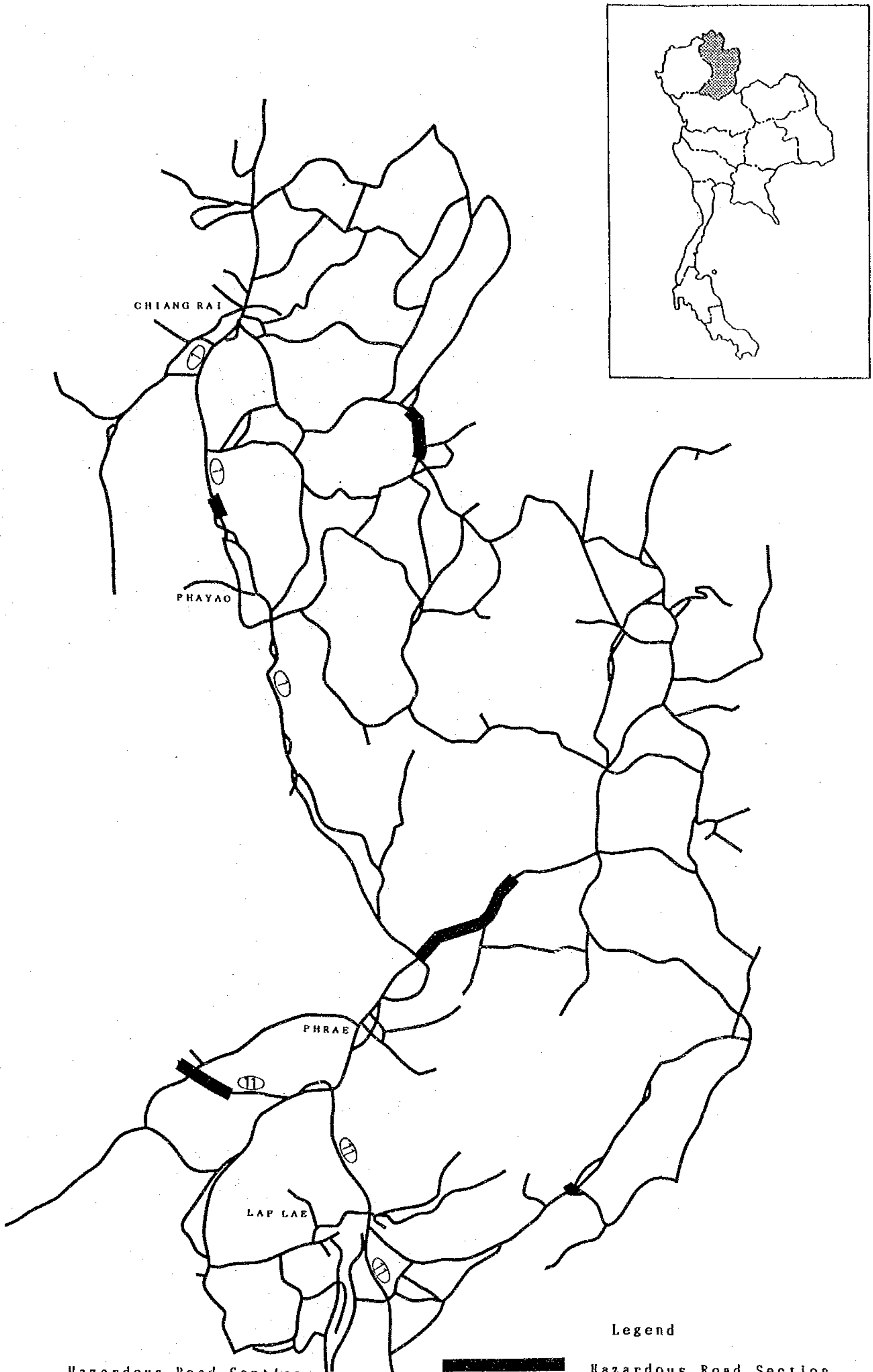





Legend

Hazardous Road Section
(Estimated with statistic method)

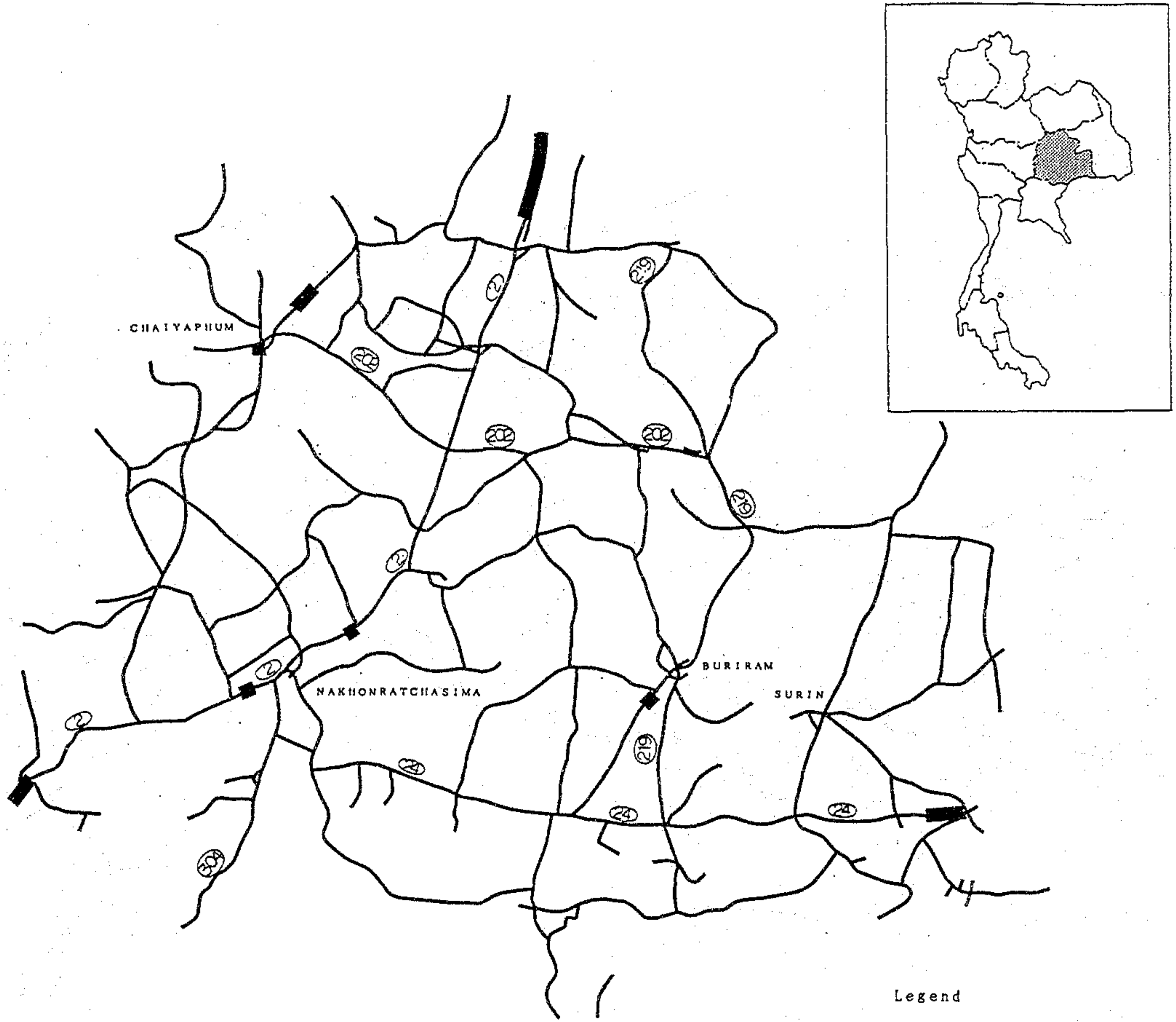
Hazardous Road Section ( Chang Mai Highway Division )




Legend

Hazardous Road Section
(Estimated with statistic method)

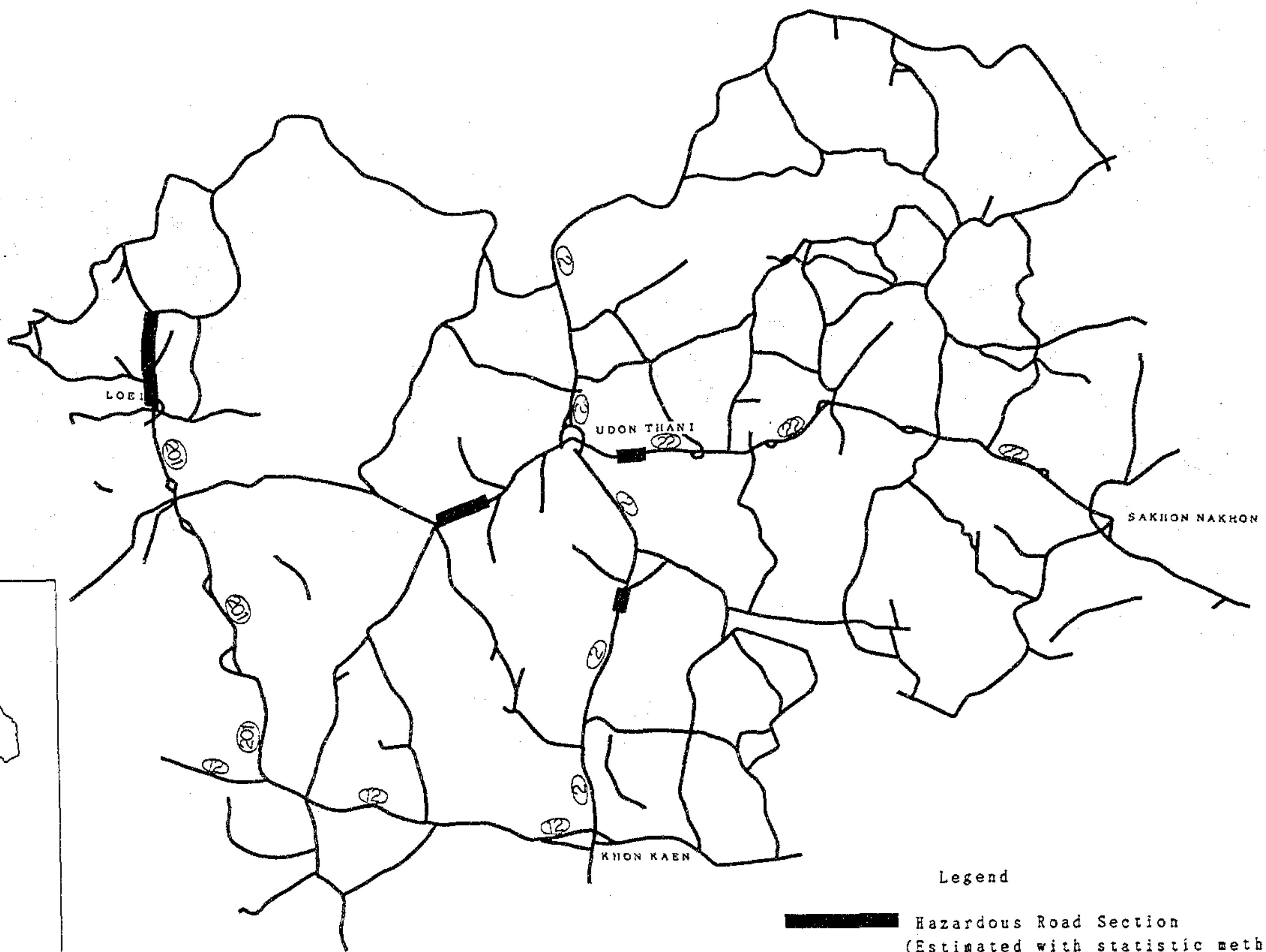
Hazardous Road Section
( Prae Highway Division )

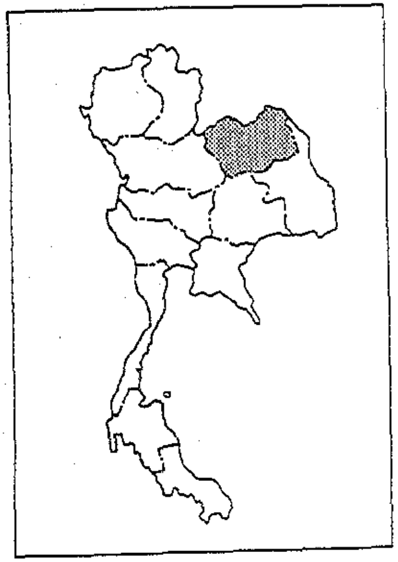



Legend

Hazardous Road Section
( Nakhon Ratchasima Highway Division )

Hazardous Road Section
(Estimated with statistic method)

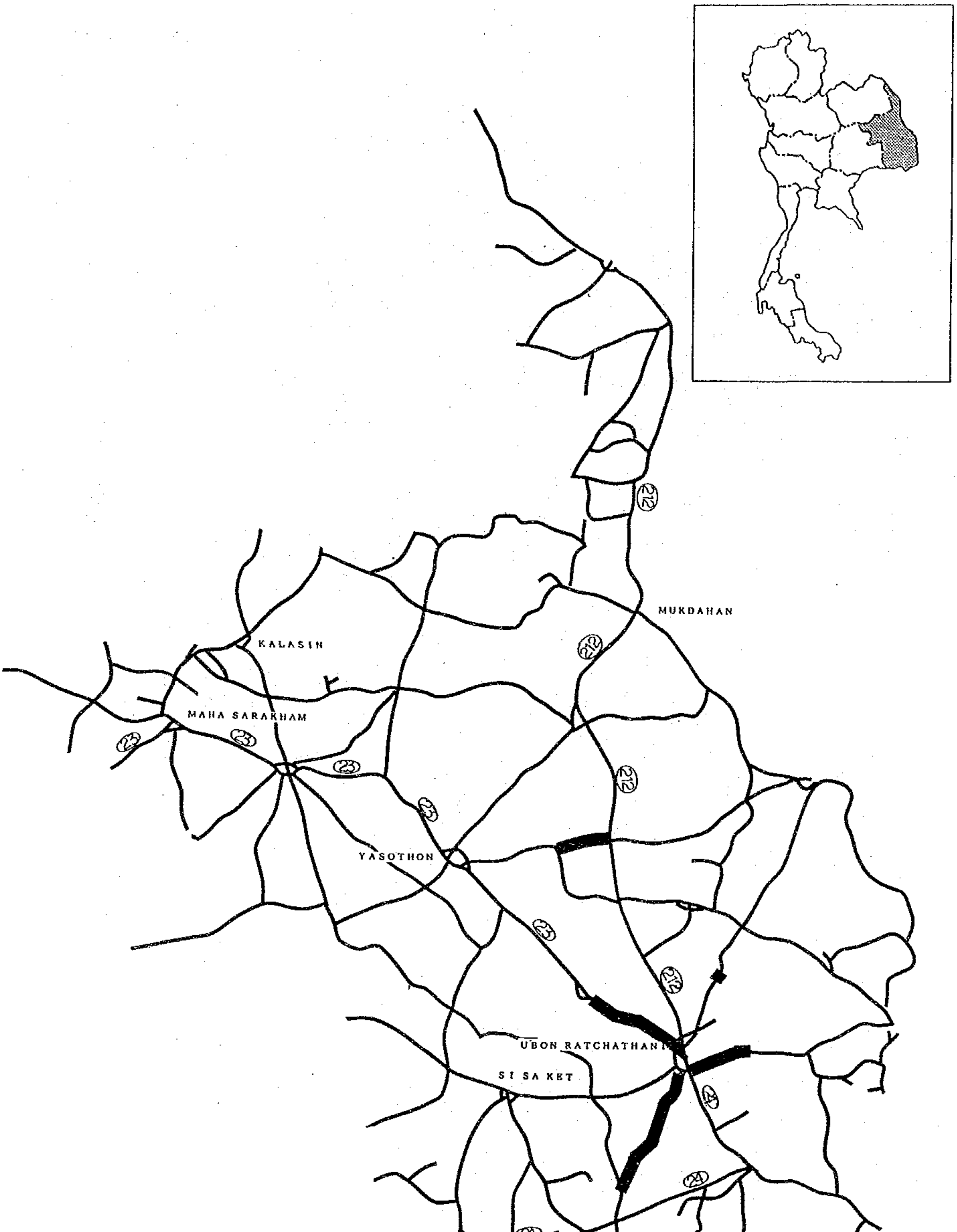


Legend

Hazardous Road Section
(Estimated with statistic method)

Hazardous Road Section ( Khon Kaen Highway Division )




Legend

Hazardous Road Section
(Estimated with statistic method)

Hazardous Road Section
( Ubonratchathani Highway Division )

# Questionnaire for the District Engineers (1)

| (1) | (2) | (3) | | (4) | | | (5) | | | | | | | | (6) | | (7) | | | (8) | | | | (9) | | Remarks (Proposal of Safety Treatment) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data No. | Route No. | Location | | Type of Problem | | | Cause of Problem | | | | | | | | Degree of Problem | | Number of Lane | | | Alignment | | | | Abutting Land Use | | |
| | | Control Section | Kilopost ( - ) | Traffic Congestion | Traffic Accident | Others | Traffic Volume | Heavy Vehicle | Bus | Parking Vehicle | Pedestrians | Bicycle | Motorcycle | Others | Very High | High | 2 | 4 more | | Horizontal | | Vertical | | Built up | Others | |
| | | | | | | | | | | | | | | | | | | Devided | Undev. | Good | Poor | Good | Poor | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |

# Questionnaire for the District Engineers (2)

| (1) | (2) | | (4) | (5) | | (6) | | | | | | | (7) | | | (8) | | | | | | | | (9) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data No. | Location | | Shape (+ , O T , Y) | No. of Lane | | Existing of Treatment | | | | | | | Type of Problem | | | Cause of Problem | | | | | | | | Degree of Problem | | Remark (Proposal of Operation Treatment) |
| | DOH v.s. DOH | DOH v.s. Other | | DOH Road | Other Road | Traffic Signal | Channelization | | Lighting | Right Lane | Left Lane | None | Traffic Congestion | Traffic Accident | Others | Traffic Volume | Heavy Vehicle | Bus | Parking Vehicle | Pedestrians | Bicycle | Motorcycle | Others | Very High | High | |
| | | | | | | | Raised Island | Painted Island | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |

# IDENTIFICATION OF PROBLEM INTERSECTIONS THROUGH THE TRAFFIC CONGESTION RATE

## 1. Introduction

Practical traffic operation of level intersections can be divided broadly into two basic methods: the [Signal Controlled Method] which employs traffic signal to regulate traffic flow; and the [Non-Signal Controlled Method] which does not rely on the application of traffic signal. The determination and evaluation for the level of smoothness in traffic intersections have become conceivable through the comparative study of the degree of congestion in a single lane, traffic capacity and actual traffic volume of intersections, and the traffic volume under design.

Based on the saturation flow rate required to reach maximum traffic volume flow sufficient traffic demand, the approach lane within a signalized intersection can be assessed by computing the intersection saturation rate according to the determined signal controlled method.

The required maximum traffic volume approach of traversing stop line non-through approach (secondary approach) in relation to the traffic volume figure of the exclusive lane (primary road), can be summarized where the actual traffic volume and the traffic volume under design can be compared to assess the maximization of the harmony of the traffic volume for non-signal controlled intersections.

## 2. Signalized Intersection

The traffic flow processing capacity of signal controlled intersections are determined by the saturation flow rate of each of the intersection approach lane and the method of signal control.

The saturation flow rate can be defined in units of vehicles/per hour of green time where the maximum flow rate through intersection approach lanes are characterized by considerable vehicle queue during a period of green signal time. Effective green time refers to the given period of time a vehicle can actually enter the intersection, generally being identical to the length of time that a signal remain green.

The optimal saturation flow rate is presented in Table 1 where road and traffic factors are ideal. Ideal road and traffic conditions are characterized by level roads, traffic flow that is not influenced by road width and pedestrian factors among others, and passenger cars running in the same direction.

Table 1 Ideal Saturation Flow Rate at Signalized Intersection

| Lane Type | Saturation Flow Rate (vehicles/hour of green time) |
|---|---|
| Though lane | 2,000 |
| Left-turn lane | 1,800 |
| Right-turn lane | 1,800 |

The saturation flow rate (possible saturation flow rate) can be computed by adjusting the various influencing factors in relation to the ideal figure of the saturation flow rate under the effect of the actual road and traffic factors.

Table 2 represents the equation for the saturation flow rate. Since right-turn vehicles proceed in turning during signal change intervals, the capacity of exclusive right-turn lane (lanes with green arrow signals), is restricted to and expressed in terms of the values per actual hour. In addition, since the complexity in the compounding of left-turn vehicles and crossing pedestrians arise, the capacity of exclusive left-turn lanes without protected left-turn phase is also restricted to and expressed in terms of the values per actual hour.

Table 2 Saturation Flow Rate/ Flow Capacity Equation

| Lane | Equation | Units |
|---|---|---|
| Through lane | $S_T = 2000\alpha_W\alpha_G\alpha_T\alpha_{RT}\alpha_{LT}$ | Veh./hr. green time/lane |
| Exclusive right-turn lane (with protected right-turn phase) | $S_R = \left(1800\frac{t}{C} + K\frac{3600}{C}\right)\alpha_W\alpha_G\alpha_T$ | Veh./hr./lane |
| Exclusive right-turn lane (without protected right-turn phase) | $S_R = S_{R0}\alpha_W\alpha_G\alpha_T = \left(1800\, f\,\frac{SG-qC}{(S-q)C} + K\frac{3600}{C}\right)\alpha_W\alpha_G\alpha_T$ | Veh./hr./lane |
| Exclusive left-turn lane (with protected left-turn phase) | $S_L = 1800\,\alpha_W\alpha_G\alpha_T$ | Veh./hr. green time/lane |
| Exclusive left-turn lane (without protected left-turn phase) | $S_L = S_{L0}\alpha_W\alpha_G\alpha_T = 1800\frac{(1-f_P)G_P + (G-G_P)}{C}\alpha_W\alpha_G\alpha_T$ | Veh./hr./lane |

where

- $\alpha_W$: adjustment factor for lane width
- $\alpha_G$: adjustment factor for vertical grade
- $\alpha_T$: adjustment factor for heavy vehicles
- $\alpha_{RT}$: adjustment factor for right-turn vehicles
- $\alpha_{LT}$: adjustment factor for left-turn vehicles
- t : exclusive right-turn (green arrow) signal time (sec.)
- c : cycle length (sec.)
- k : right-turn vehicles passed during change intervals (all signals red) (2 vehicles at a small intersection, 3 vehicles at a large intersection)
- S : saturation flow rate of opposite approach (2,000 vehicles/ 1 hour green time)
- q : traffic flow volume of opposite through vehicles (vehicles/ hour)
- G : effective green time (sec.)
- f : probability that right-turn vehicles cross the opposite through traffic flow whose volume is q (refer to Table 3)
- $G_P$: pedestrian green length (sec.)
- $f_P$: decreasing rate for exclusive left-turn lanes due to crossing pedestrians (refer to Table 4)

Table 3 Probability of Right-turn Vehicle Crossing

| q (veh./hr.) | 0 | 200 | 400 | 600 | 800 | 1,000 | <1,000 |
|---|---|---|---|---|---|---|---|
| f | 1.00 | 0.81 | 0.65 | 0.54 | 0.45 | 0.37 | 0 |

Table 4 Decreasing Rate for Exclusive Left-Turn Lanes Due to Crossing Pedestrians ($f_p$)

| Length of pedestrian crossing L(m) | Cycle length (s)* | Pedestrian volume (2-way total/ persons/ cycle) 5 | 20 | 40 | 60 |
|---|---|---|---|---|---|
| L=20 | 60 | 0.27 | 0.63 | 0.75 | 0.82 |
| | 90 | 0.18 | 0.51 | 0.74 | 0.81 |
| | 120 | 0.13 | 0.45 | 0.71 | 0.81 |
| L=30 | 60 | 0.21 | 0.60 | 0.73 | 0.83 |
| | 90 | 0.17 | 0.48 | 0.72 | 0.81 |
| | 120 | 0.12 | 0.45 | 0.69 | 0.78 |
| L=40 | 60 | 0.14 | 0.51 | 0.72 | 0.81 |
| | 90 | 0.14 | 0.49 | 0.67 | 0.80 |
| | 120 | 0.13 | 0.43 | 0.64 | 0.74 |

Note: *The green split G/C is assumed to be 0.5 for the decreasing rate ($f_p$).

For each of the following influential conditions, the appropriate adjustment factor is discussed.

(1) Adjustment factor for lane width ($\alpha_W$)

Saturation flow rates are adjusted for lane widths measuring below 3.0 m with the adjustment factor indicated in Table 5. Note that saturation flow rates must also be adjusted for exclusive right-turn lane widths measuring below 2.75 m.

(2) Adjustment factor for vertical grade ($\alpha_G$)

Saturation flow rates are reduced by vertical grades at intersections which influence the stop, go, and acceleration momentum of the vehicles. The appropriate adjustment factor for vertical grade is indicated in Table 6.

Table 5 Adjustment Factor for Lane Width

| Lane Width (m) | Adjustment Factor |
|---|---|
| 2.50-3.00 (less than) | 0.95* |
| 3.00-3.50 | 1.00 |

Note: *The adjustment factor should be 1.00 where the lane width of an exclusive right-turn lane is equal to or greater than 2.75 m.

Table 6 Adjustment Factor for Vertical Grade

| Vertical Grade (%) | Adjustment Factor |
|---|---|
| -6 | 0.95 |
| -5 | 0.96 |
| -4 | 0.97 |
| -3 | 0.98 |
| -2 | 0.99 |
| -1 | 1.00 |
| 0 | 1.00 |
| 1 | 1.00 |
| 2 | 0.95 |
| 3 | 0.90 |
| 4 | 0.85 |
| 5 | 0.80 |
| 6 | 0.75 |

(3) Adjustment factor for vehicle types ($\alpha_T$)

Since the ideal saturation flow rates are expressed in values of passenger cars, the influence of other types of vehicles must be taken into account and adjusted. As a general rule, saturation flow rates are adjusted for heavy vehicles only as indicated in Table 7. Note, that the adjustment factor shown in Table 7 is computed by formula ①.

Table 7  Adjustment Factor for Heavy Vehicles

| Percent of heavy vehicles (%) | Adjustment factor |
|---|---|
| 5 | 0.97 |
| 10 | 0.94 |
| 15 | 0.91 |
| 20 | 0.88 |
| 25 | 0.85 |
| 30 | 0.83 |
| 35 | 0.80 |
| 40 | 0.78 |
| 45 | 0.76 |
| 50 | 0.74 |

Note: *Adjustment factor for heavy vehicles 50% and above (not shown in this table) is computed by formula ① where $E_T$=1.7

$$\alpha_T = \frac{100}{100-T+E_T T} \quad \ldots. \text{①}$$

$E_T$: passenger car equivalence of heavy vehicles
T : percentage heavy vehicles (%)

The adjustment factor is computed by the above formula where 1.7 is expressed as the heavy vehicles equivalent to passenger cars based on actual measurements.

(4) Adjustment factor for right-turn vehicles in shared through right-turn lanes ($\alpha_{RT}$)

Lanes shared by through and right-turn traffic are considered as through lanes, and the appropriate saturation flow rates are adjusted for right-turn vehicles for the reason that through traffic is influenced heavily by the right-turn traffic. This influence can be adjusted by estimating the value of the through vehicles equivalent to one right-turn vehicle ($E_{RT}$). Therefore, as indicated in formula ②, the value of the through vehicles equivalent for right-turn vehicle ($E_{RT}$) can be obtained if saturation flow rate of through lanes per actual hour is divided by the capacity of the exclusive right-turn lane (without protected right-turn phase) $S_{RO}$ of Table 2.

$$E_{RT} = \frac{2000\,\frac{G}{C}}{S_{RO}} = \frac{1.1}{f\,\frac{SG - qC}{G(S-q)} + \frac{2K}{G}} \quad \cdots ②$$

Further, the adjustment factor for right-turn vehicles ($\alpha_{RT}$) can be computed by the use of the following formula ③.

$$\alpha RT = \frac{100}{100 - R + E_{RT}R} \quad \cdots\cdot ③$$

(5) Adjustment factor for left-turn vehicles in shared through right-turn lanes ($\alpha_{LT}$)

Lanes shared by through and left-turn traffic are considered as through lanes, and the appropriate saturation flow rates are adjusted for left-turn vehicles for the reason that through traffic is influenced heavily by the left-turn traffic. This influence can be adjusted by estimating the value of the through vehicles equivalent to left-turn vehicle ($E_{LT}$). Therefore, as indicated in formula ④, the value of the through vehicles equivalent for left-turn vehicle ($E_{LT}$) can be obtained if saturation flow rate of through lanes per actual hour is divided by the capacity of the exclusive left-turn lane (without protected left-turn phase) $S_{LO}$ of Table 2.

$$E_{LT} = \frac{2000\,\frac{G}{C}}{S_{LO}} = \frac{1.1G}{(1-f_p)G_p + (G-G_p)} \quad \cdots ④$$

The adjustment factor for left-turn vehicles ($\alpha_{LT}$) can be computed by in the same manner as right-turn vehicles. When the influence of crossing pedestrians is negligible, use the figures in Table 8 for the adjustment factor ($\alpha_{LT}$).

Table 8 Adjustment Factor for Left-Turn
(for negligible pedestrian crossing influence)

| Percentage of left-turn vehicles (%) | Adjustment Factor |
|---|---|
| 5 | 0.99 |
| 10 | 0.97 |
| 15 | 0.96 |
| 20 | 0.94 |
| 25 | 0.93 |
| 30 | 0.91 |
| 35 | 0.90 |
| 40 | 0.88 |
| 45 | 0.87 |
| 50 | 0.85 |

Note: *A value of 50% should be used where the percentage of left-turn vehicles exceeds 50% and computed by means of interpolation.

## 3. Non-Signalized Intersection

Siegloch (1973) developed a method on the basis of probabilistic theory which allows the proof of sufficient capacity for minor-road vehicles at non-signalized intersections under various demand volumes.
To calculate capacity for minor-road traffic at non-signalized intersections the general equation for capacity is

$$L = \lambda \int EN(t)dF(t) \qquad \text{....} ⑤$$

with $\lambda$ (veh/h) = intensity of major-road traffic
F (t) = time-gap distribution of major-road traffic
EN (t) = time-gap acceptance by minor-road traffic

For time-gap distribution of major-road traffic (F(t)), different assumptions have been made. In the case of stationary free flow conditions, ADAMS (1936) found that time-gap distribution is given by the negative exponential function

$$F(t) = 1 - \exp(-\lambda t) \qquad \text{....} ⑥$$

with $\lambda$(veh/h) = intensity of major-road traffic
t(s) = time-gap of major-road traffic

Each time-gap t of the major stream contributes to the capacity provided. In the case of $t \leq t_0$ the contribution becomes zero. The capacity contribution is calculated by multiplying of the probability density for the occurrence of a time-gap t by the average number of vehicles EN(t)

which can accept the time-gap of this length.
With $\lambda$ as the intensity of the major-road traffic, the formula in general terms for the calculation is given as in equation (5).
For free and stationary traffic-flow conditions, the vehicle arrivals of a multi-lane road are described by the POISSON-distribution. The headways or time-gaps between vehicles, in this case, follow an exponential distribution. The simple structure of this distribution makes it suitable for theoretical calculations. Furthermore, Siegloch (1972) proved that this distribution - in spite of some logical disadvantages concerning, the free traffic- flow conditions - produces realistic values in respect to capacity.
The function EN(t) is gained by observations at intersections. A time-gap of the major-road will not be accepted by any vehicle when this gap is smaller or equal to $t_o$. The larger a provided gap, the easier it will be accepted by one or more minor-road vehicles. Finally, one can assume that more vehicles will use larger time-gaps for crossing or merging and that the relationship will gradually transform into a linear function for EN(t).
The formula for time-gap acceptance or minor-road traffic given by Siegloch (1973) is widely accepted

$$EN(t) = \begin{cases} 0 & , \text{for } t \leq t_o \\ \dfrac{t - t_o}{t_f} & , \text{for } t > t_o \end{cases} \qquad \ldots (7)$$

with $t_o$ [s] = not accepted time-gap by any vehicle of minor-road traffic
$t_f$ [s] = time-gap between following vehicles of minor-road traffic entering the intersection

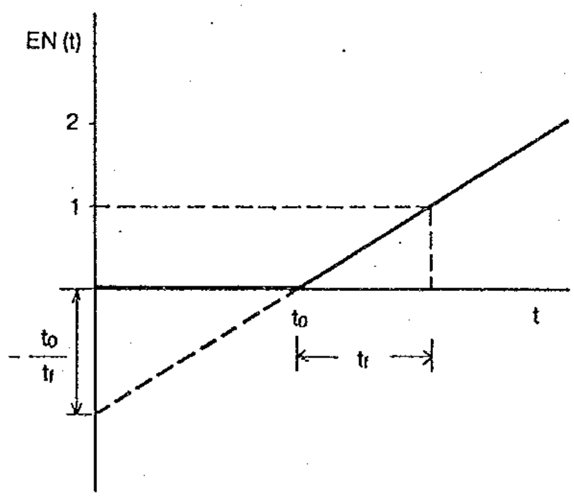



Fig. 1 : Function EN(t)

With equations ⑥ and ⑦ one derives from ⑤ :

$$\lambda \int_0^{t_0} EN(t)\ dF(t) = 0$$

$$L = 3600 \int_0^{\infty} \lambda^2 \cdot e^{-\lambda t_0} \cdot \frac{t - t_0}{t_f}\ dt$$

The integration of this results in the basic formula for the calculation of the capacity at non-signalized intersections :

$$L = 3600 \frac{e^{-\lambda t_o}}{t_f} \quad \text{(veh/h)} \qquad \ldots ⑧$$