INDONESIAN

HIGHWAY CAPACITY MANUAL

PART - I URBAN ROADS

NO. 09/T/BNKT/ 1993

DIRECTORATE GENERAL OF HIGHWAYS
MINISTRY OF PUBLIC WORKS
INDONESIAN HIGHWAY CAPACITY MANUAL

URBAN AND SEMI-URBAN TRAFFIC FACILITIES

JANUARY 1993

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FOREWORD
Planning, design and operational analysis for Indonesian highway traffic facilities have so far mainly been based on foreign capacity models, guidelines and standards. However, since 1982, some studies on Highway Traffic Engineering in Indonesia had shown that direct application of models and methods based on western traffic characteristics (e.g. speed-flow relationships, saturation flows, capacity) to situations in Indonesia often produced misleading results. Two main reasons for this were identified that:

1) The traffic composition in Indonesia includes a high ratio of motorcycles and unmotorised vehicles.
2) No right of way rules are applied at intersections and other conflict points.

The need for an Indonesian Highway Capacity Manual was thus identified in 1986 by a joint committee of Directorate General of Bina Marga, Indonesian Road Engineering, and the S2-STJR-ITB Programme. Phase 1 Indonesian Highway Capacity Manual study was started in December 1990 and the main task was Development of a Highway Capacity Manual for different types of traffic facilities in urban and semi urban environments.

The Directorate General of Bina Marga has introduced a "standardization" policy which endeavors to optimize investments, designs and construction methods for highways so as to obtain the most efficient use of available resources, finances and materials, as well as improvement of the ability of local engineers and contractors.

For this purpose, standard guidance regarding Methods Specifications, Testing Material and other aspects of Planning, Design, Construction, Operation and Maintenance have a high level of necessity in achieving a more efficient use of road facilities. This book entitled "Indonesian Highway Capacity Manual" for Urban Roads is part of the efforts of the Directorate General of Bina Marga in promoting professionalism for everyone involved in road development.
A large number of government agencies all over Indonesia have given very valuable assistance to the Development of the Manual. Directorate General of Bina Marga hereby expresses a sincere gratitude to all those who have contributed to this first version of the Indonesian Highway Capacity Manual.

As we realize that there is room for further improvement of this manual, especially considering Indonesian road traffic conditions, any comments and suggestions will be most welcome.

Jakarta, January 1993

Director of Urban Road Development

Sunaryo Sumadji
STEERING COMMITTEE

INDONESIAN HIGHWAY CAPACITY MANUAL

PHASE I - URBAN ROADS

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Secretary :
Ir. Sukawan Mertasudira M.Sc Dit. Binkot

Project Officer :
Ir. Palgunadi M.Eng.Sc Dit. Binkot

Other committee members :
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Prof. Ir. T. Soegondo MSCE ITB S2 STJR
Ir. Iskandar Abubakar M.Sc Dit. Jen. Perhubungan Darat
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Ir. Muksin M.Eng.Sc Dit. Binkot
Ir. Trihardjo Dit. Binkot
Ir. Janeydi Juni Dit. Binkot
Chapter 1: INTRODUCTION
CHAPTER 1

INTRODUCTION

1. BACKGROUND

Highway Capacity Manuals are necessary tools for proper planning, design and operation of road traffic facilities. The fundamental traffic characteristics knowledge contained in such manuals are also an essential input in models for cost-efficient management of road systems, traffic forecasting and assignment with capacity restraint. Highway administrations in many developed countries therefore devote considerable resources to the production of such manuals and guidelines appropriate to their own, conditions.

The main hypothesis behind the project that has resulted in this manual is that Indonesian traffic characteristics are fundamentally different from those in developed countries. Existing capacity manuals from such countries therefore cannot be successfully implemented in Indonesia. The aim of the research behind the production of this manual has been to explore and model Indonesian driver behaviour and fundamental road traffic characteristics by means of extensive field data collection and analysis.

The data collection was performed by the Consultants between May and December 1991. Table 1:1 presents the distribution of field data collection sites on different types of traffic facilities and cities. A total of 147 sites in 16 cities all over Indonesia were surveyed as shown in the table. At each site a continuous video recording of all traffic movements in the facility from early morning to late afternoon was obtained for data reduction and analysis in the HCM project laboratory in Bandung.

2. SCOPE AND OBJECTIVES

The scope of this first, interim edition of the Indonesian Highway Capacity Manual is restricted to traffic facilities in urban and semi-urban areas, with chapters covering different types of interurban roads to be added in the spring of 1994 as a result of the second phase of the HCM project. A comprehensive edition of the manual, including traffic engineering guidelines and computer software, will be produced in Bahasa Indonesia in the third and final HCM project phase 1995.

The types of facilities covered, and the traffic effects that can be calculated with the use of the present manual are recorded in Table 2:1 below.
<table>
<thead>
<tr>
<th>No</th>
<th>City</th>
<th>Signalised intersection</th>
<th>Unsignalized Intersection</th>
<th>Weaving Sections</th>
<th>Road links</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bandung</td>
<td>20</td>
<td>9</td>
<td>5</td>
<td>17</td>
<td>51</td>
</tr>
<tr>
<td>2</td>
<td>Jakarta</td>
<td>8</td>
<td>6</td>
<td>12</td>
<td>6</td>
<td>32</td>
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<tr>
<td></td>
<td>Cianjur</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sukabumi</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Tasikmalaya</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>yogyakarta</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Semarang</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Surabaya</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Malang</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Denpasar</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>kupang</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Ujung Pandang</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Ambon</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Palembang</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Medan</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Pontianak</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>33</td>
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<td></td>
<td></td>
<td>27</td>
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<td></td>
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<td></td>
<td>35</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>147</td>
</tr>
</tbody>
</table>

Table 1:1 Field data collection in urban and semi-urban areas during HCM project Phase 1.

The manual can also be used to analyse routes or networks within urban areas by means of successive application of the relevant chapter for each traffic facility. The total travel time can then be obtained as the sum of the travel times and delays in each link and node along the studied route.
### Traffic Facilities and Effects Covered

<table>
<thead>
<tr>
<th>TRAFFIC FACILITY TYPE</th>
<th>CHAPTER</th>
<th>TRAFFIC EFFECTS COVERED IN THE MANUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signalised intersections</td>
<td>2</td>
<td>Signal timing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Degree of saturation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Propotion of stopped vehicles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Queue length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Delay</td>
</tr>
<tr>
<td>Unsignalised intersections</td>
<td>3</td>
<td>Capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Degree of saturation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Delay</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Queue probability</td>
</tr>
<tr>
<td>Weaving sections</td>
<td>4</td>
<td>Capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Degree of saturation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speed in the weaving area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Travel time</td>
</tr>
<tr>
<td>Urban roads</td>
<td>5</td>
<td>Capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Degree of saturation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Free flow speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>speed-flow relationship</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Travel time</td>
</tr>
</tbody>
</table>

Table 2:1  Traffic facilities and effects covered by this edition of the Indonesian HCM.

### Structure and Organisation of the Manual

Chapter 1 of the manual presents background, scope, general definitions/terminology, user guidelines, and general literature references.

Chapter 2-5 cover different types of traffic facilities as listed in Table 2:1 above. Each chapter has a similar structure and organization with some variations:

- Scope and objectives.
- Characteristics of the traffic facility studied.
- Specific terminology and definitions.
- General methodology for the calculations.
- Calculation procedure.
- Worked examples on different levels of application.
- Specific literature references. Calculation forms.
4. GENERAL DEFINITIONS AND TERMINOLOGY

notations, terminology and definitions of conditions and characteristics of a more general nature are presented below. Definitions of more specific nature are presented in Chapters 2 – 5 for each type of traffic facility.

TRAFFIC CONDITIONS AND CHARACTERISTICS

<table>
<thead>
<tr>
<th>TRAFFIC ELEMENT</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veh VEHICLE</td>
<td>Traffic element on wheels</td>
</tr>
<tr>
<td>LV LIGHT VEHICLE</td>
<td>Index for motor vehicle on four wheels (including passenger car, oplet, micro bus, pick-up and micro truck according to Bina Marga classifications system)</td>
</tr>
<tr>
<td>HV HEAVY VEHICLE</td>
<td>Index for motor vehicle with two or three wheels (including bus, 2-axle truck, 3-axle truck and truck combinations according to Bina Marga classifications system).</td>
</tr>
<tr>
<td>MC MOTOR CYCLE</td>
<td>Index for motor vehicle with two or three wheels (including motor cycle and 3-wheeled vehicle according to Bina Marga classifications system).</td>
</tr>
<tr>
<td>UM UNMOTORISED</td>
<td>Index for unmotorised traffic element on wheels (including becak, bicycles, horse-carriage and pushcarts according to Bina Marga classifications system).</td>
</tr>
<tr>
<td>P RATIO</td>
<td>Ratio of a sub-population to the total populations, e.g. $P_{MC} = \text{ratio of motorcycles in the traffic flow.}$</td>
</tr>
<tr>
<td>pcu PASSENGER CAR UNIT</td>
<td>Conversion factor for different vehicle types with regard to their impact on capacity as compared to a passenger car (i.e. for passenger cars and other light vehicle pcu = 1.0)</td>
</tr>
<tr>
<td>Q TRAFFIC FLOW</td>
<td>Number of traffic elements passing a point on a road per unit of time (e.g. veh/h; pcu/h).</td>
</tr>
<tr>
<td>PHF PEAK HOUR FACTOR</td>
<td>Ratio between the peak hour flow and four times the highest quarterly flow during the same hour.</td>
</tr>
</tbody>
</table>
LEVEL OF PERFORMANCE MEASURES

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>LoP</td>
<td>LEVEL OF PERFORMANCE</td>
</tr>
<tr>
<td>LoS</td>
<td>LEVEL OF SERVICE</td>
</tr>
<tr>
<td>C</td>
<td>CAPACITY</td>
</tr>
<tr>
<td>C₀</td>
<td>BASE CAPACITY</td>
</tr>
<tr>
<td>DS</td>
<td>DEGREE OF SATURATION</td>
</tr>
<tr>
<td>V</td>
<td>SPEED</td>
</tr>
<tr>
<td>V₀</td>
<td>FREE FLOW SPEED</td>
</tr>
<tr>
<td>HOUR</td>
<td>Time unit.</td>
</tr>
<tr>
<td>min</td>
<td>MINUTE</td>
</tr>
<tr>
<td>sec</td>
<td>SECOND</td>
</tr>
<tr>
<td>T</td>
<td>TIME</td>
</tr>
<tr>
<td>TT</td>
<td>TRAVEL TIME</td>
</tr>
<tr>
<td>D</td>
<td>DELAY</td>
</tr>
<tr>
<td>Pₛᵥ</td>
<td>PROPORTION OF STOPPED VEHICLES</td>
</tr>
<tr>
<td>QP%</td>
<td>QUEUE PROBABILITY</td>
</tr>
</tbody>
</table>
GEOMETRIC CONDITIONS AND CHARACTERISTICS

L  LENGTH  Length of a road segment
W  WIDTH  Width of a road section
GRAD  GRADIENT  Gradient of a road segment in the direction of travel (+/- %).
APPROACH  Area for entering vehicle in a traffic facility.
MEDIAN  Area separating traffic directions on a road segment

ENVIRONMENT CONDITIONS

COM  COMMERCIAL  Commercial landuse (e.g. shops, restaurants, offices) with direct roadside access for pedestrians and vehicle
RES  RESIDENTIAL  Residential landuse with direct roadside access for pedestrians and vehicles.
RA  RESTRICTED ACCES  No or limited direct roadside access (e.g. due to the existence of physical barriers, frontage streets etc).
CS  CITY SIZE  Number of inhabitants in an urban area
SF  SIDE FRICTION  Interaction between traffic flow and roadside activities causing a reduction of capacity and speed.

5. USER GUIDELINES

This Highway Capacity manual should be used as a tool in planning, design and operational analysis of all highway traffic facilities. The user of the manual will thus include transportation planners, traffic engineers and highway engineers in transport and highway administrations as well as in consulting companies.

The manual is designed to allow the user to predict the level of performance of a traffic facility for a given set of traffic, geometric and environmental conditions. Default values are proposed for use in cases when some required input data is missing.

By successive calculations with adjusted input data, the geometric design which gives a desired level of performance for given traffic flow and environmental conditions can be determined. In the same way, the rate of decline of level of performance at a given traffic
facility as a result of traffic growth can be analysed, and the timing of the need for capacity expansion determined.

Many other questions relevant to a traffic or highway engineer can be answered by the same type of "trial-an-error" calculations with different sets of input data. The manual can thus be used in variety of situations as exemplified below:

a) Planning
   Determination of suitable layout and preliminary design of a new traffic facility based on forecasted traffic flows.

b) Design
   Determination of suitable detailed geometric design and traffic control parameters for a new or revised traffic facility with known traffic flow.

c) Operational analysis
   Determination of the level of performance of an existing traffic facility. Determination of signal timing for minimum delay. Prediction of the consequences of minor changes in geometry, traffic regulations and signal control.

The manual also enables calculation of the level of performance of the facility at a given traffic demand. Development of traffic engineering guidelines, and recommendations regarding threshold values for design and operation, will be undertaken in phase 3 of the HCM project for incorporation in the final version of the manual.

Standard forms are provided for each type of traffic facility for recording of input data as well as for the different calculation steps. The worked examples which have been included at the end of each traffic facility chapter also give useful guidance concerning ways to apply the manual.

Although the manual is designed for a wide range of conditions, it is advisable for the reader to make his own critical evaluation of the results and to supplement them with own field measurements of capacity and other measures of performance whenever possible.

Comments about possible errors in the manual and suggestions for improvements and further development are very much appreciated. These could be addressed to Binkot, Bina Marga or to the HCM project office in Bandung.
6. GENERAL LITERATURE REFERENCES

General literature references used for the development of the manual are presented below. For references relating to specific traffic facilities see reference lists at the end of Chapters 2 to 5.

Traffic legislation
1. GOI Undang-undang Republik Indonesia No. 13 Tahun 1980 Tentang jalan (Indonesian Road Law)
2. GOI Undang-undang No. 3 Tahun 1965 Tentang Lalu-lintas dan Angkutan Jalan Raya (Indonesian Traffic Law)
4. GOI Peraturan Pemerintah Republik Indonesia No. 26 Tahun 1985 Tentang Jalan.

Standar ds
   Ministry of Publik Works, Directorate General of Highway ; Jakarta 1988

Manuals
   Swedish National Road Administration Report TV 131,1977

Theory
   Institute of Transportation and Traffic Engineering, University of California, Los Angeles, California, Academic press, London 1963

Chapter 2: SIGNALISED INTERSECTIONS
# IHCM: SIGNALISED INTERSECTIONS

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- 1.2 CHARACTERISTICS OF TRAFFIC SIGNALS
- 1.3 DEFINITIONS AND TERMINOLOGY

### 2. METHODOLOGY
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- 2.2 OVERVIEW OF THE CALCULATION PROCEDURE
- 2.3 GUIDELINES FOR APPLICATION
  - 2.3.1 Types of application of the manual
  - 2.3.2 Default values

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- STEP A: INPUT DATA
  - A-1: Geometric/traffic control and environmental conditions
  - A-2: Traffic flow conditions
- STEP B: SIGNALISATION
  - B-1: Signal phasing
  - B-2: Clearance time and lost time
- STEP C: SIGNAL TIMING
  - C-1: Approach type
  - C-2: Effective approach width
  - C-3: Base saturation flow
  - C-4: Correction factors
  - C-5: Flow/saturation flow ratio
  - C-6: Cycle time and green times
- STEP D: CAPACITY
  - D-1: Capacity
  - D-2: Need for revisions
- STEP E: LEVEL OF PERFORMANCE
  - E-1: Preparations
  - E-2: Queue length
  - E-3: Stopped vehicles
  - E-4: Delay

### 4. WORKED EXAMPLES

### 5. LITERATURE REFERENCES

**APPENDIX 2:1** Calculation forms
1. INTRODUCTION

1.1 SCOPE AND OBJECTIVES

This chapter describes procedures for determination of signal timing, capacity and level of performance (delay, queue length and proportion of stopped vehicles) for signalised intersections in urban and semi-urban areas.

The manual primarily deals with isolated, fixed-time controlled signalised intersections (definitions see Section 1.3 below) with normal geometric layout (four-arm and three-arm) and traffic signal control devices. It can with some considerations also be used for analysis of other geometric layouts.

Signalised intersections which are part of a coordinated, fixed time control system, or isolated vehicle actuated traffic signals, can also be analysed with the help of the manual, see Section 2.3:1. Only very few such systems were however operational in Indonesia at the time of the preparation of the manual.

Normally traffic signals are introduced for one or more of the following reasons:

- to avoid blockage of an intersection by conflicting traffic streams, thus guaranteeing that a certain capacity can be maintained even during peak traffic conditions;
- to facilitate the crossing of a major road by vehicles and/or pedestrians from a minor road;
- to reduce the number of traffic accidents caused by collisions between vehicles in conflicting directions.

Signalisation does not always increase the capacity and safety of an intersection. By application of the methods described in this and other chapters in the manual it is however possible to estimate the effect of signalisation on capacity and level of performance as compared to unsignalised control or round-about control.

1.2 CHARACTERISTICS OF TRAFFIC SIGNALS

For most types of traffic facilities capacity and level of performance is primarily a function of geometric conditions and traffic demand. By means of the signals however, the planner/engineer can distribute capacity to different approaches through the green time allocated to each approach. In order to calculate capacity and level of performance it is therefore necessary to first determine the signal phasing and timing which is most appropriate for the studied conditions.

Signalisation by means of three-coloured lights (green, amber, red) is applied to separate passage of conflicting traffic movements in time. This is an absolute requirement for traffic movements arriving from intersecting streets = primary conflicts. The signals can also be used to separate turning movements from opposing straight-through traffic, or to separate turning traffic from crossing pedestrians = secondary conflicts, see Figure 1.2:1 below.
If only the primary conflicts are separated, it is possible to control the signal in two phases, one for each of the crossing streets, as shown in Figure 1.2:2. This method can always be applied if the right-turning movements have been forbidden in the intersection. Since two-phase control yields highest capacity in most cases, it is the base case in most signal analyses.

Figure 1.2:2 also illustrates the sequence of signal changes for two-phase signal control, including definitions of cycle time, green time and intergreen periods (see also Section 1.3). The purpose of the intergreen period ($IG = amber + allred$) between two consecutive signal phases is to:

1. warn discharging traffic that the phase is terminated.
2. certify that the last vehicle in the green phase which is being terminated receives adequate time to evacuate the conflict zone before the first advancing vehicle in the next phase enters the same area.

The first function is fulfilled by the amber period, the second by the allred period which serves as a clearance time between the phases.

The allred and amber periods are normally predetermined and constant throughout the
period of operation. If also the green times and the cycle time are predetermined, the signal is operated in fixed-time control mode.

Figure 1.2:2 Time sequence for two-phase signal control

In a older systems, the same time setting is used all times of the day/week; in more modern systems, different predetermined signal timing plans are used for different conditions, e.g. morning peak, evening peak, and off-peak traffic conditions. This manual can be used to calculate the best signal timing for each condition provided that traffic data is available.

If traffic safety considerations or capacity constraints require that one or more right-turning movements are separated, the number of phases has to be increased. Figure 1.2:3 shows examples of different phasing arrangements for this purpose. The introduction of more than two phases inevitably leads to an increase of the cycle time and of the ratio of time allocated to switching between phases (Intergreen). Although this may be beneficial from the traffic safety point of view, it normally means that the overall capacity of the intersection is decreased.

The discharge of traffic during green light is very much influenced by the phasing arrangement regarding right-turning movements. If right turns from the studied approach and/or from the opposing direction occur in the same phase as the discharge of the straight-through and left-turning traffic from these approaches (as in Case 1 in Figure 1.2:3), the discharge is considered to be opposed. If there are no right turns from any of these
approaches, or if the right turns are discharged when the straight-through traffic from the opposing direction has red light (as in Case 5 and 6 in Figure 1.2:3), the discharge is considered to be protected. In Case 2 and 3 the discharge from the north approach is partly opposed, partly protected. In Case 4 the discharge from the north and south approaches are protected, from the east and west approaches opposed.

<table>
<thead>
<tr>
<th>Case</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Two-phase control, only primary conflicts are separated</td>
</tr>
<tr>
<td>2.</td>
<td>Three-phase control with late cut-off in the north approach to increase the capacity for right turns from this direction</td>
</tr>
<tr>
<td>3.</td>
<td>Three-phase control with early start of the north approach to increase the capacity for right turns from this direction</td>
</tr>
<tr>
<td>4.</td>
<td>Three-phase control with separated right turns in one of the streets</td>
</tr>
<tr>
<td>5.</td>
<td>Four-phase control with separate right turns in both streets</td>
</tr>
<tr>
<td>6.</td>
<td>Four-phase control with discharge of one approach at a time</td>
</tr>
</tbody>
</table>

Figure 1.2:3 Signal phasing arrangements for separation of right-turning movements.
1.3 DEFINITIONS AND TERMINOLOGY

Notations, terminology and definitions specific to signalised intersections are listed below (see also general definitions in Chapter 1, Section 4).

**TRAFFIC CONDITIONS AND CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pcu</td>
<td>PASSENGER CAR UNIT Conversion factor for different vehicle types with regard to their green time requirement for discharge from a queue in the approach as compared to a passenger car (i.e. for passenger car/light vehicle pcu = 1.0).</td>
</tr>
<tr>
<td>Type O</td>
<td>OPPOSED DISCHARGE Discharge with conflict between right-turning movements and straight-through/left-turning movements from different approaches with green in the same phase.</td>
</tr>
<tr>
<td>Type P</td>
<td>PROTECTED DISCHARGE Discharge without any conflict between right turning movements and straight-through traffic.</td>
</tr>
<tr>
<td>LT</td>
<td>LEFT-TURNING Index for left-turning traffic.</td>
</tr>
<tr>
<td>LTOR</td>
<td>LEFT TURN ON RED Index for left-turning traffic permitted to pass against red. signal.</td>
</tr>
<tr>
<td>ST</td>
<td>STRAIGHT-THROUGH Index for straight-through traffic.</td>
</tr>
<tr>
<td>RT</td>
<td>RIGHT-TURNING Index for right-turning traffic.</td>
</tr>
<tr>
<td>P&lt;sub&gt;RT&lt;/sub&gt;</td>
<td>RATIO OF RT Ratio of right-turning traffic etc.</td>
</tr>
<tr>
<td>Q</td>
<td>TRAFFIC FLOW Number of traffic elements passing an undis turbed point upstream in the approach per unit of time (i.e. = traffic demand veh/h; pcu/h).</td>
</tr>
<tr>
<td>Q&lt;sub&gt;O&lt;/sub&gt;</td>
<td>OPPOSING FLOW Flow of traffic in an opposing approach being discharged in the same green phase.</td>
</tr>
<tr>
<td>Q&lt;sub&gt;RTO&lt;/sub&gt;</td>
<td>RIGHT-TURNING, OPPOSING TRAFFIC FLOW Flow of right-turning traffic from the opposing approach (veh/h; pcu/h).</td>
</tr>
<tr>
<td>S</td>
<td>SATURATION FLOW Rate of queue discharge in an approach during given conditions (pcu per hour of green = pcu/h).</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>S₀</td>
<td>BASE SATURATION FLOW</td>
</tr>
<tr>
<td>DS</td>
<td>DEGREE OF SATURATION</td>
</tr>
<tr>
<td>FR</td>
<td>FLOW RATIO</td>
</tr>
<tr>
<td>IFR</td>
<td>INTERSECTION FLOW RATIO</td>
</tr>
<tr>
<td>PR</td>
<td>PHASE RATIO</td>
</tr>
<tr>
<td>C</td>
<td>CAPACITY</td>
</tr>
<tr>
<td>F</td>
<td>CORRECTION FACTOR</td>
</tr>
<tr>
<td>D</td>
<td>DELAY</td>
</tr>
<tr>
<td>QL</td>
<td>QUEUE LENGTH</td>
</tr>
<tr>
<td>NQ</td>
<td>QUEUE</td>
</tr>
<tr>
<td>Psv</td>
<td>PROPORTION OF STOPPED VEHICLES</td>
</tr>
</tbody>
</table>

**GEOMETRIC CONDITIONS AND CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPROACH</td>
<td>Area of an intersection arm for vehicles queuing before discharge across the stop-line. (If left-turning or right-turning traffic movements are separated by traffic islands, an intersection arm can consist of two or more approaches).</td>
</tr>
<tr>
<td>APPROACH WIDTH</td>
<td>Width of the paved part of the approach measured at the upstream bottleneck (m).</td>
</tr>
</tbody>
</table>
**IHCM: SIGNALISED INTERSECTIONS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{\text{ENTRY}}$</td>
<td>ENTRY WIDTH</td>
</tr>
<tr>
<td>$W_{\text{EXIT}}$</td>
<td>EXIT WIDTH</td>
</tr>
<tr>
<td>$W_{\text{e}}$</td>
<td>EFFECTIVE WIDTH</td>
</tr>
<tr>
<td>L</td>
<td>DISTANCE</td>
</tr>
<tr>
<td>GRAD</td>
<td>GRADIENT</td>
</tr>
</tbody>
</table>

**ENVIRONMENTAL CONDITIONS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM</td>
<td>COMMERCIAL</td>
</tr>
<tr>
<td>RES</td>
<td>RESIDENTIAL</td>
</tr>
<tr>
<td>RA</td>
<td>RESTRICTED ACCESS</td>
</tr>
<tr>
<td>CS</td>
<td>CITY SIZE</td>
</tr>
<tr>
<td>SF</td>
<td>SIDE FRICTION</td>
</tr>
</tbody>
</table>

**SIGNAL CONTROL PARAMETERS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>PHASE</td>
</tr>
<tr>
<td>c</td>
<td>CYCLE TIME</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>g</td>
<td>GREEN TIME</td>
</tr>
<tr>
<td>g_{\text{max}}</td>
<td>MAXIMUM GREEN TIME</td>
</tr>
<tr>
<td>g</td>
<td>MINIMUM GREEN TIME</td>
</tr>
<tr>
<td>GR</td>
<td>GREEN RATIO</td>
</tr>
<tr>
<td>IG</td>
<td>INTERGREEN</td>
</tr>
<tr>
<td>CT</td>
<td>CLEARANCE TIME</td>
</tr>
<tr>
<td>LT</td>
<td>LOST TIME</td>
</tr>
<tr>
<td>ALLRED</td>
<td>ALLRED TIME</td>
</tr>
<tr>
<td>AMBER</td>
<td>AMBER TIME</td>
</tr>
</tbody>
</table>
2. METHODOLOGY

2.1 GENERAL PRINCIPLES

The methodology for analysis of signalised intersections described below is based on the following main principles.

a) Geometry

The calculations are done separately for each approach. One intersection arm can consist of more than one approach, i.e. be divided in two or more sub-approaches. This is the case if the right-turning and/or left-turning movements receive green signal in different phase(s) than the straight-through traffic, or if they are physically divided by traffic islands in the approach.

For each approach or sub-approach the effective width \( W_e \) is determined with consideration to the layout of the entry and the exit and the distribution of turning movements.

b) Traffic flow

The calculations are performed on an hourly basis for one or more periods, e.g. based on peak-hour design flows for morning, noon and afternoon traffic conditions.

The traffic flows \( Q \) for each movement (left-turning \( Q_{LT} \), straight-through \( Q_{ST} \), and right-turning \( Q_{RT} \)) are converted from vehicles per hour to passenger car units per hour using the following pcu values for protected and for opposed approach types:

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>pcu value for approach type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Protected</td>
</tr>
<tr>
<td>Light veh. (LV)</td>
<td>1.0</td>
</tr>
<tr>
<td>Heavy veh. (HV)</td>
<td>1.3</td>
</tr>
<tr>
<td>Motorcycle (MC)</td>
<td>0.2</td>
</tr>
<tr>
<td>Un-motorised (UM)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Example: \[ Q = Q_{LV} + Q_{HV} \times pcu_{HV} + Q_{MC} + Q_{UM} \times pcu_{UM} \]
c) **Basic model**

The capacity \( C \) of an approach to a signalised intersection can be expressed as follows:

\[
C = S \times \frac{g}{c} \tag{1}
\]

where

- \( C \) = Capacity (pcu/h).
- \( S \) = Saturation flow, i.e. mean discharge rate from a queue in the approach during green signal (pcu/hg = pcu per hour of green).
- \( g \) = Displayed green time (sec).
- \( c \) = Cycle time, i.e. duration of a complete sequence of signal changes (i.e. between two consecutive starts of green in the same phase).

It is thus necessary to know or to determine the signal timing of the intersection in order to calculate capacity and different measures of performance.

In Formula (1) above the saturation flow \( S \) is assumed to be constant during the duration of green. In reality, however, the discharge rate starts from 0 at the beginning of green and reaches its peak value after 10-15 seconds. It then drops slightly until the end of green, see Figure 2.1:1 below. The discharge also continues during amber and allred until it drops to 0, normally 5-10 seconds after the beginning of red signal.

![Figure 2.1:1 Observed saturation flows per six second time slices](image)

Figure 2.1:1  Observed saturation flows per six second time slices
The start-up discharge causes what can be described as a Start loss of effective green time, the discharge after end of green results in an End gain of effective green time, see Figure 2.1.2. The resulting total effective green time, i.e. the green time during which the discharge occurs with a constant rate $S$, can then be calculated as

$$\text{Eff. green} = \text{Displayed green time} - \text{Start loss} + \text{End gain} \quad (3)$$

Figure 2.1.2 Basic model for saturation flow (Akcelik 1989).

By analysis of field data from all the surveyed intersections it was concluded that the average start loss and end gain both were in the order of 4.8 sec. According to Formula (3) above the effective green time then becomes equal to the displayed green time for the studied standard case. The conclusion from this analysis was that the displayed green time and the peak saturation flow rate observed in the field for each site could be used in Formula (1) above to calculate the capacity of the approach without adjustment for start loss and end gain periods.
The saturation flow (S) can be expressed as a product between a base saturation flow ($S_0$) for a set of standard conditions, and correction factors (F) for deviation of the actual conditions from a set of pre-determined (ideal) conditions.

$$ S = S_0 \times F_1 \times F_2 \times F_3 \times F_4 \times F_n $$  \hspace{1cm} (2)

For protected approaches the base saturation flow $S_0$ is determined as a function of the effective approach width ($W_e$):

$$ S_0 = 600 \times W_e $$

Corrections are then made for the following conditions:
- City size (CS, million inhabitants)
- Side friction (SF, high or low (also a function of road environment))
- Gradient (G, % up (+) or down (-))
- Parking (P, distance stopline - first parked vehicle)
- Turning movements (RT, % right-turning; LT, % left-turning)

For opposed approaches, the queue discharge is heavily influenced by the fact that Indonesian drivers do not respect the right-of-way rule from the left, i.e. right turning vehicles push their way through the opposing straight-through traffic. Western models for this discharge, which are based on gap-acceptance theory, cannot be applied. An explanatory model based on observed driver behaviour was developed and implemented in the manual. Generally it results in lower capacities where there is a high ratio of right turning movements, than appropriate for corresponding Western models. Different pcu-values for opposed approaches are also used as described above.

The base saturation flow $S_0$ is determined as a function of effective approach width ($W_e$) and the flow of right-turning traffic in the own approach as well as in the opposing approach, since the influence of these factors is non-linear. Corrections are then made for actual conditions regarding City size, Side friction, Gradient and Parking as in Formula 2 above.

d) **Signal timing**

The signal timing for fixed-time control conditions is determined based on the Webster (1966) method for minimisation of overall vehicle delay in the intersection. First the cycle time ($c$) is determined, and after that the length of green ($g_i$) in each phase (i).

**CYCLE TIME**

$$ c = \frac{(1.5 \times LT + 5)/(1 - \Sigma FR_{crit})}{1} $$ \hspace{1cm} (3)
where
\[ c = \text{Signal cycle time (sec)} \]
\[ LT = \text{Total lost time per cycle (sec)} \]
\[ FR = \text{Flow divided by saturation flow (Q/S)} \]
\[ FR_{crit} = \text{The highest value of FR in all approaches being discharged in a signal phase.} \]

\[ \Sigma(FR_{crit}) = \text{Intersection flow ratio = sum of FR}_{crit} \text{ for all phases in the cycle.} \]

If the cycle time is shorter than this value there is a serious risk for over-saturation of the intersection. Too long cycle times result in increased average delay to the traffic. If \( F(FR_{crit}) \) is close to or over 1 the intersection is oversaturated and the formula will result in very high or negative cycle time values.

**GREEN TIME**

\[ g_i = (c - LT) \times FR_{crit}/E(FR_{crit}) \]  

where
\[ g_i = \text{Displayed green time in phase i (sec)} \]

The performance of a signalised intersection is generally much more sensitive to errors in the green time distribution than to a too long cycle time. Even small deviation from the green ratio \( g/c \) determined from Formula 3 and 4 above results in high increase of the average delay in the intersection.

e) **Capacity and degree of saturation**

The approach capacity (C) is obtained by multiplication of the saturation flow with the green ratio \( g/c \) for each approach, see Formula (1) above.

The degree of saturation (DS) is obtained as

\[ DS = Q/C = Q \times c/(S \times g) \]  

f) **Level of performance**

Different measures of level of performance can be determined based on the traffic flow (Q), degree of saturation (DS) and signal timing (c and g) as described below:

**QUEUE LENGTH**

The average number of queuing pcu at the beginning of green NQ is calculated as the number of pcu that remain from the previous green phase NQ1 plus the number of pcu that arrive during the red phase (NQ2):

\[ NQ = NQ_1 + NQ_2 = (DS-U.5) / (1-DS) + Q \times (c-g) \]
For design purposes the manual includes provision for adjustment of this average value to a desired level of probability for overloading.

The resulting queue length QL is obtained by multiplication of NQ with the average area occupied per pcu (20 sqm) and division with the entry width.

\[
QL = NQ \times \frac{20}{W_{ENTRY}} \text{(m)}
\]  
(7)

**PROPORTION OF STOPPED VEHICLES**

The proportion of stopped vehicles \(p_{SV}\), i.e. the ratio of vehicles that have to stop because of the red signal before passing the intersection, is calculated as

\[
p_{SV} = 1 + \frac{NQ}{c} - \frac{g}{c}
\]  
(8)

where \(c\) is the cycle time and \(g\) the green time in the studied approach.

**DELAY**

The average delay for an approach can be determined from the following formula (based on Webster 1966):

\[
D_i = \frac{c(1-GR)^2}{(2x(1-GRxDS) + DS^2/(2x(1-DS)xQ_i))} \times 0.9
\]

where

- \(D\) = Mean delay for approach (sec/pcu)
- \(GR\) = Green ratio (g/c)
- \(DS\) = Degree of saturation
- \(c\) = Cycle time (sec)
- \(Q\) = Traffic flow (pcu/sec)

Observe that the calculation result are not valid if the capacity of the intersection is influenced by "external" factors such as blocking of an exit due to downstream congestion, manual police control etc.
Protected discharge from a signalised approach, i.e. no conflict between right-turning vehicles and traffic from the opposing direction.

In protected approaches without median, right-turning vehicles frequently use the opposing driveway when they make their turn.
In opposed approaches right-turning vehicles usually do not respect the right-of-way of straight-through traffic.

If there is no median, right-turning vehicles block the path of the straight through movement by “cutting” into the opposing driveway.
2.2 OVERVIEW OF THE CALCULATION PROCEDURE

A flow chart of the calculation procedure is illustrated below. The different steps are described in detail in Section 3.

Figure 2.2:1  Flow chart for analysis of signalized interactions
The following forms are used for the calculations:

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIG-I</td>
<td>GEOMETRY, TRAFFIC CONTROL, ENVIRONMENT</td>
</tr>
<tr>
<td>SIG-II</td>
<td>TRAFFIC FLOW</td>
</tr>
<tr>
<td>SIG-III</td>
<td>CLEARANCE TIME, LOST TIME</td>
</tr>
<tr>
<td>SIG-IV</td>
<td>SIGNAL TIMING, CAPACITY</td>
</tr>
<tr>
<td>SIG-V</td>
<td>DELAY, QUEUE-LENGTH, NO OF STOPPED VEHICLES</td>
</tr>
</tbody>
</table>

The forms are presented in Appendix 2:1 at the end of the chapter concerning signalised intersections.

2.3 GUIDELINES FOR APPLICATION

2.3.1 Types of application of the manual

The manual can fulfill many different needs and types of calculations for signalised intersections as exemplified below:

a) Planning

Given: Daily traffic flows (AADT).
Task: Determination of layout and type of control.
Example: Determination of intersection layout and phasing for a planned intersection with given traffic demand. Comparisons with other modes of control and types of traffic facilities such as unsignalised control, roundabout layout etc.

b) Design

Given: Layout and traffic flow (daily or hourly).
Task: Determination of recommended design.
Example: Signalisation of a previously unsignalised intersection. Betterment of an existing signalised intersection, e.g. with new signal phasing and approach design. Design of a new signalised intersection.

c) Operation

Given: Geometric design, signal phasing and hourly traffic flows.
Task: Calculation of signal timing and capacity.
Example: Updating of the signal timing for different periods of the day. Estimation of reserve capacity and expected need for capacity improvement and/or changed signal phasing as a result of annual traffic growth.
The signal timing calculated in the manual is recommended for fixed-time control for the traffic conditions used as input data. In order to be on the safe side against traffic fluctuations, a 10% proportional increase of the green times and a corresponding increase of the cycle time is recommended for installation purpose. If the timing is used for traffic actuated control, the maximum green times should be set 25-40% larger than the green times at fixed-time control.

The signal timing method can also be used to determine the minimum cycle time in a system with fixed-time coordination of traffic signals (i.e. the whole system will operate with the highest cycle time required for any of its intersections).

The methodology used at each level is essentially the same, with execution of calculations of signal timing, capacity and level of performance for successive sets of input data until a satisfactory solution to the given problem has been obtained.

### 2.3.2 Default values

On the operational level (c above) all required data inputs are normally obtainable since the calculations refer to an already existing, signalised intersection. For planning and design use however a number of assumptions have to be made to be able to apply the calculation procedures described in Section 3. Preliminary guidance regarding assumptions and default values for use in these cases are presented below.

a) Traffic flows

If only daily traffic flows (AADT) are available without any knowledge of the hourly traffic distribution, the design hourly flows can be estimated as a percentage of the AADT as follows:

<table>
<thead>
<tr>
<th>Type of city and road</th>
<th>Percentage factor K</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cities &gt; 1 M inhabitants</strong></td>
<td></td>
</tr>
<tr>
<td>- Roads in commercial areas and arterial roads</td>
<td>7-8%</td>
</tr>
<tr>
<td>- Roads in residential areas</td>
<td>8-9%</td>
</tr>
<tr>
<td><strong>Cities &lt; 1 M inhabitants</strong></td>
<td></td>
</tr>
<tr>
<td>- Roads in commercial areas and arterial roads</td>
<td>8-10%</td>
</tr>
<tr>
<td>- Roads in residential areas</td>
<td>9-12%</td>
</tr>
</tbody>
</table>

If the distribution of turning movements is unknown and cannot be estimated, the following provisional default values can be used (unless some of the turning movements will be forbidden):
IHCM: SIGNALISED INTERSECTIONS

Right-turning 15% of total approach flow
Left-turning 15% of total approach flow

The following default values for traffic composition can be used in lack of better estimates:

<table>
<thead>
<tr>
<th>City size M inhabitants</th>
<th>Traffic composition %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Light veh. LV</td>
</tr>
<tr>
<td>&gt; 3 M</td>
<td>59</td>
</tr>
<tr>
<td>1 – 3 M</td>
<td>52.5</td>
</tr>
<tr>
<td>0.3 – 1 M</td>
<td>34</td>
</tr>
<tr>
<td>&lt; 0.3 M</td>
<td>60</td>
</tr>
</tbody>
</table>

b) Signal phasing and timing

If the number and types of signal phases are not known, two-phase control should be used as a base case. Separate control of right-turning movements should normally only be considered if a turning movement exceeds 200 pcu/h.

Signal timing default values recommended for use, in Step C below are

- Intergreen time (amber + allred)
  - Small intersection 5 sec per phase
  - Large intersection > 6 sec per phase

c) Approach widths

The following approach widths can be used as start-up assumptions for the analysis of a signalised intersection on the design and planning level if other information is lacking:

<table>
<thead>
<tr>
<th>Total incoming traffic flow in the intersection (pcu/h)</th>
<th>Average approach width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2500</td>
<td>4.5</td>
</tr>
<tr>
<td>2500 - 4000</td>
<td>7</td>
</tr>
<tr>
<td>4000 - 5000</td>
<td>10 (sep. RT lanes)</td>
</tr>
<tr>
<td>&gt; 5000</td>
<td>Larger design</td>
</tr>
</tbody>
</table>

The approach widths naturally have to be adjusted to imbalances in the ratio of flow between the intersecting roads and their approaches.
The very high ratio motorcycle in Indonesian cities result in big groups of motorcycles assembling at the stop-line before the start of green.
3. **CALCULATION PROCEDURE**

The procedures required for calculation of signal timing, capacity and level of performance are described below step-by-step in the following order (see also the flow chart in Figure 2.2:1 above):

**STEP A: INPUT DATA**
- A-1: Geometric, traffic control and environmental conditions
- A-2: Traffic flow conditions

**STEP B: SIGNALISATION**
- B-1: Signal phasing
- B-2: Clearance time and lost time

**STEP C: SIGNAL TIMING**
- C-1: Approach type
- C-2: Effective approach width
- C-3: Base saturation flow
- C-4: Correction factors
- C-5: Flow/saturation flow ratio
- C-6: Cycle time and green times

**STEP D: CAPACITY**
- D-1: Capacity
- D-2: Need for revisions

**STEP E: LEVEL OF PERFORMANCE**
- E-1: Preparations
- E-2: Queue length
- E-3: Stopped vehicles
- E-4: Delay

Blank forms for the calculations are presented in Appendix 2:1, and worked examples can be found in Section 4. Basically the same procedure is followed for all types of applications as described in Section 2.3, the main difference only being in the degree of detail in the input data.
STEP A: INPUT DATA

Step A-1: GEOMETRIC, TRAFFIC CONTROL AND ENVIRONMENTAL CONDITIONS (Form SIG-I).

Information to be filled in the top part of Form SIC-I:

- **General**
  Fill in Date, Handled by, City, Intersection, Case (e.g. Alt. 1) and Period (e.g. AM peak 1993) in the head of the form.

- **City size**
  Enter the population of the urban area (to the nearest 0.1 M inhabitants).

- **Signal phasing and timing**
  Use the boxes under the head of Form SIG-I to draw the existing phase diagrams (if available). Enter the existing green (g) and intergreen (IC) times in each phase box, and enter the cycle time and the total lost time (LT = EIG) for the case studied (if available).

- **Left turn on red LTOR**
  Indicate in the phase diagrams in which approaches) that Left turn on red is permitted (i.e. the turn can be made in all phases without consideration to the signals).

Use the empty space in the middle part of the form to make a sketch of the intersection, and enter all required geometric input data:

- **Layout and position of approaches, traffic islands, stoplines, pedestrian crossings, lane markings and arrows.**

- **Width** (to the nearest tenth of a meter) of the paved part of approaches, entries and exits.

- **Length of lanes with restricted length** (to the nearest m).

- **Draw an arrow indicating the direction of North** on the sketch.

If the layout and design of the intersection is not known, see Section 2.3 above regarding startup assumptions for the analysis.

Enter data on other site conditions which are relevant for the studied case in the table at the bottom part of the form:
Appraise code (Column 1)
Use North, South, East, West or any other clear indication to name the approaches. Observe that an intersection arm can be divided by traffic islands in two or more approaches.

Road environment type (Column 2)
Enter Road environment type (COM = Commercial; RES = Residential; RA = Restricted access) for each approach (definitions see. Section 1.3).

Level of side friction (Column 3)
Enter the side friction level:

High: The discharge rate at the entry and the exit is reduced by roadside activity in the approach such as public transit stops, pedestrians walking along or crossing the approach, exits and entries to roadside properties etc.

Low: The discharge rate at the entry and exit is not reduced by side friction of the types described above.

Median (Column 4)
Enter if there is a median at the right side of the stopline in the approach (Yes/No).

Gradient (Column 5)
Enter gradient in % (uphill = + % ; downhill = - %)

Left turn on red (Column 6)
Enter if Left turn on red (LTOR) is permitted (Yes/No) in the approach (additional to showing it in the phase diagrams as described above).

Distance to parked vehicle (Column 7)
Enter what the normal distance between the stop-line and the first parked vehicle upstream in the approach is for the conditions studied.

Approximate (Column 8-10)
Enter from the sketch the width (to the nearest tenth of a meter) of the paved part of each Approximate upstream of turning point for LTOR, Entry at the stop-line and Exit (bottleneck after passing the cross road).

Comments
Record on a separate sheet any other information which you think might influence the capacity of the approach.
STEP A-2: TRAFFIC FLOW CONDITIONS

- If detailed traffic data with distribution on vehicle types for each turning movement is available, Form SIG-II is recommended for use. Enter the traffic flow data for each vehicle type in veh/h in Column 3, 6, 9 and 12. In other cases it might be preferable to use a simpler form of data presentation, and to enter the results directly into Form SIG-IV. (Default traffic input values: See Section 2.3.2 above).

Several sets of traffic flow data may be needed for analysis of different periods, e.g. morning peak hour, noon peak hour, afternoon peak hour, off-peak hour etc.

Observe: If Left turn on red (LTOR) is permitted and does not interfere with the other traffic in the approach (i.e. LTOR vehicles can pass the queue of straight-through and right-turning vehicles formed in the approach during red light) the LTOR movement should be excluded in Form SIG-II.

- Calculate the traffic flow in pcu/h for each vehicle type for protected and/or opposed discharge conditions (whichever is relevant depending upon the signal phasing and permitted right-turning movements) using the following pcu values:

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>pcu - values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Protected approach</td>
</tr>
<tr>
<td>LV</td>
<td>1.0</td>
</tr>
<tr>
<td>HV</td>
<td>1.3</td>
</tr>
<tr>
<td>MC</td>
<td>0.2</td>
</tr>
<tr>
<td>UM</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Enter the results in Columns 4-5, 7-8, 10-11, 13-14.

- Calculate the total traffic flow in veh/h and pcu/h in each approach for protected and/or opposed discharge conditions (whichever is relevant depending upon the signal phasing and permitted right-turning movements). Enter the results in Columns 15-17.

- Calculate for each approach the ratio of left-turning $p_{lt}$, and the ratio of right-turning $p_{rt}$, and enter the results in Columns 18 and 19 in the respective rows for LT and RT flows:

$$PLT = \frac{LT \text{ (pcu/h)}}{Total \text{ (pcu/h)}} \quad PR = \frac{RT \text{ (pcu/h)}}{Total \text{ (pcu/h)}}$$ (same value for protected and opposed approaches).
STEP B: SIGNALISATION

Step B-1: SIGNAL PHASING (Form SIG-IV)

If the calculations shall be performed for other than the existing signal phasing scheme as drawn in Form SIG-I, a signal phasing scheme must be chosen as a start-up alternative for evaluation. Different types of signal phasing have been shown in Section 1, Figure 1.2:3.

PROCEDURE

- Select signal phasing.
  As a preliminary advice (awaiting the traffic engineering guidelines to be developed in Phase 3 of the HCM project) two-phase control should be tried as a base case, since it usually yields higher capacity and lower average delay than other types of signal phasing. Separate control of a right-turning movement is normally only preferable from a capacity point of view if it exceeds 200 pcu/h. It may however be required for traffic safety reasons in special cases.

- Sketch the chosen signal phasing in the boxes reserved for this purpose in Form SIG-IV.
Step B-2: CLEARANCE TIME AND LOST TIME (Form SIG-III).

- Determine the required clearance times and the total lost time in the intersection as described below.

- Enter the resulting total lost time LT at the bottom of Column 4 in Form SIC-IV.

For operational and design analysis a detailed calculation of the clearance times and the total lost time with the help of Form SIC-III as described below is recommended. In analysis performed for planning purposes, the following intergreen times (amber + allred) can be assumed as default values:

<table>
<thead>
<tr>
<th>Intersection size</th>
<th>Mean approach width</th>
<th>Intergreen time default values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>3 - 6 m</td>
<td>5 sec/phase</td>
</tr>
<tr>
<td>Medium</td>
<td>6 - 9 m</td>
<td>6 sec/phase</td>
</tr>
<tr>
<td>Large</td>
<td>&gt; 9 m</td>
<td>7 sec/phase</td>
</tr>
</tbody>
</table>

**PROCEDURE FOR DETAILED CALCULATIONS**

The required clearance time (CT) must allow for the last evacuating vehicle to clear the conflict point before arrival of the first advancing vehicle from the next phase to the same point. CT is a function of the speed and the distances for evacuating and advancing vehicles from the stop-line to the conflict point, and of the length of the evacuating vehicle, see Figure B-2:1 below.
The critical conflict point in each phase (i) is the point that yields the largest resulting clearance time CT:

\[
CT_i = \frac{1}{(LEV + IEV)} V_{EV} - L_{AV} / V_{AV \text{max}}
\]

Where

- \( LEV, L_{AV} \) = Distance from stop-line to conflict point for evacuating resp advancing vehicle (m)
- \( IEV \) = Length of evacuating vehicle (m)
- \( V_{EV}, V_{AV} \) = Speed of evacuating resp advancing vehicle (m/sec).

Figure B-2:1 illustrates a case with critical conflict points identified for both crossing vehicles and crossing pedestrians.

The values chosen for \( V_{EV}, V_{AV} \) and \( I_{AV} \) depend upon the traffic composition and the speed conditions at the site. The following temporary values could be chosen in lack of Indonesian regulations on this matter:

- Speed of advancing veh \( V_{AV} \): 10 m/sec (motor vehicles)
- Speed of evacuating veh. \( V_{EV} \): 10 m/sec (motor vehicles)
- "": 3 m/sec (un-motorised)
- "": 1.2 m/sec (pedestrians).
- Length of \( IEV \):
  - "": 5 m (LV or HV)
  - "": 2 m (MC or UM)

The calculations are performed with the help of Form SIG-III.

The allred periods between the phases should be equal or greater to the clearance times.

When the allred times for each phase change have been determined, the total lost time (LT) for the intersection can be calculated as the sum of the intergreen periods:

\[
LT = \Sigma (\text{allred} + \text{amber}) = \Sigma I_{Gj}
\]

The amber period in urban traffic signals in Indonesia is normally 3.0 sec.
STEP C: SIGNAL TIMING

Step C includes determination of the following factors:

C – 1: Approach type  
C – 2: Effective approach width  
C – 3: Base saturation flow  
C – 4: Correction factors  
C – 5: Flow/saturation flow ratio  
C – 6: Cycle time and green times

The calculations are entered into Form SIG-IV SIGNAL TIMING AND CAPACITY.

Step C-1: APPROACH TYPE

- Enter identification of each approach in a separate row in Form SIG-IV Column 1.

- Enter the number of the phase during which each approach has green light in Column 2.

- Determine the type of each approach (P or 0) with the help of Figure C-1:1 below, and enter the results in Column 3.

- Make a sketch showing the resulting directional flows (Form SIG-11 Column 16-17) in pcu/h in the upper left box in Form SIG-IV (select the appropriate results for protected (Type P) or opposed conditions (Type 0) as documented in Column 3).

- Enter the ratio of turning vehicles (P_{LTOK} or p,r, PKT) for each approach (from Form SIG-11 Column 18-19) in Columns 4-6.

- Enter from the sketch the flow of right-turning vehicles in pcu/h in the own direction (Q_{RT}) in Column 7 for each approach (from Form SIG-11 Column 16). Enter also for approaches of type 0 the flow of right-turning vehicles in the opposing direction (Q_{RTO}) in Column 8 (from Form SIG-II Column 17).
<table>
<thead>
<tr>
<th>Approach Type</th>
<th>Description</th>
<th>Examples of approach Configurations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protected P</td>
<td>Discharge Without conflict With traffic From the opposing direction</td>
<td>One-way street: One-way street: T-junction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[Diagram showing protected approach]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Two-way streets, restricted Right-turning movements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[Diagram showing restricted right-turns]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Two way street, separate signal Phase for each direction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[Diagram showing separate signal]</td>
</tr>
<tr>
<td>Opposed O</td>
<td>Discharge with Conflict with Traffic from The opposing direction</td>
<td>Two-way street, discharge of the Opposing directions in the same phase. All right-turns not restricted.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[Diagram showing opposed approach]</td>
</tr>
</tbody>
</table>

Figure C-1:1  Determination of approach type
Effective Approach Width

- Determine the effective width ($W_e$) of each approach based on the information about approach width ($W_A$), entry width ($W_{ENTRY}$) and exit width ($W_{EXIT}$) from the Form SIG-1 (the sketch and Column 8 - 10) as follows, and enter the result in Column 9 in Form SIG-IV:

a) For all approach types (P and O):

If Left-turn-on-red (LTOR) is permitted and does not interfere with the other traffic in the approach (i.e. LTOR vehicles can bypass the queue of straight-through and right-turning vehicles in the approach during red signal, which can generally be assumed if $W_{LTOK} > 2$ m), the effective width is determined as the smallest value of $W_A - W_{LTOR}$ and $W_{ENTRY}$:

$$W_e = \min\{W_A - W_{LTOR}, W_{ENTRY}\}$$

The LTOR movement should then be excluded from the remaining calculations (i.e. $Q = Q_{ST} + Q_{RT}$ in Form SIG IV). Proceed to b) below for a check of exit conditions (only for approach type P).

b) Control for approach type P only:

Check if the width of the approach exit is sufficient:

$$W_{EXIT} > W_{ENTRY} \times (1 - P_{RT} - P_{LT} - P_{LTOR})$$

If this condition is met, $W_e$ is determined as in 1) above. If the condition is not met, $W_e$ should be set equal to $W_{EXIT}$, and the remaining analysis for this approach is conducted for the straight-through portion of the traffic only (i.e. $Q = Q_{ST}$ in Form SIG-IV Column 18).
Step C-3: BASE SATURATION FLOW

- Determine the base saturation flow \( (S_o) \) for each approach as described below, and enter the results in Column 10:

a) **For approach type P (protected discharge):**

\[
S_o = 600 \times W_e \text{ pcu/hg}, \text{ see Figure C-3:1}
\]

![Figure C-3:1 Base saturation flow for approach type P.](image)

b) **For approach type 0 (opposed discharge):**

\( S_o \) is determined from Figure C-3:2 (for approaches *without* separate right-turning lanes), and from Figure C-3:3 (for approaches *with* separate right-turning lane) as a function of \( W_e Q_{RT} \) and \( Q_{RTO} \).

Use the figures to obtain the saturation flow values for cases with approach width larger and smaller than the actual \( W_e \) and calculate the resulting value by interpolation.
Example:

Without sep. RT lane: \( Q_{RT} = 125 \text{ pcu/h}; \ Q_{RTO} = 100 \text{ pcu/h} \)
Actual \( W_e = 5.4 \text{ m} \)

Obtain from Figure C-3:2
\( S_{6.0} = 3000; \ S_{5.0} = 2440 \)

Calculate
\[
S_{5.4} = (5.4 - 5.0) \times (S_{6.0} - S_{5.0}) + S_{5.0} = 0.4(3000 - 2440) + 2440 \\
= 2664 - 2660
\]
Figure C-3:2 \( S_o \) for approaches type O without separate right-turning lane
Figure C-3:3 \( S_o \) for approach type O with separate right-turning lane.
IHCM: SIGNALISED INTERSECTIONS

Step C-4: CORRECTION FACTORS

a) Determine the following correction actors for the base saturation flow value for both approach type P and Q as follows:

- The City size correction factor $F_{CS}$ is determined from Table C-4:3 as a function of the city size recorded in Form SIG-I. The result is entered in Column 11.

<table>
<thead>
<tr>
<th>City population (M. inhabitants)</th>
<th>City size correction factor $F_{CS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;3.0</td>
<td>1.05</td>
</tr>
<tr>
<td>1.0-3.0</td>
<td>1.00</td>
</tr>
<tr>
<td>0.3-1.0</td>
<td>0.94</td>
</tr>
<tr>
<td>&lt;0.3</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Table C-4:3 City size correction factor $F_{CS}$

- The Side friction correction factor $F_{SF}$ is determined from Table C-4:4 as a function of Road environment type and Side friction recorded in Form SIG-I. The result is entered in Column 12. If the side friction is not known, it can be assumed to be high in order not to over estimate capacity.

<table>
<thead>
<tr>
<th>Road environment</th>
<th>Correction factor $F_{SF}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High side friction</td>
</tr>
<tr>
<td>Commercial</td>
<td>0.94</td>
</tr>
<tr>
<td>Residential</td>
<td>0.97</td>
</tr>
<tr>
<td>Restricted Access</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table C-4:4 Correction factor for Road environment type and Side friction

- The Gradient correction factor $F_G$ is determined from Figure C-4:1 as a function of the gradient (GRAD) recorded in Form SIG-I, and the result is entered in Column 13 in Form SIG-IV.

![Figure C-4:1](image-url)
The Parking correction factor $F_P$ is determined from Figure C-4:2 as a function of the distance from the stop-line to the first parked vehicle (Column 7 in Form SIG-I) and the approach width ($W_A$, Column 9, in Form SIG-IV). The result is entered in Column 14. This factor can also be applied for cases with restricted length of left turning lanes.

$F_P$ can also be calculated from the following formula, which includes the effect of the length of the green time:

$$F_P = \frac{[L_p/3 - (W_A - 2) \times (L_p/3 - g)/W_A]/g}{g}$$

where

$L_p$ = Distance between stop-line and first parked vehicle (m)
(or length of short lane).

$W_A$ = Width of the approach (m).

$g$ = Green time in the approach (sec).

Figure C-4:2  Correction factor for effect of parking and short left-turn lanes $F_P$
b) Determine the following correction factors for the base saturation flow value only for approach type P as follows:

- The Right Turn correction factor \( F_{RT} \) is determined as a function of ratio of right-turning vehicles \( P_{RT} \) (from Col. 6) as follows, and the result is entered in Column 15:

Only for Approach type P; No median; Two-way street:

Calculate \( F_{RT} = 1.0 + P_{RT} \times 0.26 \), or obtain the value from Figure C-4:3 below

![Figure C-4:3 Correction factor for right turns \( F_{RT} \). (only applicable for approach type P, two-way streets)](image_url)

Explanation:
On two-way streets without median, the right-turning vehicles during protected discharge (approach type P) have a tendency to cross the centerline before the stopline when completing their turn. This causes a marked increase of the saturation flow at high ratio of right-turning traffic.
The **left turn correction factor** $F_{LT}$ is determined as a function of the ratio of left turns $P_{LT}$ as recorded in Column 5 in Form SIG-IV, and the results are entered in Column 16.

**Observe:** Only for Approach type P without LTOR:

Calculate $F_{LT} = 1.0 - P_{LT} \times 0.16$, or obtain the value from Figure C-4:4 below.

---

**Figure C-4:4** Correction factor for effect of left turn FLT *(only applicable for approach type P with no left turn on red)*

**Explanation:**
In protected approaches without provisions for left turn on red, the left-turning vehicles tend to slow down and decrease the saturation flow of the approach. Due to the generally slower discharge of traffic in opposed approaches (type O), no correction for the influence of the ratio of left turns is needed.

c) **Calculate the adjusted value of saturation flow** $S$

The adjusted saturation flow value is calculated as

$$S = S_0 \times F_{CS} \times F_{SP} \times F_{G} \times F_P \times F_{RT} \times F_{LT} \times pcu/hg$$

Enter the value in Column 17.
IHCM: SIGNALISED INTERSECTIONS

Step C-5: FLOW/SATURATION FLOW RATIO

- Enter the relevant traffic flow for each approach (Q) from Form SIG-I1 Column 16 (Protected) or Column 17 (Opposed) into Column 18 in Form SIG-IV.

Observe:

- If LTOR shall be excluded from the analysis (see Step C-2, item 1-a) only the straight-through and the right-turning movements should be included in the Q-value to be entered in Column 18.

- If \( W_e = W_{ET} \) (see Step C-2, item 2) only the straight-through movement should be included in the Q-value in Column 18.

- Calculate the Flow Ratio (FR) for each approach and enter the results in Column 19:

\[
FR = \frac{Q}{S}
\]

- Identify the critical (= highest) flow ratio (\( FR_{CRIT} \)) in each phase by encircling it in Column 19.

- Calculate the Intersection flow ratio (IFR) as the sum of the encircled (= critical) values of FR in Column 19, and enter the result in the box at the bottom of the Column 19.

\[
IFR = \sum( FR_{crit} )
\]

- Calculate the Phase Ratio (PR) for each phase as the ratio between \( FR_{CRIT} \) and IFR, and enter the results in Column 20.

\[
PR = \frac{ FR_{crit} }{ IFR }
\]
Step C-6: CYCLE TIME AND GREEN TIMES

a) Cycle time

- Calculate the cycle time \( c \) for fixed time control, and enter the result in Cycle time box at the bottom in Column 10 in Form SIG-IV.

\[
c = \frac{1.5 \times LT + 5}{1-IFR}
\]

where
\[
c = \text{Signal cycle time (sec)}
\]
\[
LT = \text{Total lost time per cycle (sec)}
\]
\[
(\text{From the bottom left corner in Form SIG-IV})
\]
\[
IFR = \text{Intersection flow ratio } F(FR_{\text{crit}})
\]
\[
(\text{From the bottom of Column 19})
\]

The cycle time can also be obtained from Figure C-6:1 below.

Figure C-6:1 Determination of cycle time
If alternative signal phasing schemes are evaluated, the one which yields the lowest value of \((IFR + LT/c)\) is the most efficient.

Adjust the calculated cycle time with the regard to the recommended limits below (based on traffic engineering judgement), and enter the adjusted value below the calculated cycle time at the bottom in Column 10 in Form SIG IV:

<table>
<thead>
<tr>
<th>Type of control</th>
<th>Feasible cycle time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-phase control</td>
<td>40 - 80</td>
</tr>
<tr>
<td>Three-phase control</td>
<td>50 - 100</td>
</tr>
<tr>
<td>Four phase control</td>
<td>80 - 130</td>
</tr>
</tbody>
</table>

The lower values refer to intersections with street widths < 10 m, the higher values to wider streets. Cycle times lower than the recommended values will lead to difficulties for pedestrians to cross the streets. Cycle times in excess of 130 seconds should be avoided other than in very special cases (very large intersections), since it often results in loss of overall capacity.

If the calculations yield a much higher cycle time than the recommended limits, it indicates that the capacity of the current layout of the intersection is insufficient. This problem is dealt with in Step E below.

b) **Green time**

Calculate green times \((g)\) for each phase:

\[
g_i = (c - LT) \times PR_i
\]

where

- \(g_i\) = Displayed green time in phase i (sec)
- \(c\) = Adjusted cycle time (sec) (From bottom of Column 10)
- \(LT\) = Total lost time per cycle (From bottom of Column 4)
- \(PR_i\) = Phase ratio \(FR_{crit}/\Sigma(FR_{crit})\) (From Column 20)

Shorter green times than 10 seconds should be avoided, since they may result in excessive driving against red light and difficulties for pedestrians to cross the road. If the green times need to be adjusted, the corresponding adjustment must also be made of the cycle time. Enter the adjusted green times in Column 21.
STEP D: CAPACITY

Step D includes determination of the capacity of each approach, and a discussion of revisions to be made if the capacity is insufficient.

The calculations are entered into Form SIG-IV.

Step D-1: CAPACITY

- Calculate the capacity $C$ of each approach and enter the result in Column 22:

$C = S \times g/c$ where the values for $S$ are obtained from Column 17, $g$ and $c$ from Column 10 (bottom).

- Calculate the Degree of saturation $DS$ for each approach, and enter the result in Column 23:

$DS = Q/C$ where the values for $Q$ and $C$ are obtained from Column 18 and 22.

If the signal timing has been correctly done, $DS$ will be the same in all critical approaches.
Step D-2: NEED FOR REVISIONS

If the degree of saturation (DS) is close to or higher than 1.0, the intersection is oversaturated, which will lead to accumulating queues during peak-traffic conditions. The possibility to increase the capacity of the intersection by any of the following measures should therefore be considered:

a) **Increase of approach width**

If it is possible to increase the approach widths, the best effect of such a measure will be obtained if the width is increased in the approaches with the highest critical FR value (Column 19).

b) **Changed signal phasing**

If approaches with opposed discharge (type 0) and high ratio of right-turning traffic (P_{RT}) show high critical FR values, an alternative phasing scheme with separate phase for right-turning traffic might be appropriate. See Section 1.2 above for selection of signal phasing. Introduction of separate phases for right-turning traffic may have to accompanied with widening measures as well.

If the intersection is operated in four phases with separate discharge of each approach, as phase scheme with only two phases might give higher capacity, provided that the right-turning movements are not too high (< 200 pcu/h).

c) **Prohibition of right-turning movement(s)**

The prohibition of one or more right-turning movements will normally increase capacity, particularly if it leads to a reduction of the number of phases required. Proper traffic management planning is however required to make sure that the trips served by the right-turning movements to be forbidden can be accomplished without excessive detours and disturbances to adjacent intersections.
**STEP E: LEVEL OF PERFORMANCE**

Step E includes determination of the level of performance of the signalised intersection in terms of queue-length, no. of stopped vehicles and delay. The calculations are performed using Form SIG-V.

**Step E-1: PREPARATIONS**

- Fill in the information required in the head of Form SIG-V.

- Enter approach code in Column I (same as Column 1 in Form SIC-IV).

- Calculate the traffic flow for each approach in pcu/sec by dividing the value of Q (Form SIC-IV Column 18) with 3600, and enter the result in Column 2.

- Enter the flow ratio in Column 3 (from Column 19 in Form SIG-IV).

- Calculate the green ratio CR = g/c from the adjusted results in Form SIC-IV (Columns 10 bottom and Column 21), and enter the result in Column 4.

- Enter the degree of saturation in Column 5 (from Form SIG-IV Column 23).
Step E-2: QUEUE LENGTH

- Use the calculate value of degree of saturation DA (Column 5) to calculate the number of queuing pcu \((NQ_1)\) that remain from the previous green phase. Use the formula or Figure E-2:1 below, and enter the result in Column 6.

\[
NQ_1 = \begin{cases} 
\frac{DS - 0.5}{1 - 0.5} & \text{for } DS > 0.5 \\
0 & \text{for } DS \leq 0.5 
\end{cases}
\]

Figure E-2:1 Number of queuing vehicles that remain from the previous green phase \(NQ_1\)

- Calculate the number of queuing pcu that arrive during the red phase \((NQ_2)\), and enter the result in Column 7.

\[
NQ_2 = Q \times (c - g)
\]

- Obtain the total number of queuing vehicles and enter the result in Column 8:

\[
NQ = NQ_1 + NQ_2
\]
- Use Figure E-2:2 below to adjust $NQ$ with regard to the desired probability for overloading $P_{OL} (%)$, and enter the resulting value $NQ_{MAX}$ in Column 9. For planning and design $P_{OL} \leq 5\%$ is recommended, for operation a $P_{OL} = 5 - 10\%$ might be acceptable.

- Calculate the queue length $QL$ by multiplying $NQ_{MAX}$ with the average area occupied per pcu (20 sqm) and dividing with the entry width, and enter the result in Column 10.

$$QL = NQ_{MAX} \times 20 / W_{ENTRY} \text{ (m)}$$

![PROBABILITY FOR OVERLOADING $P_{OL}$](image)

Figure E-2:2 Calculation of no. of queuing pcu $N_{C MAX}$
Step E-3: STOPPED VEHICLES

- Calculate the proportion of stopped vehicles $p_{SV}$ from the formula below or using Figure E-3:1. $p_{SV}$ is a function of $NQ$ (Column 8) divided by the cycle time, and the green ratio (Column 4). Enter the result in Column 11.

$$p_{SV} = 1 + \frac{NQ}{c} - \frac{g}{c}$$

If a higher value than 1.0 is obtained, select 1.0 (= all vehicles are stopped at least once).

Figure E-3:1    Proportion of stopped vehicles $p_{SV}$

- Calculate the number of stopped vehicles $N_{SV}$ and enter the results in Column 12:

$$N_{SV} = Q \times p_{SV}$$

- Calculate the average proportion of stopped vehicles for the whole intersection and enter the result at the bottom of Column 12:

$$p_{SV,TOT} = \frac{\Sigma N_{SV}}{\Sigma Q}$$
Step E-4: DELAY

The delay for an approach can be determined from the following formula (based on Webster 1966):

\[ D_j = (A_j \times c + B_j / Q_j) \times 0.9 \]

where

\[ D_j = \text{Mean delay for approach } j \text{ (sec/pcu)} \]
\[ A_j = \frac{(1 - GR)^2}{2x(1 - CR \times DS)} \]
\[ B_j = \frac{DS^2}{2(1 - DS)} \]
\[ c = \text{Cycle time (sec)} \]
\[ Q_j = \text{Traffic flow for approach } j \text{ (pcu/sec)} \]

Determine the value of \( A \), from the formula above or from Figure E-4:1 below by entering with the value of degree of saturation (from Column 5) on the horizontal axis, the green ratio (from Column 4), and reading the resulting \( A \) value on the vertical axis. Enter the value of \( A \) in Column 13.

Figure E-4:1 Determination of \( A \) in the delay formula
Multiply the value of $A_i$ (Column 13) with the cycle time and enter the value in Column 14.

Determine the value of $B_i$ from the formula or from Table E-4:1 below by entering with the value of degree of saturation (from Column 5). Enter the value in Column 15.

<table>
<thead>
<tr>
<th>Degree of saturation DS</th>
<th>0.00</th>
<th>0.01</th>
<th>0.02</th>
<th>0.03</th>
<th>0.04</th>
<th>0.05</th>
<th>0.06</th>
<th>0.07</th>
<th>0.08</th>
<th>0.09</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.006</td>
<td>0.007</td>
<td>0.008</td>
<td>0.010</td>
<td>0.011</td>
<td>0.013</td>
<td>0.015</td>
<td>0.017</td>
<td>0.020</td>
<td>0.022</td>
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<tr>
<td>0.2</td>
<td>0.025</td>
<td>0.028</td>
<td>0.031</td>
<td>0.034</td>
<td>0.038</td>
<td>0.042</td>
<td>0.046</td>
<td>0.050</td>
<td>0.054</td>
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<tr>
<td>0.3</td>
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<td>0.070</td>
<td>0.075</td>
<td>0.081</td>
<td>0.088</td>
<td>0.094</td>
<td>0.101</td>
<td>0.109</td>
<td>0.116</td>
<td>0.125</td>
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<td>0.4</td>
<td>0.133</td>
<td>0.142</td>
<td>0.152</td>
<td>0.162</td>
<td>0.173</td>
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<td>0.196</td>
<td>0.208</td>
<td>0.222</td>
<td>0.235</td>
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<tr>
<td>0.5</td>
<td>0.250</td>
<td>0.265</td>
<td>0.282</td>
<td>0.299</td>
<td>0.317</td>
<td>0.336</td>
<td>0.356</td>
<td>0.378</td>
<td>0.400</td>
<td>0.425</td>
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<td>0.6</td>
<td>0.450</td>
<td>0.477</td>
<td>0.506</td>
<td>0.536</td>
<td>0.569</td>
<td>0.604</td>
<td>0.641</td>
<td>0.680</td>
<td>0.723</td>
<td>0.768</td>
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<tr>
<td>0.7</td>
<td>0.817</td>
<td>0.889</td>
<td>0.928</td>
<td>0.987</td>
<td>1.05</td>
<td>1.13</td>
<td>1.20</td>
<td>1.29</td>
<td>1.38</td>
<td>1.49</td>
</tr>
<tr>
<td>0.8</td>
<td>1.60</td>
<td>1.73</td>
<td>1.87</td>
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<td>2.21</td>
<td>2.41</td>
<td>2.64</td>
<td>2.91</td>
<td>3.23</td>
<td>3.60</td>
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<tr>
<td>0.9</td>
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<td>4.60</td>
<td>5.28</td>
<td>6.18</td>
<td>7.38</td>
<td>9.03</td>
<td>11.5</td>
<td>15.7</td>
<td>24.0</td>
<td>49.0</td>
</tr>
</tbody>
</table>

Table E-4:1 Determination of $B_i$

Divide the value of $B_i$ (Column 15) with $Q$ (column 2) and enter the value in Column 16.

Calculate the average delay $D$ (sec/pcu) as the sum of Column 14 and 16 multiplied by 0.9 (see the formula above) and enter the resulting delay values in Column 17.

Calculate the total delay in seconds by multiplying the average delay (Column 17) with the traffic flow (Column 2), and enter the results in Column 18.

Calculate the average delay for the whole intersection $D_1$, by dividing the sum of the delay values in Column 18 with the sum of the traffic flow values in Column 2:

$$D_1 = \frac{\Sigma (Q \times D_i)}{\Sigma Q_i}$$

Enter the value in the bottom box in Column 18.

The average delay can be used as an indicator of the level of service of each individual approach as well as of the intersection as a whole.
In the U.S. Highway Capacity Manual (TRB Special Report 209 1985) the following relation between level of service and delay is given:

<table>
<thead>
<tr>
<th>Level of Service</th>
<th>Stopped delay (sec/veh)</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt;5</td>
</tr>
<tr>
<td>B</td>
<td>5.1 - 15</td>
</tr>
<tr>
<td>C</td>
<td>15.1 - 25</td>
</tr>
<tr>
<td>D</td>
<td>25.1 - 40</td>
</tr>
<tr>
<td>E</td>
<td>40.1 - 60</td>
</tr>
<tr>
<td>F</td>
<td>&gt; 60</td>
</tr>
</tbody>
</table>

(Corresponding service levels for use in Indonesia will developed in the third phase of the HCM project)
4. WORKED EXAMPLES

EXAMPLE 1

Intersection: JI Iskandarsyah - Jl Wijaya, Jakarta

Task:  

a) Update the signal timing for the AM peak hour and calculate capacity and level of performance with the new signal timing.

b) Calculate signal timing and degree of saturation if the west approach on Jl. Wijaya is given green 10 seconds before the east approach, i.e. four-phase control with pregreen for the west approach.

Input data: Geometry, control and environmental conditions see Form SIG-I. Traffic flow data see separate table.

Results: The results of the calculations for task a) are shown on Form SIG II, III, IV and V, for task b) in Form SIG IV.

Comments:  

a) In Form SIG-II the LTOR traffic movement from the East approach has been omitted, since it can be discharged without disturbing the other traffic movements in that approach.

Form SIG-III shows that the required clearance time for phase 1, 2 and 3 is 1.9, 1.8 and 3.0 sec respectively. The allred periods between the phases should therefore be set equal to or greater than these values for traffic safety reasons. Together with the amber periods (3.0 sec), the intergreen between then becomes 5 (4.9), 5 (4.8) and 6.0 sec, and the total Intergreen time = Lost time = 16 sec.

Form SIG-IV shows that the Intersection Flow Ratio IFR = 0.778, leading to a calculated cycle time for minimum delay of 130.9 sec which is adjusted to 130 sec (max. feasible value). The calculated green times in phase 1, 2 and 3 are 29, 37 and 48 sec (existing green times 17, 27 and 28 sec and cycle time 87 sec). The existing timing can therefore be expected to lead to long queues, which also corresponds with the existing situation.

Form SIGN finally shows the level of performance with the new signal timing. As can be seen, the intersection is still heavily congested with queue-lengths in the order of 100 m, average proportion of stopped vehicles 0.96, and average delay 46 sec = Level of Service E according to the US HCM 1985.
b) Form SIG-IV case b) shows the analysis for the situation with pregreen for the west approach, which thus gets green light in both phase 3 and 4. The analysis for this approach is therefore first done separately for phase 3 (protected conditions) and phase 4 (opposed condition). For the determination of the Flow ratio (Column 19) for the west approach however, a total value for phase 3 and 4 is calculated assuming that phase 3 corresponds to 25% and phase 4 75% of the total green time in phase 3+4 (see calculation at the bottom of the form). The resulting flow ratio is equal to 0.298, which gives IFR = 0.749 and the cycle time = 115.6 sec. Since the instruction in task b) was to evaluate a 10 sec. pregreen for the west approach, the cycle time is kept constant at 130 sec. as in case a).

The total green time for the west approach becomes 45 sec, and for the east approach 35 sec (45 - 10). From the calculation of the degree of saturation (Column 23) it can be seen that the north, south and west approach obtain a slightly lower DS (0.854) compared to case a), but that the east approach now becomes critical with a DS = 0.997. Installation of a 10 sec. pregreen for the west approach is therefore not recommended.
### Example 1

**INDONESIAN HIGHWAY CAPACITY MANUAL**

**Form SIG-I**

<table>
<thead>
<tr>
<th>SIGNALISED INTERSECTION</th>
<th>GEOMETRY</th>
<th>Date: 02 February 1993</th>
<th>Handled by: KLB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form SIG-I:</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>City: Jakarta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intersection: Jl. Iskandarsyah – Jl. Wijaya</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City size: 8.3 M</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Case: a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### EXISTING SIGNAL PHASES

| Cycle time: | 87 |
| Total lost time: | \( LT = \sum IG = 15 \) |

#### SITE CONDITIONS

<table>
<thead>
<tr>
<th>Approach Code</th>
<th>Road Environment Type</th>
<th>Side Friction H/L</th>
<th>Median Y/N</th>
<th>Gradient +/- %</th>
<th>Left-turn On Red Y/N</th>
<th>Distance To parked Vehicle (m)</th>
<th>Approach with (m)</th>
</tr>
</thead>
<tbody>
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<td>L</td>
<td>Y</td>
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<td>Y</td>
<td>11.5</td>
<td>11.5</td>
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<tr>
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<td>RES</td>
<td>L</td>
<td>Y</td>
<td>0</td>
<td>Y</td>
<td>10.9</td>
<td>10.9</td>
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<td>L</td>
<td>N</td>
<td>0</td>
<td>Y</td>
<td>9.3</td>
<td>6.8</td>
</tr>
<tr>
<td>W</td>
<td>RES</td>
<td>L</td>
<td>N</td>
<td>0</td>
<td>Y</td>
<td>6.8</td>
<td>6.8</td>
</tr>
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</table>

**Jl. Prapanca**

---

IHCM: SIGNALISED INTERSECTIONS
## IHCM: SIGNALISED INTERSECTIONS

### Example 1

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<th></th>
<th></th>
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</thead>
<tbody>
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<td></td>
<td>LH</td>
<td>HV</td>
<td>MC</td>
</tr>
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<td>0.084</td>
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<td>ST</td>
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<td>0.651</td>
<td>0.084</td>
<td>0.262</td>
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<td>RT</td>
<td>464</td>
<td>0.651</td>
<td>0.084</td>
<td>0.262</td>
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<tr>
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<td>TOT</td>
<td>1786</td>
<td>0.651</td>
<td>0.084</td>
<td>0.262</td>
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<td>0.772</td>
<td>0.031</td>
<td>0.193</td>
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<td>ST</td>
<td>950</td>
<td>0.772</td>
<td>0.031</td>
<td>0.193</td>
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<td>RT</td>
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<td>0.772</td>
<td>0.031</td>
<td>0.193</td>
</tr>
<tr>
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<td>TOT</td>
<td>2018</td>
<td>0.772</td>
<td>0.031</td>
<td>0.193</td>
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<td>0.337</td>
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<td>0.563</td>
<td>0.337</td>
<td>0.394</td>
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<td>RT</td>
<td>44</td>
<td>0.563</td>
<td>0.337</td>
<td>0.394</td>
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<tr>
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<td>1671</td>
<td>0.563</td>
<td>0.337</td>
<td>0.394</td>
</tr>
<tr>
<td>W</td>
<td>LTOR</td>
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<td>0.537</td>
<td>0.079</td>
<td>0.079</td>
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<tr>
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</table>
### Form SIG-II

**Date:** 02 February 1993

**City:** Jakarta

**Interception:** Jl. Irian Barat - Jl. Malaka

**Traffic Flow:**

<table>
<thead>
<tr>
<th>Light Vehicles (L/V)</th>
<th>psc protected = 1.0</th>
<th>psc protected = 1.3</th>
<th>psc protected = 1.6</th>
<th>psc protected = 1.9</th>
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</thead>
<tbody>
<tr>
<td>Prot. v/h</td>
<td>Opp. v/h</td>
<td>Prot. v/h</td>
<td>Opp. v/h</td>
<td>Prot. v/h</td>
</tr>
<tr>
<td>N</td>
<td>ST</td>
<td>RT</td>
<td>S</td>
<td>E 0</td>
</tr>
<tr>
<td>59</td>
<td>8</td>
<td>10</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>L/TAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>8</td>
<td>10</td>
<td>24</td>
<td>5</td>
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**Total**

<table>
<thead>
<tr>
<th>Prot. v/h</th>
<th>Opp. v/h</th>
<th>Prot. v/h</th>
<th>Opp. v/h</th>
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</thead>
<tbody>
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<td>Total</td>
<td>179</td>
<td>179</td>
<td>179</td>
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</tbody>
</table>

**Remarks:**

- **Example 1**

---

**INDONESIAN HIGHWAY CAPACITY MANUAL**

**IHMCM: SIGNALISED INTERSECTIONS**

**Exam**

- **ppl 1**

---

**Example 2**

- **AM peak hour 1992**
**INDONESIAN HIGHWAY CAPACITY MANUAL**

**Form SIG-III**  

**Example 1**

**SIGNALISED INTERSECTIONS**  
**Form SIG-III:** CLEARENCE TIME

**LOST TIME**

**Date:** 02 February 1993  
**Handled by:** KLB  
**City:** Jakarta  
**Intersection:** Jl. Iskandarsyah – Jl. Wijaya  
**Case:** a

### EVACUATING TRAFFIC

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<tr>
<th>Approach</th>
<th>Speed $V_e$ m/sec</th>
<th>Approach</th>
<th>N</th>
<th>S</th>
<th>E</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

|          |                   | Speed $V_A$ m/sec | 16+6-3 | 2.2-0.3 | 1.8 |
| N        | 10                |                   |        |         |     |
|          |                   | Distance evac-adv (m)* |        |         |     |
|          |                   | Time evac-adv (sec)** |        |         |     |

|          |                   | 15+6-3 | 2.1-0.3 | 1.8 |
| S        | 10                |                   |        |         |     |
|          |                   | Distance evac-adv (m)* |        |         |     |
|          |                   | Time evac-adv (sec)** |        |         |     |

|          |                   | 27+6-3 | 3.3-0.3 | 3.0 |
| E        | 10                |                   |        |         |     |
|          |                   | Distance evac-adv (m)* |        |         |     |
|          |                   | Time evac-adv (sec)** |        |         |     |

|          |                   | 3.3-0.3 | 3.0 |
| W        | 10                |                   |        |         |     |
|          |                   | Distance evac-adv (m)* |        |         |     |
|          |                   | Time evac-adv (sec)** |        |         |     |

### ADVANCING TRAFFIC

<table>
<thead>
<tr>
<th>Approach</th>
<th>Speed $V_e$ m/sec</th>
<th>Approach</th>
<th>N</th>
<th>S</th>
<th>E</th>
<th>W</th>
</tr>
</thead>
<tbody>
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<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

|          |                   | Speed $V_A$ m/sec | 16+6-3 | 2.2-0.3 | 1.8 |
| N        | 10                |                   |        |         |     |
|          |                   | Distance evac-adv (m)* |        |         |     |
|          |                   | Time evac-adv (sec)** |        |         |     |

|          |                   | 15+6-3 | 2.1-0.3 | 1.8 |
| S        | 10                |                   |        |         |     |
|          |                   | Distance evac-adv (m)* |        |         |     |
|          |                   | Time evac-adv (sec)** |        |         |     |

|          |                   | 27+6-3 | 3.3-0.3 | 3.0 |
| E        | 10                |                   |        |         |     |
|          |                   | Distance evac-adv (m)* |        |         |     |
|          |                   | Time evac-adv (sec)** |        |         |     |

|          |                   | 3.3-0.3 | 3.0 |
| W        | 10                |                   |        |         |     |
|          |                   | Distance evac-adv (m)* |        |         |     |
|          |                   | Time evac-adv (sec)** |        |         |     |

### Dimensioning clearance time (=allred)

| Phase 1 → Phase 2 | 2 |
| Phase 2 → Phase 3 | 3 |
| Phase 3 → Phase 1 | 2 |
| Phase → Phase     |   |

**Total amber time (3 sec/phase)**  
**Total lost time (LT) = Total all red + amber time (sec/cycle)**  

*) From drawing, see example Figure B-2:1  
***) Time for evacuation = (LEV+IEV)/VEV  
Time for advancement = LAV/VAV
### INDONESIAN HIGHWAY CAPACITY MANUAL

#### SIGNALISED INTERSECTIONS

**Form SIG-IV**

<table>
<thead>
<tr>
<th>Appr. code</th>
<th>Green in phase no.</th>
<th>Appr. type</th>
<th>Ratio of turning vehicles</th>
<th>RT-flow pcu/h</th>
<th>Eff. width (m)</th>
<th>Base value</th>
<th>All appr. types</th>
<th>Only type P</th>
<th>Adjusted value pcu/h</th>
<th>Traffic flow pcu/h</th>
<th>Flow ratio FR</th>
<th>Phase ratio PR</th>
<th>Green time sec</th>
<th>Capacity pcu/h</th>
<th>Degree of saturation</th>
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<td>1.00</td>
<td>1.00</td>
<td>3528</td>
<td>1154</td>
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</tbody>
</table>

| Total lost time LT: | 16 | Cycle time: | (sec.) | 130.9 |
| Adjusted cycle time (c): | (sec.) | 130 |

**Example 1**
### INDIAN HIGHWAY CAPACITY MANUAL

**Form SIG-V**

**SIGNALISED INTERSECTIONS**

**QUEUE-LENGTH**

**NO OF STOPPED VEHICLES**

**DELAY**

<table>
<thead>
<tr>
<th>Approach code</th>
<th>Volume Q (pcu/s)</th>
<th>Q/S</th>
<th>Green ratio g/c</th>
<th>Degree of saturation c * Q</th>
<th>No. of queuing vehicles NQ</th>
<th>No. of stopped vehicles Nsv</th>
<th>A</th>
<th>Average delay D (sec/pcu)</th>
<th>Total Delay = Q * D (sec)</th>
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</thead>
<tbody>
<tr>
<td>N</td>
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<td>0.201</td>
<td>0.226</td>
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<td>S</td>
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<td>0.888</td>
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</table>

**Total:** 1.377

**Average prop. of stopped pcu:** 0.957

**Average intersection delay (sec/pcu):** 46.4

**Level of Service (US HCM 1985):** E
### INDORESEAN HIGHWAY CAPACITY MANUAL

**Form SIG-IV**

**SIGNALISED INTERSECTIONS**

**Date:** 02 February 1993
**City:** Jakarta
**Case:** b
**Intersection:** Jl. Iskandarsyah - Jl. Wijaya

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
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<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic flow distribution (pcu/h)</th>
<th>Traffic flow pcu/h (RT)</th>
<th>Saturation flow pcu/h</th>
<th>Correction factors</th>
<th>Adjusted value pcu/h</th>
<th>Traffic flow pcu/h</th>
<th>FR</th>
<th>Cap. pcu/h</th>
<th>Degree of saturation</th>
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<td>0.01</td>
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<tr>
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<td>1 P</td>
<td>0.11</td>
<td>Side fric.</td>
<td>6540</td>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<td>1.00</td>
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<td>1.00</td>
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<td>0.16</td>
<td>Parking ing</td>
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<td>1.00</td>
<td>1.00</td>
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<td>4 O</td>
<td>0.16</td>
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<td>1.00</td>
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</table>

**Total lost time LT:** 16 (sec.)
**Cycle time:** 115.6 (sec.)
**Adjusted cycle time:** 130 (sec.)

\[ Q/S = (0.25 \times 1039 + 0.75 \times 1154) / (0.25 \times 4532 + 0.75 \times 3528) = 0.298 \]

\[ C = (10 \times 4532 + 35 \times 3528) / 130 = 128 \]
EXAMPLE 2

**Intersection:** JI Martadinata - JI A. Yani, Bandung

**Task:**
- a) Calculate signal timing, capacity and delay with two-phase operation.
- b) Calculate signal timing, capacity and degree of saturation with four-phase operation (separate green phase for each approach).
- c) Discuss the effect of two-phase versus four-phase control.

**Input data:** Geometry, control and environmental conditions see Form SIG-I. Traffic flow data, see separate table.

**Results:** The results of the calculations are shown in Form SIG-11 and in Form SIGIV and SIC-V separately for the two-phase and the four-phase case.

**Comments:** Form SIG-11 shows the traffic flow results in pcu/h for all directions. Since the LTOR movements can be discharged without disturbing the remaining traffic movements in all approaches, they have been omitted.

Default values for Clearance times and Lost time have been chosen instead of calculating them with the use of Form SIG-111. The existing signal timing with inter-green periods between the phases of only 0.3 sec shows that there is no allred, i.e. the existing clearance time is = 0!

**TWO-PHASE CONTROL:**
Form SIG-IV shows that the Intersection flow ratio is 0.618, i.e. far below 1.0. The calculated cycle time for minimum delay is 60.2 sec, and the green times in phase I and 2 26 and 23 sec respectively (existing cycle time = 61 sec and green times 23 and 32 sec.) The existing distribution of green time is not correct, leading to unnecessary queuing in the north and south approaches.

Form SIG-V shows that the max. queue-lengths at the new signal timing is around 30 m, and the average delay 19.5 sec (= LoS C US HCM 85).

**FOUR-PHASE CONTROL:**
The control was changed from two-phase to four-phase control during 1991, leading to excessive queuing in the area. The calculations for four-phase control shows the reason why, the Intersection flow ratio increases to 0.92, and the degree of saturation becomes over 1.0 in all approaches during the studied peak hour.

The reason to change from two-phase to four-phase control was probably that the there were many traffic accidents in the intersection. An alternative action would have been to increase the inter-green periods from 3 to 6 sec between the phases, and to keep two-phase control which obviously results in a much higher intersection capacity and better level of performance level.
**INDONESIAN HIGHWAY CAPACITY MANUAL**

**Example 2**

**Form SIG-I**

**SIGNALISED INTERSECTION**

<table>
<thead>
<tr>
<th>GEOMETRY</th>
<th>TRAFFIC CONTROL</th>
<th>ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date:</strong> 02 February 1993</td>
<td><strong>City:</strong> Jakarta</td>
<td><strong>Intersection:</strong> Jl. Martadinata – Jl. A. Yani</td>
</tr>
<tr>
<td><strong>Handled by:</strong> KLB</td>
<td><strong>City size:</strong> 2.1 M</td>
<td><strong>Case:</strong> a+b</td>
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<tr>
<td><strong>Period:</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EXISTING SIGNAL PHASES**

- **Cycle time:** $c = 61$
- **Total lost time:**
  $$LT = \sum IG = 6$$

**SITE CONDITIONS**

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<tr>
<th>Approach Code (1)</th>
<th>Road Environment Type (2)</th>
<th>Side Friction H/L (3)</th>
<th>Median Y/N (4)</th>
<th>Gradient +/- % (5)</th>
<th>Left-turn On Red Y/N (6)</th>
<th>Distance To parked Vehicle (m) (7)</th>
<th>Approach width (m)</th>
<th>Entry WENTRY (9)</th>
<th>Exit WEXIT (10)</th>
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### Example 2

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</table>
### INDONESIAN HIGHWAY CAPACITY MANUAL

**Form SIG-II**

**SIGNALISED INTERSECTIONS**

**TRAFFIC FLOWS**

**Date:** 02 February 1993  
**Handled by:** KLB  
**City:** Bandung  
**Case:** a + b  
**Intersection:** Jl. Martadinata - Jl. A. Yani  
**Period:** FM peakhour 1992

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<th>Direction</th>
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<th>Heavy Vehicles (HV)</th>
<th>Motorcycles (MC)</th>
<th>Unmotorised (UM)</th>
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</table>

Example 2
### Example 2

**Traffic flow distribution (pcu/h)**

- **N**: 185
- **LTO**: 248
- **W**: 360
- **S**: 446

**Phase 1**

**Phase 2**

**Phase 3**

**Phase 4**

### Table: Traffic Flow and Capacity

<table>
<thead>
<tr>
<th>Appr. code</th>
<th>Green in phase no.</th>
<th>Appr. type</th>
<th>Ratio of turning vehicles</th>
<th>RT-flow pcu/h</th>
<th>Eff. width (m)</th>
<th>Saturation flow pcu/h</th>
<th>Base value</th>
<th>Correction factors</th>
<th>Adjusted value</th>
<th>Traffic flow pcu/h</th>
<th>Flow ratio</th>
<th>Phase ratio FR</th>
<th>Green time sec</th>
<th>Capacity pcu/h</th>
<th>Degree of saturation</th>
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<tbody>
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<td>3400</td>
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<td>0.5374</td>
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<tr>
<td>E</td>
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<td>O</td>
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</tr>
<tr>
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</table>

**Total lost time LT**: 12

**Cycle time**: (sec.) 60.21

**Adjusted cycle time (c)**: (sec.) 61

**IFR** = 0.618

Σ FRcrit
### Example 2

#### Indonesian Highway Capacity Manual

**Form SIG-V**

<table>
<thead>
<tr>
<th>Approach code</th>
<th>Volume Q (pcu/s)</th>
<th>Q/S</th>
<th>Green ratio g/c</th>
<th>Degree of saturation c * Q</th>
<th>No. of queuing vehicles</th>
<th>Queue length - QL (m)</th>
<th>Prop. of stopped vehicles p sv</th>
<th>No. of stopped vehicles N sv (veh/s)</th>
<th>A</th>
<th>A * c</th>
<th>B</th>
<th>B/Q</th>
<th>Average delay D (sec/pcu)</th>
<th>Total delay = Q * D (sec)</th>
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<td>0.332</td>
<td>0.432</td>
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<td>9.9</td>
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**Total:**

- Volume Q: 1.093
- Queue length - QL: 0.911
- Total delay: 19.5

Average prop. of stopped pcu: 0.834
Average intersection delay (sec/pcu): 17.9
Level of Service (US HCM 1965): C
### Example 2

#### INDONESIAN HIGHWAY CAPACITY MANUAL

**Form SIG-IV**

**Signalised Intersections**

**Traffic Flow Distribution (pcu/h)**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Flow Diagram</th>
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<tbody>
<tr>
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<tr>
<td>3</td>
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<td>4</td>
<td><img src="image4" alt="Diagram" /></td>
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</table>

**Traffic Flow Table**

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<tr>
<th>Appr. code</th>
<th>Green in phase no.</th>
<th>Appr. type</th>
<th>Ratio of turning vehicles</th>
<th>RT-flow pcu/h</th>
<th>Eff. own dir.</th>
<th>Opp. dir. width (m)</th>
<th>Base value</th>
<th>Saturation flow pcu/hg</th>
<th>Traffic flow pcu/h</th>
<th>Flow ratio FR</th>
<th>Phase ratio PR =</th>
<th>Green time sec</th>
<th>Capacity pcu/h</th>
<th>Degree of saturation</th>
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</thead>
<tbody>
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<td>747</td>
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<td>0.2207</td>
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<td>685</td>
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<tr>
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<td>P</td>
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<td>700</td>
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</tbody>
</table>

**Total lost time LT:** 20 (sec.)

**Cycle time:** (sec.) 453.1

**Adjusted cycle time:** (sec.) 130

**IFR =** 0.923

**Σ FFrΩ**
EXAMPLE 3

New residential areas will be developed in the north-east part of Yogyakarta. The areas will be served by a new street (Jl Baru) with a four-arm, signalised intersection with Jl Sudirman.

**Intersection:** Jl Sudirman - Jl Baru, Yogyakarta

**Task:**

a) Make preliminary intersection layout, design and signal phasing.

b) Calculate signal timing, capacity and delay.

c) Adjust the design and signal phasing so that the intersection operates with an average delay in range of the 15 - 25 sec/veh.

**Input data:** Traffic flow data.

**Jl Baru:**
- North approach 5 000 veh/day (AADT)
- South approach 10 000 veh/day (AADT)

**Jl Sudirman:**
- East approach 15 000 veh/day (AADT)
- West approach 15 000 veh/day (AADT)

**Results:** The results are shown in Form SIG-II, IV and V.

**Comments:** Default values for the peak-hour %, traffic composition, and preliminary layout and approach widths have been used.

The chosen approach widths as shown in Form SIG-I resulted in an Intersection flow ratio of 0.67, and in average delays of 21 sec/pcu, i.e. LoS C according to the US HCM 1985.
## INDIAN HIGHWAY CAPACITY MANUAL

### Example 3

**Form SIG-I**

**SIGNALISED INTERSECTION**

<table>
<thead>
<tr>
<th>Date:</th>
<th>02 February 1993</th>
<th>Handled by: KLB</th>
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<tbody>
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<td>City:</td>
<td>Yogyakarta</td>
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<tr>
<td>Intersection:</td>
<td>Jl. Baru – Jl. Sudirman</td>
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<tr>
<td>City size:</td>
<td>0.42 M</td>
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</tr>
<tr>
<td>Case:</td>
<td>a</td>
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<tr>
<td>Period:</td>
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### EXISTING SIGNAL PHASES

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### SITE CONDITIONS

<table>
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<th>Side Friction</th>
<th>Median Y/N</th>
<th>Gradient +/- %</th>
<th>Left-turn On Red Y/N</th>
<th>Distance To parked Vehicle (m)</th>
<th>Approach Width W_A (m)</th>
<th>Entry Width W_ENTRY (m)</th>
<th>Exit Width W_EXIT (m)</th>
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</thead>
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<td>RA</td>
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**IHCM: SIGNALISED INTERSECTIONS**

**INDONESIAN HIGHWAY CAPACITY MANUAL**

**Form SIG-I**

**SIGNALISED INTERSECTION**

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### EXISTING SIGNAL PHASES

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### SITE CONDITIONS

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<th>Median Y/N</th>
<th>Gradient +/- %</th>
<th>Left-turn On Red Y/N</th>
<th>Distance To parked Vehicle (m)</th>
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<th>Entry Width W_ENTRY (m)</th>
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<tbody>
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2 - 70
### Example 3

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### SIGNALISED INTERSECTIONS

**TRAFFIC FLOWS**

**Date:** 02 February 1993  
**City:** Yogyakarta  
**Intersection:** Jl. Baru - Jl. Sudirman  
**Handed by:** DK  
**Case:** a + b  
**Period:** FM peak hour 1992

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<th>Direction</th>
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<td></td>
<td></td>
<td>510</td>
<td>510</td>
<td>45</td>
<td>58</td>
</tr>
<tr>
<td>W</td>
<td>LT/LTOR</td>
<td>76</td>
<td>76</td>
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<td>9</td>
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<td></td>
<td></td>
<td>358</td>
<td>358</td>
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<td>40</td>
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<tr>
<td></td>
<td>RT</td>
<td>76</td>
<td>76</td>
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<td>510</td>
<td>45</td>
<td>58</td>
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</tbody>
</table>

**Example 3**
### INDONESIAN HIGHWAY CAPACITY MANUAL

#### SIGNALISED INTERSECTIONS

**Form SIG-IV**

**SIGNAL TIMING AND CAPACITY**

**Date:** 02 February 1993  
**City:** Yogyakarta  
**Intersection:** Jl. Baru - Jl. Sudirman  
**Handled by:** DK  
**Case:** a  
**Period:**

---

**Traffic flow distribution (pcu/h)**

**Phase 1**

**Phase 2**

**Phase 3**

**Phase 4**

---

<table>
<thead>
<tr>
<th>Appr. code</th>
<th>Green type in phase no.</th>
<th>Appr. type</th>
<th>Ratio of turning vehicles</th>
<th>RT-flow pcu/h</th>
<th>Eff. width (m)</th>
<th>Base value</th>
<th>Correction factors</th>
<th>Adjusted value pcu/h</th>
<th>Traffic flow pcu/h</th>
<th>Flow ratio FR</th>
<th>Phase ratio PR=</th>
<th>Green time sec</th>
<th>Capacity pcu/h</th>
<th>Degree of saturation</th>
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</thead>
<tbody>
<tr>
<td>N</td>
<td>1</td>
<td>O</td>
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<td>0.15</td>
<td>0.15</td>
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<td>105</td>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<td>S</td>
<td>1</td>
<td>O</td>
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<td>0.15</td>
<td>0.15</td>
<td>105</td>
<td>52</td>
<td>4.5</td>
<td>2330</td>
<td>0.94</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>E</td>
<td>2</td>
<td>O</td>
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<td>0.00</td>
<td>0.15</td>
<td>160</td>
<td>160</td>
<td>7.0</td>
<td>3300</td>
<td>0.94</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>W</td>
<td>2</td>
<td>O</td>
<td>0.15</td>
<td>0.00</td>
<td>0.15</td>
<td>160</td>
<td>160</td>
<td>7.0</td>
<td>3300</td>
<td>0.94</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Total lost time LT:** 12  
**Cycle time:** (sec.) 70.1  
**Adjusted cycle time (c):** (sec.) 70  

---

**IFR=** 0.672  

---

**Example 3**
### SIGNALISED INTERSECTIONS

**Form SIG-V**

<table>
<thead>
<tr>
<th>Approach code</th>
<th>Volume Q (pcu/s)</th>
<th>Q/S</th>
<th>Green ratio g/c</th>
<th>Degree of saturation c * Q</th>
<th>No. of queuing vehicles</th>
<th>Queue length QL (m)</th>
<th>Prop. of stopped vehicles p sv</th>
<th>No. of stopped vehicles N sv (veh/s)</th>
<th>A</th>
<th>A * c</th>
<th>B</th>
<th>B/Q</th>
<th>Average delay D (sec/pcu)</th>
<th>Total delay = Q * D (sec)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.068</td>
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<td>S</td>
<td>0.199</td>
<td>0.326</td>
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<td>0.816</td>
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<td>0.157</td>
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<td>18.7</td>
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<td>E</td>
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<td>0.346</td>
<td>0.429</td>
<td>0.807</td>
<td>1.6</td>
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<td>18.87</td>
<td>27.9</td>
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<td>0.84</td>
<td>0.251</td>
<td>0.249</td>
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<td>1.687</td>
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<td>W</td>
<td>0.298</td>
<td>0.346</td>
<td>0.429</td>
<td>0.807</td>
<td>1.6</td>
<td>17.3</td>
<td>18.87</td>
<td>27.9</td>
<td>79.6</td>
<td>0.84</td>
<td>0.251</td>
<td>0.249</td>
<td>17.4</td>
<td>1.687</td>
</tr>
</tbody>
</table>

**Total:** 0.894

**Average prop. of stopped pcu:** 0.813

**Average intersection delay (sec/pcu):** 21.1

**Level of Service (US HCM 1985):** C
5 LITERATURE REFERENCES


## IHCM: SIGNALISED INTERSECTIONS

### Appendix 2:1

### INDONESIAN HIGHWAY CAPACITY MANUAL

#### Form SIG-I

<table>
<thead>
<tr>
<th>SIGNALISED INTERSECTION</th>
<th>Date:</th>
<th>Handled by:</th>
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<tbody>
<tr>
<td>Form SIG-I:</td>
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<td></td>
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</tbody>
</table>

### GEOMETRY

<table>
<thead>
<tr>
<th>TRAFFIC CONTROL</th>
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</thead>
<tbody>
<tr>
<td>ENVIRONMENT</td>
<td></td>
<td></td>
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</tbody>
</table>

### EXISTING SIGNAL PHASES

<table>
<thead>
<tr>
<th>Case:</th>
<th>Period:</th>
<th>Cycle time:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$c =$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total lost time:</th>
<th>LT = $\sum G =$</th>
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### SITE CONDITIONS

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<thead>
<tr>
<th>Approach Code</th>
<th>Road Environment Type</th>
<th>Side Friction H/L</th>
<th>Median Y/N</th>
<th>Gradient +/- %</th>
<th>Left-turn On Red Y/N</th>
<th>Distance To parked Vehicle (m)</th>
<th>Approach Width (m)</th>
<th>Entry Width (m)</th>
<th>Exit Width (m)</th>
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<tbody>
<tr>
<td>(1)</td>
<td>(2) (3)</td>
<td>(4)</td>
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<td>(6)</td>
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<td>(9)</td>
<td>(10)</td>
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</table>

2 - 76
## INDONESIAN HIGHWAY CAPACITY MANUAL

### SIGNALISED INTERSECTIONS

<table>
<thead>
<tr>
<th>Approach code</th>
<th>Direction</th>
<th>Light Vehicles (LV)</th>
<th>Heavy Vehicles (HV)</th>
<th>Motorcycles (MC)</th>
<th>Unmotorised (UM)</th>
<th>Total</th>
<th>Ratio of turning</th>
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<tbody>
<tr>
<td></td>
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<td>pcu protected = 1.0</td>
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<td></td>
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<td>pcu opposed = 0.4</td>
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<tr>
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<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
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</tbody>
</table>

<table>
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</tr>
</thead>
<tbody>
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<td>pcu/h</td>
<td>veh/h</td>
<td>pcu/h</td>
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<td>Total</td>
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</tr>
</tbody>
</table>

### Form SIG-II

**Date:**

**Handled by:**

**City:**

**Case:**

**Intersection:**

**Period:**

**Page 2 - 77**

---

**Appendix 2.1**
## Form SIG-III

### SIGNALISED INTERSECTIONS

**Date:**

**Handled by:**

**City:**

**Intersection:**

**Case:**

### EVACUATING TRAFFIC

<table>
<thead>
<tr>
<th>Approach</th>
<th>Speed $V_E \text{ m/sec}$</th>
<th>Speed $V_A \text{ m/sec}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distance evac-adv (m)*)</th>
<th>Time evac-adv (sec)**)</th>
<th>Distance evac-adv (m)*)</th>
<th>Time evac-adv (sec)**)</th>
<th>Distance evac-adv (m)*)</th>
<th>Time evac-adv (sec)**)</th>
<th>Distance evac-adv (m)*)</th>
<th>Time evac-adv (sec)**)</th>
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<tbody>
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</tbody>
</table>

### ADVANCING TRAFFIC

<table>
<thead>
<tr>
<th>Approach</th>
<th>Distance evac-adv (m)*)</th>
<th>Time evac-adv (sec)**)</th>
<th>Distance evac-adv (m)*)</th>
<th>Time evac-adv (sec)**)</th>
<th>Distance evac-adv (m)*)</th>
<th>Time evac-adv (sec)**)</th>
<th>Distance evac-adv (m)*)</th>
<th>Time evac-adv (sec)**)</th>
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</thead>
<tbody>
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<td></td>
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</tr>
</tbody>
</table>

### Clearance Time (sec)

**Dimensioning clearance time (=allred)**

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 2</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Phase 3</td>
<td>Phase 1</td>
</tr>
<tr>
<td>Phase</td>
<td>Phase</td>
</tr>
</tbody>
</table>

**Total amber time (3 sec/phase)**

**Total lost time (LT) = Total all red + amber time (sec/cycle)**

*) From drawing, see example Figure B-2:1

**) Time for evacuation = $(L_{EV} + L_{IEV})/V_{EV}$

Time for advancement = $L_{AV}/V_{AV}$
## IHCM: SIGNALISED INTERSECTIONS

**Form SIG-IV**

### Indoneisan Highway Capacity Manual

#### SIGNAL TIMING AND CAPACITY

<table>
<thead>
<tr>
<th>Appr. code</th>
<th>Green in phase no.</th>
<th>Appr. type</th>
<th>Ratio of turning vehicles</th>
<th>RT-flow pcu/h</th>
<th>Eff. width (m)</th>
<th>Saturation flow pcu/h</th>
<th>Correction factors</th>
<th>Adjusted value pcu/h</th>
<th>Traffic flow pcu/h</th>
<th>Flow ratio</th>
<th>Phase ratio FR</th>
<th>Green time sec</th>
<th>Capacity pcu/h</th>
<th>Degree of saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td>All appr. types</td>
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<td>City size</td>
<td>F, C, S</td>
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<td>Side friction</td>
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<td>Parking F, P</td>
<td>F, F</td>
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<td>Right turns F, F, F</td>
<td>F, F</td>
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<tr>
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<td></td>
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<td>Left turns F, F, F</td>
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</tr>
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</tr>
</tbody>
</table>

### Traffic flow distribution (pcu/h)

- Phase 1
- Phase 2
- Phase 3
- Phase 4

### Total lost time LT:
- LT (sec.)

### Adjusted cycle time (c):

### Cycle time:

---

**Appendix 2.1**
### INDOONESIAN HIGHWAY CAPACITY MANUAL

#### Form SIG-V

**Signalised Intersections**

**Queue-Length**

**No of Stopped Vehicles**

**Delay**

<table>
<thead>
<tr>
<th>Approach code</th>
<th>Volume Q (pcu/s)</th>
<th>Q/S</th>
<th>Green ratio g/c</th>
<th>Degree of saturation c * Q</th>
<th>No. of queuing vehicles</th>
<th>Queue length QL (m)</th>
<th>Prop. of stopped vehicles p sv</th>
<th>No. of stopped vehicles N sv (veh/s)</th>
<th>A</th>
<th>f * c</th>
<th>B</th>
<th>B/Q</th>
<th>Average delay D (sec/pcu)</th>
<th>Total delay = Q * D (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

**Total:**

**Average prop. of stopped pcu:**

**Average intersection delay (sec/pcu):**

**Level of Service (US HCM 1985):**
Chapter 3 : UNSIGNALISED INTERSECTIONS
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1. INTRODUCTION

1.1 SCOPE AND OBJECTIVES

This Chapter deals with 3-way and 4-way unsignalised intersections (definition see Section 1.2), which are formally controlled by the basic Indonesian traffic code rule give-way to the left.

The following performance measures can be estimated for given conditions regarding geometry, environment and traffic with the method outlined in this chapter:
- Capacity
- Degree of saturation
- Delay
- Queue probability

These measures are defined in Chapter 1 Section 4 "General definitions and terminology". Since the methods described in this manual are empirical, the results should always be made subject to a qualified traffic engineering judgement. This is especially important if the method is used outside the range of variation for the variables in the empirical data base. This range is shown in Table 1.1:1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>4-way</th>
<th>3-way</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry width</td>
<td>3.5</td>
<td>5.4</td>
</tr>
<tr>
<td>Left-turning-%</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Right-turning-%</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Split-%</td>
<td>27</td>
<td>38</td>
</tr>
<tr>
<td>Light vehicle-%</td>
<td>29</td>
<td>56</td>
</tr>
<tr>
<td>Heavy vehicle-%</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Motor cycle-%</td>
<td>19</td>
<td>33</td>
</tr>
<tr>
<td>Unmotorised-%</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 1.1:1 Range of variation in empirical data for input variables The method assumes right angled intersections in flat terrain.

The method estimates the expected impact of the influencing variables based on the empirical data collected. Used on the data from which it is derived the error of the capacity estimate is normally less than ±20%.

The method is valid for degree of saturation less than 0.8-0.9. At higher traffic demands traffic behaviour becomes more aggressive and there is a major risk that the intersection gets blocked by drivers competing for the limited space in the conflict zone.

The method is derived from sites, which are operating with average Indonesian traffic behaviour. If this behaviour changes, for instance through implementation and enforcement...
of STOP- or YIELD-sign control in unsignalised intersections, or through an enforcement of the formal traffic code rules, the method would be less valid.

1.2 DEFINITIONS AND TERMINOLOGY

Notations, terminology and definitions used especially for unsignalised intersections are listed below. General definitions, e.g. for performance measures, are given in Chapter 1, Section 4.

Geometric conditions

<table>
<thead>
<tr>
<th>NOTATION</th>
<th>TERMINOLOGY</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-WAY AND 4-WAY INTERSECTION</td>
<td>Intersection with 3 arms and 4-arms respectively.</td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="3-way intersection" /></td>
<td><img src="image" alt="4-way intersection" /></td>
<td></td>
</tr>
<tr>
<td>W&lt;sub&gt;x&lt;/sub&gt; ENTRY WIDTH FOR APPROACH X (m)</td>
<td>Width of the paved part of the approach, measured at the bottleneck, used by moving traffic. X denotes approach identification. If the approach is extensively used for parking, 2m should be deducted from the physical width.</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1.2:1 3-and 4-way intersection

MAJOR/MINOR ROAD The major road is the most important road in the intersection, e.g. in terms of road classification. In 3-way intersections the continuous road is always defined as the major road.

A,B,C,D APPROACH Area for entering vehicles in an intersection arm. Major road approaches are denoted B and D, minor A and C giving a clockwise order.

MAJOR ROAD MEDIAN TYPE Classification of major road median type depending on possibility to use the median to pass the major road in two steps.
IHCM: UNSIGNALISED INTERSECTION

**WE**  
INTERSECTION ENTRY WIDTH (m)  
Average effective width for all approaches with entering traffic.

**W_{AC}**  
ROAD ENTRY WIDTH (m)  
Average width of the approach(es) to an intersection from one road.

**W_{BD}**  
INTERSECTION TYPE  
Code for number of intersection arms and number of lanes on minor and major road in the intersection.

**IT**  
NUMBER OF LANES  
Number of lanes defined from the road entry widths of the road, see Figure 1.2:2

<table>
<thead>
<tr>
<th>Road entry width, $W_{AC}, W_{BD}$ (m)</th>
<th>No. of lanes. (total for both directions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{BD} = (b + d/2)/2 &lt; 5.5$</td>
<td>2</td>
</tr>
<tr>
<td>$W_{AC} = (a/2 + c/2)/2 \geq 5.5$</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 1.2:2  
Determination of number of lanes

**Environmental conditions**  
See definitions in Chapter 1, Section 4.

**Traffic conditions**

**LT**  
LEFT-TURNING  
Index for left-turning traffic.

**ST**  
STRAIGHT-THROUGH  
Index for straight-through traffic.

**RT**  
RIGHT-TURNING  
Index for right-turning traffic.

**Q_v**  
TOTAL ACTUAL FLOW (veh/h)  
Total incoming flow to the intersection (veh/h).

**Q_p**  
TOTAL ACTUAL FLOW (pcu/h)  
Total incoming flow to the intersection (pcu/h).

**Q_{MA}**  
TOTAL MAJOR ROAD FLOW  
Total incoming flow from major road (veh/h or pcu/h).

**Q_{MI}**  
TOTAL MINOR ROAD FLOW  
Total incoming flow from minor road (veh/h or pcu/h).
IHCM: UNSIGNALISED INTERSECTION

**SP%** ROAD FLOW SPLIT-% % minor road flow of total incoming flow (based on calculation in veh/h).

**LV%** LIGHT VEHICLE-% % Light vehicles of all vehicles entering the intersection.

**HV%** HEAVY VEHICLE-% % Heavy vehicles of all vehicles entering the intersection.

**MC%** MOTOR CYCLE-% % Motor cycles of all vehicles entering the intersection.

**UM%** UNMOTORISED-% % Unmotorised vehicles of all vehicles entering the intersection.

**P** PCU-FACTOR Factor to convert a flow expressed in veh/h into pcu/h.

**K** AADT-FACTOR Conversion factor from AADT to peak hour traffic.

**Calculation factors:**

<table>
<thead>
<tr>
<th>NOTATION</th>
<th>TERMINOLOGY</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₀</td>
<td>BASE CAPACITY (pcu/h)</td>
<td>Capacity for an intersection type for a predetermined (&quot;base&quot;) set of influencing conditions.</td>
</tr>
<tr>
<td>F₆</td>
<td>ENTRY WIDTH CORRECTION FACTOR</td>
<td>Correction factor for base capacity due to intersection entry width.</td>
</tr>
<tr>
<td>F₇</td>
<td>MAJOR ROAD MEDIAN TYPE CORRECTION FACTOR</td>
<td>Correction factor for base capacity due to major road median type.</td>
</tr>
<tr>
<td>F₈</td>
<td>CITY SIZE CORRECTION FACTOR</td>
<td>Correction factor for base capacity due to city size.</td>
</tr>
<tr>
<td>F₉</td>
<td>ROAD ENVIRONMENT TYPE AND SIDE FRICTION CORRECTION FACTOR</td>
<td>Correction factor for base capacity due to road environment type and side friction level.</td>
</tr>
<tr>
<td>F₁₀</td>
<td>LEFT-TURNING CORRECTION FACTOR</td>
<td>Correction factor for base capacity due to left turning%.</td>
</tr>
<tr>
<td>F₁₁</td>
<td>RIGHT-TURNING CORRECTION FACTOR</td>
<td>Correction factor for base capacity due to right turning%.</td>
</tr>
<tr>
<td>$F_N$</td>
<td>ROAD FLOW SPLIT</td>
<td>Correction factor for base capacity due to road flow split-%.</td>
</tr>
<tr>
<td>-------</td>
<td>----------------</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>CORRECTION FACTOR</td>
<td></td>
</tr>
</tbody>
</table>
Typical conflicts at an unsignalised intersection in Bandung
Unsignalised four-arm intersection in Palembang

Unsignalised four-arm intersection in Ujung Pandang

Right-of-way from the left is generally not respected in unsignalised intersection
2. METHODOLOGY

2.1 GENERAL PRINCIPLES

The method and procedures described in this manual have an empirical basis. The reason for this is that the Indonesian traffic behaviour in unsignalised intersections in terms of give-way rules, lane discipline and queuing rules are very difficult to describe in an explanatory, behavioural model such as gap-acceptance based stop/give way models. The driver behaviour is entirely different from what is found in most Western countries, which makes the adoption of methods from Western capacity manuals impossible. The most decisive results for traffic behaviour are on average almost two thirds of all crossing vehicles from minor road pass the intersection in non-gapping behaviour, and the critical gap for the vehicles that do not pass by "force" is very low (around 2 seconds).

The method estimates the impact on capacity and other related measures from site conditions regarding geometry, environment and traffic demand.

a) Capacity

The total capacity for all arms of the intersection is calculated as the product between a base capacity \((C_0)\) for a set of predetermined (ideal) conditions and correction factors \((F)\), taking account of the influence on capacity of the actual site conditions.

The format of the capacity model is thus as follows:

\[
C = C_0 \times F_W \times F_M \times F_{CS} \times F_{RF} \times F_{LT} \times F_{RT} \times F_{SP}
\]

The input variables for estimation of capacity \(C\) (pcu/h) by use of the model are as follows:

<table>
<thead>
<tr>
<th>Variable type</th>
<th>Variable description and input name</th>
<th>Model factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry</td>
<td>Intersection type</td>
<td>IT</td>
</tr>
<tr>
<td></td>
<td>Intersection entry width</td>
<td>(W_E)</td>
</tr>
<tr>
<td></td>
<td>Major road median type</td>
<td>(M)</td>
</tr>
<tr>
<td></td>
<td>City size class</td>
<td>(CS)</td>
</tr>
<tr>
<td></td>
<td>Road environment and side friction class</td>
<td>(RF)</td>
</tr>
<tr>
<td>Environment</td>
<td>Left-turning-%</td>
<td>(LT%)</td>
</tr>
<tr>
<td></td>
<td>Right-turning-%</td>
<td>(RT%)</td>
</tr>
<tr>
<td></td>
<td>Road flow split-%</td>
<td>(SP%)</td>
</tr>
</tbody>
</table>

Table 2.1:1 Overview of capacity model input variables

In some western manuals the angle in skew intersection has an effect on capacity. The Indonesian manuals is not based on gap-acceptable methods, and there is no clear distinction
between major and minor road. Since the Manual also does not enable calculation of approach capacity but intersection capacity, the turn angle of the approach is not used.

b) **Degree of saturation**

Degree of saturation for the whole intersection, DS, is calculated as:

\[
DS = \frac{Q_p}{C},
\]

where

- \(Q_p\) Total actual flow (pcu/h) is calculated as follows:
  \[Q_p = Q_v \times P\]
- \(P\) The pcu-factor, calculated as follows:
  \[P = \frac{(pcu_{LV} \times LV\% + pcu_{HV} \times HV\% + pcu_{MC} \times MC\% + pcu_{UM} \times UM\%)}{100}\]
  where \(pcu_{LV}\), \(pcu_{HV}\), \(pcu_{MC}\), \(MC\%\) and \(pcu_{UM}\), \(UM\%\) are pcu-values and %-flow for light vehicles, heavy vehicles, motor cycles and unmotorised vehicles.
- \(C\) Capacity (pcu/h)

c) **Delay D**

Average delay for the whole intersection (sec/pcu) is estimated from an empirically based delay/degree of saturation curve. Delay increases significantly with total flow, simultaneously with major and minor flow and with degree of saturation. The results obtained from observations showed that there is no gapping behaviour at high flows. This means that Western models for stop/give-way behaviour of the traffic from the minor road are not applicable. The maximum stable outflow at predefined conditions is very difficult to define, since the variance in behaviour and outflow is enormous. Instead capacity has been defined as the total intersection flow when the average delay per vehicle exceeds a predefined value considered high, 15 seconds. Delay values from this method can be used together with delay and travel time values from methods for other types of traffic facilities described in this manual in order to estimate travel times along routes in networks.

d) **Queue probability QP%**

Queue probability QP% (%) is estimated from an empirically based queue probability/degree of saturation curve.
2.2 OVERVIEW OF CALCULATION PROCEDURE

Capacity (C) and the performance measures Degree of saturation DS, Delay D (sec/pcu) and Queue probability QP% are calculated for given geometric, environmental and traffic conditions as follows, see Figure 2.2:1.

Figure 2.2:1 Overview of the calculation procedure.

Recording of the input data as well as of the results from the calculations can be done in Form UNSIG-I (Appendix 3:1). The form is divided into four main parts: GEOMETRY, TRAFFIC, ENVIRONMENT and ANALYSIS. In GEOMETRY an overview sketch of the intersection is drawn and geometric conditions are entered. In TRAFFIC the design traffic situation is visualised and traffic input conditions are recorded. In ENVIRONMENT, environmental conditions are entered. In ANALYSIS the results from the different calculation steps are documented. Each column in the ANALYSIS part has an identifier, which is used in the explanation of how to enter data into the form.
2.3 GUIDELINES FOR APPLICATION

This Highway capacity manual can be used for many different applications such as design, planning and operational analysis.

The purpose of design is to find suitable layout and geometric dimensions which meets defined objectives for the design traffic conditions. The method is used as follows, see Figure 2.3:1.

![Diagram of calculation procedure for design, planning and operational analysis]

**Figure 2.3:1** Overview of the calculation procedure for design, planning and operational analysis

**Planning** differs from design only in time scale. In the design application, the input traffic data normally relate to a peak hour. In planning, traffic data information is usually in the form of a predicted AADT, which then has to be converted to a design peak hour, normally by using a default percentage factor.

**Operational analysis** normally is done with the purpose to estimate intersection performance measures for a specified lay-out, environmental and traffic situation.
3. CALCULATION PROCEDURE

STEP A: INPUT DATA

STEP A-1: GEOMETRIC CONDITIONS

Overview sketch

Normally a sketch of the geometric layout is drawn in Form UNSIG-I, see example below in Figure A-1:1. Minor and major road names and city name are noted in the head of the sketch as well as an optional name of the design alternative. The sketch should give a good overview of the intersection with information on kerbs, carriageway, shoulder and median widths. For orientation it should also contain a directional arrow.

Major road is the road which is considered to be of most importance in the intersection, e.g. the road with the highest functional classification. For 3-way intersections the continuous road is always the major road.

The minor road approaches should be denoted A and C. The major road approaches should be denoted B and D. The notation should be made in a clock-wise order.

![Figure A-1:1 Example of geometric input data sketch.](image)

Figure A-1:1 Example of geometric input data sketch.
**Geometric input conditions**

The following geometric input data is needed for the capacity analysis, and should be recorded in the geometry part of the form.

a) **Road entry widths** $W_{AC}$, $W_{BD}$ and **Intersection entry width** $W_E$.

Enter the individual approach widths and calculate average Road entry widths and Intersection entry width. The individual approach width is measured at 10 m distance from the imaginary line connecting the edge of pavement of the crossing road. Road entry widths for minor road $W_{AC}$ and major road $W_{BD}$ are the average approach widths for minor and major road. Intersection entry width, $W_E$ (m) is the average effective entry width for approaches with permitted entering traffic, see Figure A-1:2.

For approaches, where the entry is frequently used for parking at distance less than 20 m from the imaginary line connecting edge of pavement of the crossing road, 2m should be subtracted from the approach entry width.

![Diagram of road entry widths](image)

Intersection entry width (approach average), $W_E$

$W_E = (a/2 + b + c/2 + d/2)/4$

If $A$ is only exit:

$W_E = (b + c/2 + d/2)/3$

Road entry widths

$W_{AC} = (a + c)/2$  \quad  $W_{BD} = (b + d/2)/2$

Figure A-1:2  Road entry widths $W_{AC}$, $W_{BD}$ and Intersection entry width $W_E$

b) **Intersection type**

Intersection type defines number of intersection arms and number of lanes on minor and major road in the intersection by a three digit code, see Table A-1:1.

<table>
<thead>
<tr>
<th>IT code</th>
<th>No. of intersection arms</th>
<th>No. of minor road lanes</th>
<th>No. of major road lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>322</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>324</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>342</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>422</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>424</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Table A-1:1  Intersection type code
The number of arms is the number of arms with either entering or exiting traffic, or both.

The number of lanes is defined from the average Intersection entry width for the roads, \( W_E \), as follows, see Figure A-1:3.

\[
\begin{align*}
\text{Road entry width, } W_{AC}, W_{BD} \quad & \text{No. of lanes. (total for both directions)} \\
W_{BD} = (b + d/2)/2 & < 5.5 \quad 2 \\
W_{AC} = (a/2 + c/2)/2 & \geq 5.5 \quad 4
\end{align*}
\]

Figure A-1:3 Number of lanes and road entry width \( W_E \)

Major road median type M

The major road should be classified by median type, if the major road is 4-lane, as follows, see Table A-1:2.

<table>
<thead>
<tr>
<th>Type M</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>No major road median.</td>
</tr>
<tr>
<td>Narrow</td>
<td>Major road median exists, but does not allow passage in two steps.</td>
</tr>
<tr>
<td>Wide</td>
<td>Major road median exists and allows passage in two steps.</td>
</tr>
</tbody>
</table>

Table A-1:2 Major road median types.

Traffic engineering judgement is needed to decide the median factor. The median is wide if a standard light vehicle can shelter in the median area without disturbing the discharge of traffic on the major road. This is possible if the median is 4m or wider. In some cases, e.g if the major road approaches are wide, this might occur at more narrow medians.
STEP A-2: ENVIRONMENTAL CONDITIONS

The following environmental data is needed for calculation and should be filled in the environment part of the form.

a) Road environment type RE

The road environment should be classified by type. Road environment type classes describe landuse and accessibility of the roads from surrounding activities. It is defined qualitatively from traffic engineering judgement:

<table>
<thead>
<tr>
<th>Commercial</th>
<th>Commercial landuse (e.g. shops, restaurants, offices) with direct roadside access for pedestrians and vehicles.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Residential landuse with direct road side access for pedestrians and vehicles.</td>
</tr>
<tr>
<td>Restricted access</td>
<td>No or limited direct roadside access (e.g. due to the existence of physical barriers, frontage streets etc).</td>
</tr>
</tbody>
</table>

Table A-21 Road environment type classes.

c) Side friction class SF

Side friction describes the impact of road side activities in the intersection area on the traffic discharge, e.g. pedestrians walking on or crossing the carriageway, angkutan kota and buses stopping to pick up or let off passengers, vehicles entering and leaving premises and parking lots outside the carriageway. Side friction is defined qualitatively from traffic engineering judgement as High or Low

d) City size class CS

The city size should be classified by the population of the whole urban area.

<table>
<thead>
<tr>
<th>CS</th>
<th>No. of inhabitants (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>Medium</td>
<td>0.3 - 1.0</td>
</tr>
<tr>
<td>Large</td>
<td>1.0 - 3.0</td>
</tr>
<tr>
<td>Very large</td>
<td>&gt;3.0</td>
</tr>
</tbody>
</table>

Table A-2:2 City size classes
STEP A-3: TRAFFIC CONDITIONS

The input data on traffic conditions consists of three parts, definition of the traffic situation, a traffic flow sketch and traffic input variables.

The traffic flow sketch is optional and gives more detailed traffic information than what is needed for the analysis of unsignalised intersections. If the alternative to signalise the intersection is also to be tested, this information is however needed.

Traffic situation

The traffic situation is defined by year and hour or AADT-factor (for planning). An optional name of the traffic alternative could be entered.

Traffic flow sketch - optional

For design and operational analysis a sketch of the traffic situation could be drawn in Form UNSIG-l. The sketch should show traffic movements (veh/h) by approach A_LT, A_ST, A_RT and so on. Flow dimension, veh/h or AADT, is marked in the form.

![Traffic flow sketch](image-url)
Traffic input variables

The following traffic data are needed for the calculation and should be filled in the traffic part of the form, see also Figure A-3:2

Figure A-3:2 Traffic flow variables

The variables are described below in 'the order they appear in the UNSIG-I form.

<table>
<thead>
<tr>
<th>COLUMN IN FORM</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic flows</td>
<td>Defines if flows are in veh/h or AADT.</td>
</tr>
<tr>
<td>AADT-factor K</td>
<td>The total flow is given as an AADT-value $Q_{AADT}$ AADT-factor, $K$, is a conversion factor to estimate an average peak hour traffic from an AADT, as follows. $Q_{peak} = K \times Q_{AADT}$ The following default values could be used if no better information is available:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Road environment</th>
<th>K-factor - City size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt;1M</td>
</tr>
<tr>
<td>Roads in commercial areas and arterial roads</td>
<td>0.07-0.08</td>
</tr>
<tr>
<td>Roads in residential areas</td>
<td>0.08-0.09</td>
</tr>
</tbody>
</table>

Table A-3:1 K-factor default values

Minor road traffic (veh/h) Total entering traffic $Q_{MI}$ from minor road. For split-% calculation.
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major road traffic (veh/h)</td>
<td>Total entering traffic $Q_{MA}$ from major road. For total traffic calculation.</td>
</tr>
<tr>
<td>Left turning traffic $Q_{LT}$</td>
<td>Total left turning traffic. For LT%-calculation.</td>
</tr>
<tr>
<td>Right turning traffic $Q_{RT}$</td>
<td>Total right turning traffic. For RT%-calculation.</td>
</tr>
<tr>
<td>Total traffic $Q_v$</td>
<td>Total entering traffic.</td>
</tr>
<tr>
<td>Left turning-% LT%</td>
<td>Left-turning-%, LT%, is the overall left-turning-% for the intersection calculated for veh/h.</td>
</tr>
<tr>
<td>Right turning-% RT%</td>
<td>Right-turning-%, RT%, is the total right-turning-% for the intersection calculated for veh/h.</td>
</tr>
<tr>
<td>Road flow split-% SP%</td>
<td>Road flow split-%, SP% is the % minor road traffic of total incoming traffic calculated for veh/h.</td>
</tr>
<tr>
<td>$PCU_{LV}$</td>
<td>pcu-factor for light vehicles. Default: $PCU_{LV}=1.0$.</td>
</tr>
<tr>
<td>LV%</td>
<td>%a-light vehicles of total flow, LV%</td>
</tr>
<tr>
<td>$PCU_{HV}$</td>
<td>pcu-factor for heavy vehicles. Default: $PCU_{HV}=1.3$. Comment: If there are a lot of heavy trucks $PCU_{HV}=2.0$ could be used.</td>
</tr>
<tr>
<td>HV%</td>
<td>%-heavy vehicles of total flow, HV%</td>
</tr>
<tr>
<td>$PCU_{MC}$</td>
<td>pcu-factor for motor cycles. Default: $PCU_{MC}=0.5$.</td>
</tr>
<tr>
<td>MC%</td>
<td>%-motor cycles of total flow, MC%</td>
</tr>
<tr>
<td>$PCU_{UM}$</td>
<td>pcu-factor for unmotorised vehicles. Default: $PCU_{UM}=1.0$. Comment: If most unmotorised are bicycles $PCU_{UM}=0.3$ could be used.</td>
</tr>
<tr>
<td>UM%</td>
<td>%-unmotorised of total flow UM%</td>
</tr>
<tr>
<td>P</td>
<td>$P$ is calculated from pcu-values and flow composition data:</td>
</tr>
<tr>
<td></td>
<td>$P = \frac{(PCU_{LV} \times LV% + PCU_{HV} \times HV% + PCU_{MC} \times MC% + PCU_{MC} \times UM%)}{100}$</td>
</tr>
<tr>
<td></td>
<td>Normally the default pcu-values for the different vehicle types are used.</td>
</tr>
</tbody>
</table>
Total traffic $Q_P$ (pcu/h) is calculated as follows:

$$Q_P = Q_v \times P,$$

where

$Q_v = \text{total entering flow (veh/h)}$

$P = \text{pcu-factor}$

Example: $Q_v = 2000 \text{ veh/h}$ with

<table>
<thead>
<tr>
<th>LV</th>
<th>HV</th>
<th>MC</th>
<th>UM</th>
</tr>
</thead>
<tbody>
<tr>
<td>pcu</td>
<td>%</td>
<td>pcu</td>
<td>%</td>
</tr>
<tr>
<td>1.0</td>
<td>56</td>
<td>1.3</td>
<td>4</td>
</tr>
<tr>
<td>1.0</td>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Solution:

$$P = \frac{(1.0 \times 56 + 1.3 \times 4 + 0.5 \times 33 + 1.0 \times 7)}{100} = 0.85$$

$$Q_P = P \times Q_v = 0.85 \times 2000 = 1700 \text{ pcu/h}$$

**Traffic variable default values**

Traffic data is often lacking or of poor quality. The following default values could be used if better information is not available, see Table C-1:2, for AADT-factor K, road flow split SP%, left-turning-% LT%, right turning-% RT%, composition P-factor and vehide percentages.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT-factor, see Table C-1:1, K</td>
<td>0.07-0.12</td>
</tr>
<tr>
<td>Split-%, SP%</td>
<td>25</td>
</tr>
<tr>
<td>Left turning-%, LT%</td>
<td>15</td>
</tr>
<tr>
<td>Right turning-%, RT%</td>
<td>15</td>
</tr>
<tr>
<td>Pcu-factor, P</td>
<td>0.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>City size M inhabitants</th>
<th>Traffic composition %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LV</td>
</tr>
<tr>
<td>&lt;0.3</td>
<td>60.0</td>
</tr>
<tr>
<td>0.3 – 1.0</td>
<td>34.0</td>
</tr>
<tr>
<td>1.0-3.0</td>
<td>52.5</td>
</tr>
<tr>
<td>&gt;3.0</td>
<td>59.0</td>
</tr>
</tbody>
</table>

Table A-3:2 Default traffic variable

3 - 20
STEP B: DESIGN /PLANNING OBJECTIVES

For design/planning calculations, objectives expressed in performance measures must be chosen.
A recommended default objective for design/planning is to find a design which operates with degree of saturation DS<=0.8

Chosen objectives are entered into the UNSIG-I form in the OBJECTIVES-part.
**STEP C: CAPACITY C**

Actual capacity, $C$ (pcu/h), is calculated from the following formulae:

$$C = C_0 \times F_W \times F_M \times F_{CS} \times F_{RF} \times F_{LT} \times F_{RT} \times F_{SP}$$

The calculation is executed in a number of steps as shown in the flow chart below, Figure C:1.

![Flow chart](image)

Figure C:1 Capacity calculation flow chart

Input data for the calculation steps is available in the UNSIG-I form. Results from every step could be entered in the ANALYSIS-part of the form. The different steps are described in detail below.
STEP C-1:  BASE CAPACITY VALUE $C_0$

Base capacity value $C_0$ is taken from Table C-1:1 and is recorded in Column C-1 in the ANALYSIS part of the form. Input variable is intersection type IT.

<table>
<thead>
<tr>
<th>Intersection type IT</th>
<th>Base capacity $C_0$ (pcu/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>322</td>
<td>2700</td>
</tr>
<tr>
<td>342</td>
<td>2900</td>
</tr>
<tr>
<td>324</td>
<td>3200</td>
</tr>
<tr>
<td>422</td>
<td>2900</td>
</tr>
<tr>
<td>424</td>
<td>3400</td>
</tr>
</tbody>
</table>

Table C-1:1  Intersection type base capacity $C_0$ (pcu / h)

STEP C-2:  ENTRY WIDTH CORRECTION FACTOR $F_W$

The entry width correction, $F_W$, is estimated from Figure C-2:1, and is recorded in Column C-2 in the ANALYSIS-part of the form.

Input variables are intersection entry width $W_E$ and intersection type IT.

The range given in the figure is the range for the empirical base of the manual.

![Figure C-2:1  Entry width correction factor $F_W$](image)
STEP C-3: **MAJOR ROAD MEDIAN CORRECTION FACTOR F_M**

The major road median correction factor $F_M$ is estimated using Table C-3:1. The result is entered in Column C-3 in the ANALYSIS-part of the form. The correction should only be used for 4-lane major roads! Input variable is major road median type.

<table>
<thead>
<tr>
<th>Major road median type</th>
<th>Median correction factor, $F_M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>1.0</td>
</tr>
<tr>
<td>Narrow</td>
<td>1.0</td>
</tr>
<tr>
<td>Wide</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Table C-3:1  Major road median correction factor $F_M$

**STEP C-4: CITY SIZE CORRECTION FACTOR F_CS**

City size correction factor $F_{CS}$ is decided from Table C-4:1. The result is entered in Column C-4 in the ANALYSIS-part of the form. Input variable is city size, $CS$.

<table>
<thead>
<tr>
<th>City size $CS$</th>
<th>Inhab. (M)</th>
<th>City size correction factors $F_{CS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>&lt; 0.3</td>
<td>0.83</td>
</tr>
<tr>
<td>Medium</td>
<td>0.3-1.0</td>
<td>0.94</td>
</tr>
<tr>
<td>Large</td>
<td>1.0-3.0</td>
<td>1.00</td>
</tr>
<tr>
<td>Very large</td>
<td>&gt; 3.0</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Table C-4:1  City size correction factor $F_{CS}$

**STEP C-5: ROAD ENVIRONMENT TYPE AND SIDE FRICTION CORRECTION FACTOR F_RF**

Road environment type and side friction correction, $F_{RF}$ is calculated using Table C-5:1 below, and the result is recorded Column C-5 in the ANALYSIS-part of the form. Input variables are road environment type $RE$ and side friction class $SF$.

<table>
<thead>
<tr>
<th>Road environment type class RE</th>
<th>Side friction class SF</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td></td>
<td>1.00</td>
<td>0.94</td>
</tr>
<tr>
<td>Residential</td>
<td></td>
<td>1.00</td>
<td>0.97</td>
</tr>
<tr>
<td>Restricted access</td>
<td></td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table C-5:1  Road environment type and side friction correction factor $F_{RF}$
**STEP C-6: LEFT-TURNING CORRECTION FACTOR FLT**

Left-turning correction factor $F_{LT}$ is estimated from Figure C-6:1 below.

Input variable is left-turning-%, $LT\%$.

The range given for $LT\%$ is the range for the empirical base of the manual.

![Figure C-6:1 Left-turning correction factor $F_{LT}$](image-url)

*Figure C-6:1 Left-turning correction factor $F_{LT}$*
STEP C-7: RIGHT-TURNING-% CORRECTION FACTOR $F_{RT}$

Right-turning-% correction, $F_{RT}$, is estimated from Figure C-7:1 below for 3-way intersections.

Input variable is right-turning-%, RT%.

The range given for RT% in the figure is the range for the empirical base of the manual.

For 4-way intersections $F_{RT}=1.0$

Figure C-7:1 Right-turning-% correction factor $F_{RT}$
STEP C-8: SPLIT CORRECTION FACTOR $F_{SP}$

Split correction factor $F_{SP}$ is estimated from Figure C-8:1 below.

Input variables are road flow split-% and intersection type IT.
The range noted "empirical data" for SP% in the figure is the range for the empirical base of the manual.

Figure C-8:1 split correction factor $F_{SP}$

<table>
<thead>
<tr>
<th>IT</th>
<th>$F_{Sp}$</th>
<th>SP% range</th>
</tr>
</thead>
<tbody>
<tr>
<td>424</td>
<td>1.19E-04 SP%² * 0.0119 SP% + 1.19</td>
<td>10.40</td>
</tr>
<tr>
<td>424</td>
<td>1.95E-07 SP%⁴ * 3.33E-05 SP%³ * 3 + 2.53E-03 SP%² * 0.086 SP% + 1.95</td>
<td>10.30</td>
</tr>
<tr>
<td>322</td>
<td>1.19E-04 SP%² * 0.0119 SP% + 1.11</td>
<td>10.30</td>
</tr>
<tr>
<td>322</td>
<td>6.95E-06 SP%⁴ * 5.95E-05 SP%³ * 0.74</td>
<td>10.30</td>
</tr>
<tr>
<td>324</td>
<td>1.19E-04 SP%² * 0.0119 SP% + 1.19</td>
<td>10.30</td>
</tr>
<tr>
<td>324</td>
<td>2.33E-04 SP%² * 0.0238 SP% + 1.49</td>
<td>10.30</td>
</tr>
<tr>
<td>324</td>
<td>1.95E-07 SP%⁴ * 3.33E-05 SP%³ * 3 + 2.53E-03 SP%² * 0.086 SP% + 1.95</td>
<td>10.30</td>
</tr>
<tr>
<td>1.11E-04 SP%² * 0.0111 SP% + 1.11</td>
<td>50.90</td>
<td></td>
</tr>
<tr>
<td>5.55E-05 SP%² * 5.55E-03 SP% + 0.68</td>
<td>50.90</td>
<td></td>
</tr>
</tbody>
</table>

STEP C-9: ACTUAL CAPACITY C (pcu/h)

Actual capacity, C (pcu/h), is calculated using the following formulae, where the different factors have been calculated above:

$$C = C_o \times F_{W} \times F_{M} \times F_{CS} \times F_{RF} \times F_{LT} \times F_{RT} \times F_{SP}$$
**STEP D: DEGREE OF SATURATION DS**

Degree of saturation, DS, is calculated using the fold formulae. The result is noted in the ANALYSIS-part of the form in Column D:

\[
DS = \frac{Q_P}{C},
\]

where

- \(Q_P\) Actual total flow (pcu/ h) from traffic input.
- \(P\) pcu-factor from traffic input.
- \(C\) Actual capacity from STEP C.

Example: \(C = 2700\) pcu / h and \(Q_v = 2000\) veh / h with

<table>
<thead>
<tr>
<th>LV</th>
<th>HV</th>
<th>MC</th>
<th>UM</th>
</tr>
</thead>
<tbody>
<tr>
<td>pcu</td>
<td>%</td>
<td>pcu</td>
<td>%</td>
</tr>
<tr>
<td>1.0</td>
<td>56</td>
<td>1.3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculations:

\[
P = \frac{(1.0 \times 56 + 1.3 \times 4 + 0.5 \times 33 + 1.0 \times 7)}{100} = 0.85
\]

\[
Q_P = P \times Q_v = 0.85 \times 2000 = 1700\text{ pcu/ h}
\]

Degree of saturation \(DS = \frac{Q_P}{C} = \frac{1700}{2700} = 0.63\)
STEP E:  DELAY D

Delay D (sec/pcu) is average delay per entering vehicle. Delay is estimated from the empirical relationship between delay D and degree of saturation DS, see Figure E:1.

Input variable is degree of saturation DS from STEP D.

The result is noted in the ANALYSIS-part of the form in Column E.

![Figure E:1  Delay D (sec/pcu) versus degree of saturation DS = \( \frac{Q_p}{C} \)]
STEP F: QUEUE PROBABILITY QP %

A range of queue probability QP% (%) is estimated from the empirical relationship between queue probability QP% and degree of saturation DS.

Input variable is degree of saturation DS from STEP D.

The result is noted in the ANALYSIS-part of the form in Column F.

Figure F:1 Range of queue probability QP % (%) versus degree of saturation DS = QP / C
STEP G: PERFORMANCE MEASURES COMPARED WITH DESIGN/PLANNING OBJECTIVES.

This step comprises the following sub-steps:

a) Compare calculated performance measures with design/planning objectives

b) If not satisfying, assume a new design and repeat calculations.

   In some cases the objectives cannot be met. the objectives and/or traffic conditions then have to be changed.

   Traffic can be changed by the introduction of turning regulations for some movements, or through alternative traffic schemes.

c) If satisfying, stop calculations.

The COMMENT-lines in the form UNSIG-I could be used for STEP G.
4. WORKED EXAMPLES

EXAMPLE

Determine capacity, degree of saturation, delay and queue probability for the unsignalised intersection between Jalan BD and Jalan AC with layout and traffic as in Figure 4:1 below. The traffic situation is an existing PM peak hour. The intersection is located in a medium sized city KOTA-M in a commercial area with high friction. Jalan BD is the major road.

Figure 4:1 Example layout and traffic
### Geometric Conditions

- **Major road (BD):** JL. BD
- **Minor road (AC):** JL. AC
- **City:** KOTA M
- **Design alternative:** EXAMPLE

### Traffic Conditions

- **Traffic alternative:** EXAMPLE
- **Traffic flow sketch (optimal)**

### Typical Data

<table>
<thead>
<tr>
<th>Entry widths (m)</th>
<th>Minor</th>
<th>Major</th>
<th>Avq Traffic flows veh/h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$W_a$</td>
<td>$W_e$</td>
<td>$W_{BD}$</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.5</td>
<td>4</td>
</tr>
</tbody>
</table>

### Environmental Conditions

- **City size CS:**
  - Small < 0.3M
  - Medium 0.3 – 1M
  - Large 1 - 3M
- **Traffic composition:**
  - Light (PCU%)
  - Heavy (HV%)
  - Motor cycles (MC%)
  - Unmotorised (UM%)

### Design/Planning Objectives

<table>
<thead>
<tr>
<th>DS</th>
<th>Delay</th>
<th>QP%</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS</td>
<td>Delay</td>
<td>QP%</td>
</tr>
</tbody>
</table>

### Analysis

<table>
<thead>
<tr>
<th>Alterative geometry</th>
<th>Intersection base capacity</th>
<th>Corrections</th>
<th>Environment corrections</th>
<th>Traffic corrections</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type base capacity</td>
<td>Entry width</td>
<td>Major road median</td>
<td>City size</td>
<td>Road Env. Friction</td>
</tr>
<tr>
<td></td>
<td>$C_0$</td>
<td>$F_W$</td>
<td>$F_M$</td>
<td>$F_{CS}$</td>
<td>$F_{RF}$</td>
</tr>
<tr>
<td></td>
<td>Pcu/h</td>
<td>(C-1)</td>
<td>(C-2)</td>
<td>(C-3)</td>
<td>(C-4)</td>
</tr>
<tr>
<td></td>
<td>(C-1)</td>
<td>1.0</td>
<td>1.0</td>
<td>0.94</td>
<td>0.94</td>
</tr>
</tbody>
</table>

### Comments

---

Analyzing engineer: 
Checking engineer: 
Date: day ..... Month ..... Year .....
SOLUTION

See the filled form UNSIG-I and the comments for each position in the form below, which follow the manual steps.

STEP A INPUT DATA AND INPUT VARIABLES

STEP A-1 GEOMETRIC CONDITIONS

Overview sketch

Fill in road names Jalan BD (major) and Jalan AC (minor) and city name KOTA-M. Name the design EXAMPLE.

Enter the sketch of the intersection with north arrow and denote approaches A, B, C and D starting from north in a clock-wise order.

Geometry input variables

Input geometry variables in the form as follows.

<table>
<thead>
<tr>
<th>Form position</th>
<th>Input in form</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry widths</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WA = 6/2 = 3m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WC = 7/2 = 3.5m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAC = 3.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WB = 8/2 = 4m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WD = 7/2 = 3.5m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WBD = 3.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WE = 3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intersection type</td>
<td>422</td>
<td>From road entry widths, see Figure 1a:3</td>
</tr>
<tr>
<td>Major road median</td>
<td>None</td>
<td>From example text</td>
</tr>
</tbody>
</table>

STEP B ENVIRONMENTAL CONDITIONS

Road environment type  Commercials From example text
Side friction class    High From example text
City size              Medium From example text

STEP C TRAFFIC CONDITIONS

Traffic situation

Input data from the text in the example.
**IHCM: UNSIGNALISED INTERSECTION**

<table>
<thead>
<tr>
<th>Year</th>
<th>Present</th>
<th>From the example text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hour</td>
<td>PM Peak</td>
<td>From the example text</td>
</tr>
</tbody>
</table>

**Traffic alternative:** Example  
Optional, to give the traffic situation a name

**Traffic flow sketch**

Enter the sketch of the traffic situation to the form.

**Traffic input variables**

<table>
<thead>
<tr>
<th>Traffic flows</th>
<th>veh/h</th>
<th>Flows in veh/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>QMI</td>
<td>800</td>
<td>50+200+300+100+100+50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>From flows in Figure 4:1</td>
</tr>
<tr>
<td>QMA</td>
<td>1900</td>
<td>200+800+100+300+400+100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>From flows in Figure 4:1</td>
</tr>
<tr>
<td>QLT</td>
<td>900</td>
<td>200+300+300+100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>From flows in Figure 4:1</td>
</tr>
<tr>
<td>QRT</td>
<td>300</td>
<td>100+50+100+50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>From flows in Figure 4:1</td>
</tr>
<tr>
<td>Qv</td>
<td>2700</td>
<td>800+1900</td>
</tr>
</tbody>
</table>

**Traffic composition**

<table>
<thead>
<tr>
<th>PCU&lt;sub&gt;LV&lt;/sub&gt;</th>
<th>1.0</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV %</td>
<td>60</td>
<td>From the example text</td>
</tr>
<tr>
<td>pcu&lt;sub&gt;HV&lt;/sub&gt;</td>
<td>1.3</td>
<td>Default value</td>
</tr>
<tr>
<td>HV %</td>
<td>0</td>
<td>From the example text</td>
</tr>
<tr>
<td>pcu&lt;sub&gt;MC&lt;/sub&gt;</td>
<td>0.5</td>
<td>Default value</td>
</tr>
</tbody>
</table>
IHCM: UNSIGNALISED INTERSECTION

MC % 35 From the example text
PcuUM 1.0 Default value
UM% 5 From the example text
P 0.83 \((1 \times 60 + 1.3 \times 0 + 0.5 \times 35 + 1.0 \times 5) / 100\)
Q_P 2240 0.83\(\times 2700\)

DESIGN/PLANNING - Analysis. No objectives!

STEP C CAPACITY

Input under ANALYSIS

Alternative 0 Optional, to use if more calculations are performed to identify the alternatives

STEP C-1 BASE CAPACITY VALUE C_o
C_o (C-1) 2900 From Table C-1:1

STEP C-2 ENTRY WIDTH CORRECTION FACTOR F_W
F_W (C-2) 1.0 W_E = 3.5m Figure C-2:1

STEP C-3 MAJOR ROAD MEDIAN TYPE CORRECTION FACTOR F_M
F_M (C-3) 1.0 From Table C-3:1 with no median

STEP C-4 CITY SIZE CORRECTION FACTOR F_CS
F_CS (C-4) 0.94 From Table C-4:1 with medium city size

STEP C-5 ROAD ENVIRONMENT TYPE AND SIDE FRICTION CORRECTION FACTOR F_RF
F_RF (C-5) 0.94 From Table C-5:1 with Commercial and high friction

STEP C-6 LEFT TURNING CORRECTION FACTOR F_LT
F_{LT} (C-6) 1.37  From Figure C-6:1 with LT % = 33

STEP C-7  RIGHT-TURNING CORRECTION FACTOR \( F_{RT} \)

\[ F_{RT} (C-7) = 1.00 \text{  4-way!} \]

STEP C-8  SPLIT CORRECTION FACTOR \( F_{SP} \)

\[ F_{SP} (C-9) = 0.94 \text{  From Figure C-8:1 with SP %}=30 \text{ for } 422 \]

STEP C-9  CAPACITY

\[ C (C-9) = 3300 \text{  } 2900 \times 1.0 \times 1.0 \times 0.94 \times 1.0 \times 0.94 \times 1.37 \times 1.0 \times 0.94 \]

STEP D  DEGREE OF SATURATION

\[ DS (D) = 0.68 \text{  } \frac{Q_p}{C} = 2240 / 3300 \]

STEP E  DELAY

\[ D (E) = 7.5 \text{ sec/pcu} \text{  Figure E:1 with DS = 0.68} \]

STEP F  QUEUE PROBABILITY

\[ QP\% (F) = 19-39\% \text{  Figure F:1 with DS=0.68} \]
5. LITERATURE REFERENCES

| US5 | FGSV | Merkblatt zur Berechnung der Leistungsfähigkeit von Knotenpunkten ohne Lichtsignalanlagen (Guideline for calculation of capacity in unsignalised intersections (in German).) |

Overviews:

### INDONESIAN HIGHWAY CAPACITY MANUAL : FORM UNSIG-I UNSIGNALISED INTERSECTION

#### GEOMETRIC CONDITIONS

<table>
<thead>
<tr>
<th>Major road (BD):</th>
<th>Minor road (AC):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**City:**

- Design alternative:

**Intersection sketch:**

**Traffic condition:**

- Year:
- Hour:
- Traffic alternative:

**Traffic flows veh/h**

- Minor road flows:
  - $Q_U$:
- Major road flows:
  - $Q_M$:
- left turning flows:
  - $Q_L$:
- Right turning flows:
  - $Q_R$:
- Total actual Flow $Q_V$:

**Entry widths (m):**

- Minor:
- Major:
- Avq:

**Intersection type IT:**

- 322
- 324
- 342
- 422
- 424

#### ENVIRONMENTAL CONDITIONS

**City size CS**

- Traffic composition:
  - Small < 0.3M
  - Light
  - Heavy
  - Motor cycles
  - Unmotorised

**Commercial**

- Low
- Medium 0.3 – 1M

**Residential**

- High
- Large 1 - 3 M

**Restricted access**

- Very Large > 3M

**Total actual flow $Q_P$ (pcu/h):**

#### DESIGN/PLANNING OBJECTIVES

<table>
<thead>
<tr>
<th>DS delay</th>
<th>QP%</th>
</tr>
</thead>
</table>

#### ANALYSIS

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Geometry</th>
<th>Intersection Type base Capacity</th>
<th>Entry Width</th>
<th>Major Road Median</th>
<th>City Size</th>
<th>Road Env. Friction</th>
<th>Traffic corrections</th>
<th>Degree Of Saturation</th>
<th>Measures Delay</th>
<th>Queue Prob. Qp%</th>
</tr>
</thead>
</table>

**Comments:**

---

Analyzing engineer: 

Checking engineer: 

Date: 

---

### IHCM: UNSIGNALISED INTERSECTION

Appendix 3:1
Chapter 4: WEAVING SECTIONS
CHAPTER 4

WEAVING SECTIONS

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1. INTRODUCTION

1.1 SCOPE AND OBJECTIVES

This Chapter deals with weaving sections, which are formally controlled by the basic Indonesian traffic code rule give-way to the left. Weaving sections are divided into two main types - single weaving sections and roundabout weaving sections.

The following performance measures can be estimated at given geometric, environmental and traffic conditions with the methods outlined in this chapter, see Table 1.1:1.

<table>
<thead>
<tr>
<th>Performance measure</th>
<th>Single</th>
<th>Roundabout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Degree of saturation</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Delay</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Queue probability</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Travel speed</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Travel time</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

Table 1.1:1 Performance measures

These measures are defined in Chapter 1 Section 4 "General definitions and terminology".

The methods are basically empirical. Therefore they must always be used together with an experienced traffic engineering judgement. The latter is extremely important if the methods are used outside the range of variation for the variables in the empirical data. This range is as follows, see Table 1.1:2. The method assumes flat terrain.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Roudabout</th>
<th>Single</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry width</td>
<td>6 9 11</td>
<td>8 9.6 11</td>
</tr>
<tr>
<td>Weaving width</td>
<td>9 12.6 20</td>
<td>8 11.5 20</td>
</tr>
<tr>
<td>Weaving length</td>
<td>21 33.9 50</td>
<td>50 96 183</td>
</tr>
<tr>
<td>Width/length</td>
<td>0.22 0.43 0.80</td>
<td>0.06 0.13 0.20</td>
</tr>
<tr>
<td>Weaving-%</td>
<td>32 76 94</td>
<td>32 74 95</td>
</tr>
<tr>
<td>Light vehicle-%</td>
<td>35 60 75</td>
<td>49 63 81</td>
</tr>
<tr>
<td>Heavy vehicle-%o</td>
<td>0 2 3</td>
<td>0 3 13</td>
</tr>
<tr>
<td>Motor cycle-%</td>
<td>20 33 55</td>
<td>16 32 45</td>
</tr>
<tr>
<td>Unmotorised-%</td>
<td>1 5 18</td>
<td>0 2 6</td>
</tr>
</tbody>
</table>

Table 1.1:2 Range of variation in empirical data for input variables
The methods describe the average impact of the input conditions based on the empirical data collected. Applied on the data from which it is derived, the aggregate capacity estimate error is normally less than ± 15%.

The method is valid for degree of saturation less than 0.8-0.9. At higher traffic demands traffic behaviour becomes more aggressive and there is a major risk that the weaving section gets blocked by drivers competing for the limited space in the weaving section.

In the individual case the impact from one of these variables might be different from the model prediction. There could also be other variables, which might be of importance for the capacity.

The method is derived from sites, which are operating with average Indonesian traffic behaviour. If this behaviour changes, for instance through implementation of a traffic control scheme in weaving sections or through an enforcement of the formal traffic code rules, the method would be less valid.

1.2 DEFINITIONS AND TERMINOLOGY

Notations, terminology and definitions used especially for weaving sections are listed below. General definitions, e.g. for performance measures, are given in Chapter 1, Section 4.

Geometric conditions

<table>
<thead>
<tr>
<th>NOTATION</th>
<th>TERM</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROUNDABOUT WEAVING SECTION</td>
<td>Weaving section within a roundabout design</td>
<td></td>
</tr>
<tr>
<td>SINGLE WEAVING SECTION</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1.2:1 Weaving section types and measures
IHCM: WEAVING SECTIONS

APPROACH Area for entering vehicles from a road to the weaving section.

EXIT Area for exiting traffic to a road from the weaving section.

In a single weaving section approaches are denoted A and D, exits B and C giving a dock wise order. In a roundabout road approaches are denoted A,B,C and D in a clock-wise order.

$W_x$ ENTRY WIDTH FOR APPROACH $X$ (m) Width of the paved part of the approach measured at the bottleneck, used by moving traffic. $X$ denotes approach identification. If the approach is extensively used for parking 2m should be deducted from the physical width for each side with extensive parking.

$W_E$ ENTRY WIDTH (m) Average effective entry width for approaches with permitted entering traffic.

$W$ WEAVING WIDTH (m) Effective weaving width for the weaving section (at the bottleneck). If the weaving section is frequently used for parking 2m should be subtracted from the width for each side with parking.

$L$ WEAVING LENGTH (m) Effective weaving length for the weaving section.

**Environmental conditions** See definitions in Chapter 1, Section 4.

**Traffic conditions**

LT LEFT-TURNING Index for left turning traffic.

ST STRAIGHT-THROUGH Index for straight through traffic.

RT RIGHT-TURNING Index for right turning traffic.

W WEAVING Index for weaving traffic.

NW NON-WEAVING Index for non-weaving traffic.

$Q_v$ TOTAL ACTUAL FLOW (veh / h) Total incoming flow in veh/h.

$Q_w$ TOTAL WEAVING FLOW (veh / h) Total incoming weaving flow in veh/h.
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W%</td>
<td>WEAVING-%</td>
</tr>
<tr>
<td>LV%</td>
<td>LIGHT VEHICLE-%</td>
</tr>
<tr>
<td>HV%</td>
<td>HEAVY VEHICLE-%</td>
</tr>
<tr>
<td>MC%</td>
<td>MOTOR CYCLE-%</td>
</tr>
<tr>
<td>UM%</td>
<td>UNMOTORISED-%</td>
</tr>
<tr>
<td>P</td>
<td>PCU-FACTOR</td>
</tr>
<tr>
<td>K</td>
<td>AADT-FACTOR</td>
</tr>
</tbody>
</table>

**Calculations factors:**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₀</td>
<td>BASE CAPACITY (pcu/h)</td>
</tr>
<tr>
<td>F₁s</td>
<td>CITY SIZE CORRECTION FACTOR</td>
</tr>
<tr>
<td>Fᵣₑ</td>
<td>ROAD ENVIRONMENT TYPE AND SIDE FRICTION CORRECTION FACTOR</td>
</tr>
</tbody>
</table>
Typical wearing sections in Bandung
IHCM: WEAVING SECTIONS

Roundabout in Ujung Pandang

Entrance and exit of weaving section in Medan
2. METHODOLOGY

2.1 GENERAL PRINCIPLES

The method and procedures described in this manual have an empirical basis. The reason for this is that the Indonesian traffic behaviour in weaving sections in terms of give-way rules, lane discipline and queuing rules are very difficult to describe in an explanatory, behavioural model such as gap-acceptance based stop/give way models. The driver behaviour is entirely different from what is found in most Western countries, which makes the adoption of methods from Western capacity manuals impossible. The method used in the Manual is adapted from Wardrop concept formulae, which was derived in the fifties in UK for priority entering traffic. The reason for adaption of Wardrop formulae was that Indonesian weaving sections operate in a mode which was thought to be similar with UK weaving section operation before the change to offside priority rule in UK.

The method estimates the impact on capacity and other related measures from site conditions regarding geometry, environment and traffic demand.

a) Capacity

The total capacity for weaving section is calculated as the product between a base capacity \( C_0 \) for a set of predetermined (ideal) conditions and correction factors \( F \), taking account of the influence on capacity of the actual site conditions.

The format of the capacity model is thus as follows:

\[
C = 135 \times W^{1.3} \times (1+W_E/W)^{1.5} \times (1-W%/300)^{0.5} \times F_{CS} \times F_{RF} / (1+W/L)^{1.8}
\]

The input variables to the model to estimate actual capacity, \( C \) (pcu/h), are as follows:

<table>
<thead>
<tr>
<th>Variable type</th>
<th>Variable description and input name</th>
<th>Model factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry</td>
<td>Entry width</td>
<td>( W_E )</td>
</tr>
<tr>
<td></td>
<td>Weaving width</td>
<td>( W )</td>
</tr>
<tr>
<td></td>
<td>Weaving length</td>
<td>( W )</td>
</tr>
<tr>
<td></td>
<td>Width/length</td>
<td>( W/L )</td>
</tr>
<tr>
<td></td>
<td>City size class</td>
<td>( CS )</td>
</tr>
<tr>
<td></td>
<td>Road envir. type and side friction</td>
<td>( RE )</td>
</tr>
<tr>
<td></td>
<td>Weaving</td>
<td>( W % )</td>
</tr>
<tr>
<td>Environment</td>
<td></td>
<td>( F_{CS} )</td>
</tr>
<tr>
<td>Traffic</td>
<td></td>
<td>( F_{RF} )</td>
</tr>
</tbody>
</table>

Table 2.1:1 Overview input variables to capacity model for weaving section

b) Degree of saturation DS

Degree of saturation, DS, is calculated as:
IHCM: WEAVING SECTIONS

DS = \frac{Q_P}{C}, \text{ where}

Q_P \quad \text{Total actual flow (pcu/h) is calculated as follows: } Q_P = Q_n \times P, \text{ where}

P \quad \text{the pcu-factor is calculated as:}

P = \frac{(pcu_{LV} \times LV\% + pcu_{HV} \times HV\% + pcu_{MC} \times MC\% + pcu_{UM} \times UM\%)/100}{100}

\text{where } pcu_{LV}, LV\%, pcu_{HV}, HV\%, pcu_{MC}, MC\% \text{ and } pcu_{UM}, UM\% \text{ are pcu-values and } \%\text{-flow for light vehicles, heavy vehicles, motor cycles and unmotorised vehicles.}

C \quad \text{Capacity (pcu / h)}

c) Delay D - for roundabout weaving sections

Average delay (sec/pcu) is estimated from an empirical based delay/degree of saturation curve. Delay values from this method can be used with delay and travel time values from the other facility type methods to estimate travel times along routes in networks.

d) Queue probability OP\% - for roundabout weaving sections

Queue probability QP\% (%) is estimated from an empirical based queue probability/degree of saturation curve.

e) Travel speed V - for single weaving sections

Travel speed V over the weaving section (km/.h) is estimated from the following empirical formulae:

V = V_o \times 0.5 \times (1+(1-DS)^{0.5}), \text{ where}

V_o \quad \text{free flow speed (km/h), calculated as:}

V_o = 45.2 \times (1 + HV\%/100)^{-2.8} \times (1-W%/300), \text{ where}

HV\% = \text{Heavy vehicle-}\%

W\% = \text{Weaving-}\%

DS \quad \text{Degree of saturation}

f) Travel time, TT - for single weaving sections

Travel time TT (sec.) over the weaving section is calculated as:

TT = L \times 3.6 / V, \text{ where}

L \quad \text{Length of weaving section (m)}

V \quad \text{Travel speed (km/h)}

Travel times from this method could be used with delay and travel time values from the other facility type methods to estimate travel times along routes in networks.
2.2 OVERVIEW OF CALCULATION PROCEDURE

Capacity C and the other related performance measures degree of saturation DS, delay D (sec/pcu) and queue probability QP% for roundabout weaving sections; and travel speed V (km / h) and travel time TTI (sec/pcu) for single weaving sections are calculated for a given geometry, environment and traffic as follows, see Figure 2.2:1.

![Figure 2.2:1 Overview calculation procedure](image)

Recording of the input data as well as of the results from the calculations can be done in Form WEAV-I (Appendix 4:1). The form is divided into four main parts: GEOMETRY, TRAFFIC, ENVIRONMENT and ANALYSIS. In GEOMETRY an overview sketch of the weaving section is drawn and geometric conditions are entered. In TRAFFIC the design traffic situation is visualised and traffic input conditions are recorded. In ENVIRONMENT, environmental conditions are entered. In ANALYSIS the results from the different calculation steps are documented. Each column in the ANALYSIS part has an identifier, which is used in the explanation of how to enter data into the form.
2.3 GUIDELINES FOR APPLICATION

The measures from the method could be used for different applications such as **design**, **planning** and **operational analysis**.

**Design** is to find an intersection layout and geometric dimensions which meets defined objectives for a design traffic situation. The method is used as follows, see Figure 2.3:1.

![Diagram](image)

Figure 2.3:1 Overview calculation procedure for design, planning and operational analysis

**Planning** differs from design only in time scale. In the **design** situation, the given traffic conditions normally relate to a peak hour situation. In the **planning** situation, the input traffic data normally is in the form of a future AADT (Annual Average Daily Traffic), which has to be converted to a design peak hour, normally by using rough defaults.

**Operational analysis** normally is done with the purpose to estimate weaving section performance measures for a specified lay-out, geometric design, environmental and traffic situation.
3. **CALCULATION PROCEDURE**

**STEP A: INPUT DATA.**

**STEP A-1: GEOMETRIC CONDITIONS**

**Overview sketch**

Normally a sketch of the site geometry is drawn in Form WEAV-l, see examples below for a roundabout design and for a single weaving section, Figure A-1:1. Approaching and exiting road names and city name are noted in the head of the sketch as well as an optional name of the design alternative.

The sketch should give a good overview of the weaving section(s) with information on kerbs, entry width, weaving width and length and shoulder width. For orientation it should also contain a directional arrow.

The road approaches and exits could be denoted A, B, C and D, giving a clock-wise order.

![Weaving section sketch](image)

![Weaving section sketch](image)

Figure A-1:1  Example of geometry input data sketch
Geometry input variables

The following geometry variables are needed for the calculation and should be entered in the geometry part of the form.

a) **Weaving section type**

Enter S for Single weaving section or R for Roundabout weaving section design.

b) **Entry width** $W_1, W_2, W_E$, **Weaving width** $W$ and **Weaving length** $L$

Enter the approaches effective entry width and calculate average entry width. Entry width, $W$ (m) is the average effective entry width for approaches with permitted entering traffic, see Figure A-1:2. $W_E/W$ is the ratio between average entry width and weaving section width and $W/L$ is the ratio between weaving width and weaving length.

For approaches where the entry is frequently used for parking and for weaving section that frequently used for parking, 2m should be subtracted from the approach entry width and weaving width for each side with frequent parking.

![Single weaving section](image)

![Roundabout weaving section](image)

Figure A-1:2 Weaving section types and measures
STEP A-2: ENVIRONMENTAL CONDITIONS

The following environment data are needed for calculation and should be filled in the environment part of the form.

a) Road environment type RE

The road environment should be classified by type. Road environment type classes describe land-use and accessibility of the roads from surrounding activities. It is defined qualitatively from traffic engineering judgement.

<table>
<thead>
<tr>
<th>Road environment type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>Commercial landuse (e.g. shops, restaurants, offices) with direct roadside access for pedestrians and vehicles.</td>
</tr>
<tr>
<td>Residential</td>
<td>Residential landuse with direct road side access for pedestrians and vehicles.</td>
</tr>
<tr>
<td>Restricted access</td>
<td>No or limited direct roadside access (e.g. due to the existence of physical barriers, frontage streets etc).</td>
</tr>
</tbody>
</table>

Table A-2:1 Road environment type classes

c) Side friction class SF

Side friction describes the impact of road side activities in the intersection area on the traffic discharge. Normally the most disturbing types are pedestrians walking on or crossing the carriageway, angkutan kota and buses stopping to pick up or let off passengers and vehicles entering and leaving premises and parking lots outside the carriageway. Side friction is defined qualitatively from traffic engineering judgement as High or Low.

d) City size class CS

The city size should be classified by the population of the whole urban area.

<table>
<thead>
<tr>
<th>CS</th>
<th>No. of inhabitants (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>Medium</td>
<td>0.3-1.0</td>
</tr>
<tr>
<td>Large</td>
<td>1.0-3.0</td>
</tr>
<tr>
<td>Very large</td>
<td>&gt;3.0</td>
</tr>
</tbody>
</table>

Table A-2:2 City size classes
STEP A-3: TRAFFIC CONDITIONS

The input data consists of three parts, definition of traffic situation, a traffic flow sketch, and traffic input variables.

The traffic flow sketch is optional and gives more detailed traffic information than needed.

Traffic situation

The traffic situation is defined by year and hour or AADT-factor (for planning). An optional name of the traffic alternative could be entered.

Traffic flow sketch - optional

For design and operational analysis a sketch -of the traffic situation is drawn in Form WEAV-l. The sketch should show traffic movements (veh/h) by approach A\textsubscript{W}, A\textsubscript{NW}, D\textsubscript{W} and D\textsubscript{NW}, if single and A\textsubscript{LT}, A\textsubscript{ST}, A\textsubscript{RT} and so on if roundabout design, see examples below in Figure A-3:1. This is a slightly more detailed traffic information than needed. Approaches should be denoted as for geometry.

![Example of traffic flow sketch](image)

Figure A-3:1 Example of traffic flow sketch
Traffic input variables

The following traffic data are needed for a complete calculation and should be filled in the traffic part of the form, see Figure A-3:2.

![Diagram of traffic flow](image)

<table>
<thead>
<tr>
<th>Weaving section</th>
<th>Actual flow $a$</th>
<th>Weaving flow $O_w$</th>
<th>Weaving % $W%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>$A^TDST+D_{RT}+C_{RT}$</td>
<td>$A_{ST}+A_{RT}+D_{ST}+C_{RT}$</td>
<td>$100xQ_{WAB}/Q_{AB}$</td>
</tr>
<tr>
<td>BC</td>
<td>$B+A_{ST}+A_{RT}+D_{RT}$</td>
<td>$B_{ST}+B_{RT}+A_{ST}+A_{RT}$</td>
<td>$100xQ_{WBC}/Q_{BC}$</td>
</tr>
<tr>
<td>CD</td>
<td>$C+B_{ST}+B_{RT}+A_{RT}$</td>
<td>$C_{ST}+C_{RT}+B_{ST}+A_{RT}$</td>
<td>$100xQ_{WCD}/Q_{CD}$</td>
</tr>
<tr>
<td>DA</td>
<td>$D+C_{ST}+C_{RT}+B_{RT}$</td>
<td>$D_{ST}+D_{RT}+C_{ST}+B_{RT}$</td>
<td>$100xQ_{WDA}/Q_{DA}$</td>
</tr>
</tbody>
</table>

LT = Left Turning  ST = Straight through  RT = Right-Turning

A,B,C,D defence traffic flow

Figure A-3:2  Traffic flow variables

The variable are described in the order they appear in the form.

<table>
<thead>
<tr>
<th>COLUMN IN FORM</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic flows</td>
<td>Defines if flows are in veh/h or AADT.</td>
</tr>
<tr>
<td>Alternative/section</td>
<td>Comment possibility to define which weaving section is meant within a roundabout or to define a design alternative.</td>
</tr>
<tr>
<td>Total actual flow $Q_v$ (veh/h)</td>
<td>Total actual entering flow.</td>
</tr>
<tr>
<td>Total weaving flow $Q_w$ (veh/h)</td>
<td>Total entering weaving flow. For $W%$-calculation.</td>
</tr>
<tr>
<td>Weaving-% $W%$ = 100 x $Q_w$ / $Q_v$</td>
<td>Weaving-%, $W%$, is the overall weaving-% for the weaving section.</td>
</tr>
<tr>
<td>AADT-factor $K$</td>
<td>The total flow is given as an AADT=value $Q_{AADT}$. AADT-factor, $K$, is a conversion factor to estimate an average peak hour traffic from an AADT, as follows: $Q_{pak} = K \times Q_{AADT}$</td>
</tr>
</tbody>
</table>
The following default values could be used if no better information is available.

<table>
<thead>
<tr>
<th>Road environment</th>
<th>K-factor - City size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads in commercial areas and arterial roads</td>
<td>&gt;1M</td>
</tr>
<tr>
<td>Roads in residential areas</td>
<td>0.07-0.08</td>
</tr>
</tbody>
</table>

Table A-3:1    K-factor default values

pcuLV, pcu-factor for light vehicles. Default: pcuLV = 1.0

LV%, % of light vehicles of total flow

PcuHV, pcu-factor for heavy vehicles. Default: pcuHV = 1.3

Comment: If there are a lot of big trucks PCUHV = 2.0 could be used.

HV%, % of heavy vehicles of total flow.

pcuMC, pcu-factor for motor cycles. Default: pcuMC = 0.5

MC%, % of motor cycles of total flow.

pcuUM, pcu-factor for unmotorised vehicles. Default: pcuUM = 1.0

Comment: If most unmotorised are bicycles pcuUM = 0.3 could be used.

UM%, % of unmotorised of total flow.

Pcu-factor P

P is calculated from pcu-values and flow composition data:

\[ P = \frac{(pcu_{LV} \times LV\% + pcu_{HV} \times HV\% + pcu_{MC} \times MC\% + pcu_{UM} \times UM\%)}{100} \]

Normally the default pcu-values for the different vehicle types are used.

Total traffic \( Q_p \) (pcu/h)

Total flow \( Q_p \) (pcu/h) is calculated as follows:

\[ Q_p = Q_v \times P, \text{ where:} \]

\[ Q_v = \text{total entering flow (veh/h)} \]

\[ P = \text{pcu-factor} \]

Example: \( Q_v = 2000 \text{ veh/h} \) with

<table>
<thead>
<tr>
<th>LV</th>
<th>HV</th>
<th>MC</th>
<th>UM</th>
</tr>
</thead>
<tbody>
<tr>
<td>pcu</td>
<td>%</td>
<td>pcu</td>
<td>%</td>
</tr>
<tr>
<td>1.0</td>
<td>56</td>
<td>1.3</td>
<td>4</td>
</tr>
</tbody>
</table>
Solution:
\[ P = \frac{(1.0 \times 56 + 1.3 \times 4 + 0.5 \times 33 + 1.0 \times 7)}{100} = 0.85 \]

\[ Q_T = P \times Q_V = 0.85 \times 2000 = 1700 \text{ pcu/h} \]

Traffic variable default values

Traffic data is often lacking or of poor quality. The following default values could be used if better information is not available, see Table A-3:2 for AADT-factor K, weaving-% W%, traffic composition P-factor and vehicle type percentages.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT-factor, see Table C-1:1, K</td>
<td>0.07-0.12</td>
</tr>
<tr>
<td>Weaving-%, W%</td>
<td>75</td>
</tr>
<tr>
<td>Pcu-factor, P</td>
<td>0.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>City size M inhabitants</th>
<th>Traffic composition %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LV</td>
</tr>
<tr>
<td>&lt; 0.3</td>
<td>60.0</td>
</tr>
<tr>
<td>0.3-1.0</td>
<td>34.0</td>
</tr>
<tr>
<td>1.0-3.0</td>
<td>52.5</td>
</tr>
<tr>
<td>&gt; 3.0</td>
<td>59.0</td>
</tr>
</tbody>
</table>

Table A-3:2 Default traffic variables
STEP B: DESIGN / PLANNING OBJECTIVES

For design/planning calculations, objectives expressed in performance measures must be chosen.

A recommended default objective for design/planning is to find a design which operates with degree of saturation DS<=0.8.

Chosen objectives are entered in Form WEAV-I in the OBJECTIVES-part.
**STEP C: CAPACITY C**

Actual capacity, C (pcu/h), is calculated from the following formulae:

\[ C = 135 \times W^{1.3} \times (1+W_E/W)^{1.5} \times (1-W% /300)^{0.5} \times F_{CS} \times F_{RF} / (1+W/L)^{1.8} \]

Tile calculation is executed in a number of steps as shown in the flow chart below.

Figure C:1  Capacity calculation flow chart

Input data for the calculation steps are available in the WEAV-I-form. Results from every step could be entered to the ANALYSIS-part of the form. The different steps are described in detail below.

**STEP C-1: BASE CAPACITY C₀**

Base capacity C₀ is calculated using the following formulae.

Input variables are weaving width W, weaving width/entry width ratio Wₑ/W, weaving% W% and weaving width/length-ratio W/L.

\[ C₀ = 135 \times W^{13} \times (1+W_E/W)^{1.5} \times (1-W% /300)^{0.5} / (1+W/L)^{1.8} \]

The range of variation for the variables in the empirical base of the manual.

The three geometry factors 135xWₚ, (1+Wₑ/W)ₚ and 1/(1+W/L)ₚ and the traffic factor (1-W%/300)₂ₜ could be estimated using the following figures C-1:1 through C-1:4.

Enter the values of the factors into the corresponding Columns C-1:1 thru C-1:4 in the ANALYSIS-part of the form.
Calculate the base capacity $C_0$ by multiplying the four factors with each other and input in Column C-1.

Figure C-1:1 $135 \times W^{1.3}$ –factor

Figure C-1:2 $(1 + \frac{W_E}{W})^{1.5}$ –faktor
Figure C-1.3 \[ \frac{1}{1 + \frac{W}{L}}^{1.8} \text{-factor} \]

Figure C-1.4 \[ (1 - \frac{W\%}{300})^{0.5} \text{-factor} \]
STEP C-2: CITY SIZE CORRECTION FACTOR $F_{CS}$

City size correction factor $F_{CS}$ is decided from Table C-2:1. Input in Column C-2 in the ANALYSIS-part of the form. Input variable is city size, CS.

<table>
<thead>
<tr>
<th>City size CS</th>
<th>Inhab. (M)</th>
<th>City size correction factors $F_{CS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>&lt; 0.3</td>
<td>0.83</td>
</tr>
<tr>
<td>Medium</td>
<td>0.3-1.0</td>
<td>0.94</td>
</tr>
<tr>
<td>Large</td>
<td>1.0-3.0</td>
<td>1.00</td>
</tr>
<tr>
<td>Very large</td>
<td>&gt; 3.0</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Table C-2:1 City size correction factor $F_{CS}$

STEP C-3: ROAD ENVIRONMENT TYPE AND SIDE FRICTION CORRECTION FACTOR $F_{RF}$

Road environment type and side friction correction, $F_{RF}$, is defined using Table C-3:1 below. Input in Column C-3 in the ANALYSIS-part of the form. Input variables are road environment type RE and side friction class SF.

<table>
<thead>
<tr>
<th>Road environment type class RE</th>
<th>Side friction class SF</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>Low</td>
<td>1.00</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>1.00</td>
<td>0.97</td>
</tr>
<tr>
<td>Residential</td>
<td>Low</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table C-3:1 Road environment type and side friction correction factor $F_{RF}$

STEP C-4: ACTUAL CAPACITY $C$

Actual capacity, $C$ (pcu/h), is calculated using the following formulae, where the different factors have been calculated above:

$$C = C_0 \times F_{CS} \times F_{RF}$$

Enter the results in Column C-4 in the ANALYSIS-part of the form.
STEP D: DEGREE OF SATURATION DS

Degree of saturation, DS, is calculated using the following formulae. The result is noted in the ANALYSIS-part of the form in Column D:

\[
DS = \frac{Q_P}{C}, \text{ where}
\]

- \( Q_P \): actual total flow (pcu/h) from traffic input
- \( P \): pcu-factor from traffic input
- \( C \): actual capacity from STEP C.

Example: C=2700 pcu/h and \( Q_v = 2000 \text{ veh/h} \) with

<table>
<thead>
<tr>
<th>PCU</th>
<th>%</th>
<th>PCU</th>
<th>%</th>
<th>PCU</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>56</td>
<td>1.3</td>
<td>4</td>
<td>0.5</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
</tbody>
</table>

Calculations:

\[
P = \frac{(1.0 \times 56 + 1.3 \times 4 + 0.5 \times 33 + 1.0 \times 7)}{100} = 0.85
\]

\[
Q_P = P \times Q_V = 0.85 \times 2000 = 1700 \text{ pcu/h}
\]

Degree of saturation \( DS = \frac{Q_P}{C} = \frac{1700}{2700} = 0.63 \)
Delay D (sec/pcu) is the average delay per entering vehicle. Delay is estimated from the empirical relationship between delay D and degree of saturation DS, see Figure E:1.

Input variable is degree of saturation DS from STEP D.

The result is noted in the ANALYSIS-part of the form in Column E.

Figure E:1  
Delay D (sec/pcu) versus degree of saturation DS = \( \frac{Q_p}{C} \)
STEP F: QUEUE PROBABILITY QP% - ROUNDABOUT WEAVING SECTIONS

Queue probability QP% (%) is estimated from the empirical relationship between queue probability QP% and degree of saturation DS.

Input variable is degree of saturation DS from STEP D.

The result is noted in the ANALYSIS-part of the form in Column F.

Figure F:1 Queue probability QP% (%) versus degree of saturation DS = Qp /C
STEP G: TRAVEL SPEED V – SINGLE WEAVING SECTIONS

Travel speed; is calculated in 2 steps as follows:

STEP G-1: Estimate free flow speed $V_0$ (km/h)

STEP G-2: Estimate travel speed $V$ (km/h)

Input variables are weaving-% $W\%$, heavy vehicle-% $HV\%$ and degree of saturation $DS$ from STEP D.

STEP G-1: FREE FLOW SPEED $V_0$

Free flow speed $V_0$ (km/h) is estimated from the following formulae:

$$V_0 = 45.2 \times (1+HV\%/100)^{-2.8} \times (1-W\%/300),$$

where $HV\% = $ Heavy vehicle-% and $W\% = $ weaving-%

The factor $45.2 \times (1+HV\%/100)^{-2.8}$ could be estimated from Figure G-1:1, and enter the factor value in Column G-1:1 in the ANALYSIS part of the form. The factor $1-W\%/300$ could be estimated from Figure G-1:2, and enter the factor value in Column G-1:2 in the ANALYSIS part of the form.

Calculate $V_0$ by multiplying the two factors and enter the result in Column G-1 in the ANALYSIS part of the form.

![Figure G-1:1](45.2 \times (1+HV\%/100)^{-2.8} –factor)
The range of variation for the variables in the empirical base of the manual is given in Table G-1:1 below. Use outside of this range is more uncertain.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min</th>
<th>Avg</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry width $W_E$</td>
<td>8</td>
<td>9.7</td>
<td>11</td>
</tr>
<tr>
<td>Weaving width $W$</td>
<td>8</td>
<td>11.6</td>
<td>20</td>
</tr>
<tr>
<td>Weaving length $L$</td>
<td>50</td>
<td>84</td>
<td>121</td>
</tr>
<tr>
<td>Width/length $W/L$</td>
<td>0.07</td>
<td>0.14</td>
<td>0.20</td>
</tr>
<tr>
<td>Weaving-% $W$%</td>
<td>69</td>
<td>80</td>
<td>95</td>
</tr>
<tr>
<td>HV%</td>
<td>0</td>
<td>2</td>
<td>13</td>
</tr>
</tbody>
</table>

Table G-1:1 Empirical range for free flow speed model

Comment: The free flow speed model assumes geometry restrict entry speeds. If better free speed information is available it should be used. A possibility is to use the urban road free flow speed model presented in Chapter 5.

For Semanggi in Jakarta, one of the field sites not used for the free speed model, free speeds were around 60 km/h.
STEP G-2: ESTIMATE TRAVEL SPEED V (KM/H)

Travel speed V (km/h) is estimated from the following formulae:

\[ V = V_o \times 0.5 \times (1+(1-DS)^{0.5}), \]

where

- \( V_o \) free flow speed (km/h) calculated in STEP G-1
- DS degree of saturation calculated in STEP D

The factor \( 0.5 \times (1+(1-DS)^{0.5}) \) could be estimated from Figure G-2:1. Enter the result in Column G-2 in the ANALYSIS-part of the form.

V is obtained by multiplying Columns G-1 and G-2. Enter the result in Column G in the ANALYSIS-part of the form.

Figure G-2:1 \( 0.5 \times (1+(1-DS)^{0.5}) \)-factor
Travel time $TT$ (sec/pcu) for the single weaving section is calculated with the following formulae.

Input variables are travel speed $V$ and weaving length $L$.

$$TT = \frac{L \times 3.6}{V},$$

where

- $L$ weaving section length (m)
- $V$ travel speed (km/h) calculated in STEP F

The result is entered in Column H in the ANALYSIS-part of the form.
STEP I: PERFORMANCE MEASURES COMPARED WITH DESIGN/PLANNING OBJECTIVES

This step comprises the following substeps:

a) Compare calculated performance measures with design/planning objectives

b) If not satisfying, assume a new design and repeat calculations.

   In some cases the objectives cannot be met.
   Objectives and/or traffic conditions then have to be changed.

   Traffic can be changed by prohibitions of some movements or through alternative traffic schemes.

c) If satisfying, stop calculations

The COMMENT-lines in the form WEAV-1 could be used for STEP I.
4. WORKED EXAMPLES

4.1 ROUNDABOUT WEAVING SECTIONS

EXAMPLE

Decide capacity, degree of saturation DS and delay for the roundabout weaving section between Jalan A and Jalan B with layout and traffic as in Figure 4.1:1 below. The traffic situation is a PM peak in 2005. The weaving section is located in a large city KOTA on an arterial with restricted access and high friction.

Figure 4.1:1 Example layout and traffic
## Geometric Conditions

**A:** JL. A  
**B:** JL. B  
**Year:** 2005  
**Hour:** PM PEAK  
**City:** KOTA  
**Traffic alternative:** EXAMPLE  

**Design alternative:** EXAMPLE

### Traffic Conditions

- **Weaving section sketch:**

### Traffic Flow Sketch (optimal)

#### Traffic Flow Sketch

- **Traffic composition:**

#### Geometric Input

<table>
<thead>
<tr>
<th>Weaving Section Type</th>
<th>Roundabout</th>
<th>Single</th>
<th>Alt / Sect</th>
<th>Qv</th>
<th>Qw</th>
<th>W%</th>
<th>AADT Factor K</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>4500</td>
<td>3500</td>
<td>78</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Environmental Conditions

- **Road environment type:** RE  
- **Side friction SF:**
  - Small < 0.3M
  - Medium 0.3–1M
  - Large 1-3 M
  - Very Large>3M
- **Commercial:** Low  
- **Residential:** High

#### Design/Planning Objectives

<table>
<thead>
<tr>
<th>Alt, Dr Section</th>
<th>DS</th>
<th>D</th>
<th>QP%</th>
<th>V</th>
<th>TT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>2694</td>
<td>2.52</td>
<td>0.70</td>
<td>0.86</td>
<td>4086</td>
</tr>
</tbody>
</table>

#### Analysis

- **Base Capacity:**
  - C_o:  
  - Fcs:  
  - FRF:  
  - C:  
  - C-1:  
  - C-2:  
  - C-3:  
  - C-4:  
  - D:  
  - E:  
  - F:  
  - G:  
  - H:  

#### Comments

- **Analyzing engineer:** 
- **Checking engineer:**

Date: day... Month... Year ...

**Date:** Day ... Month ... Year ...
SOLUTION

See the filled form WEAV-I and the comments for each position in the form below, which follow the manual steps.

STEP A: INPUT DATA

STEP A-1: GEOMETRIC CONDITIONS

Overview sketch

Record the road names Jalan A and Jalan B and city name KOTA. Name the design EXAMPLE. Enter the sketch of the roundabout with North arrow and denote approaches and exits A, B, C and D starting from west in a clock-wise order.

Geometry input variables

Input geometry variables in the form as follows.

<table>
<thead>
<tr>
<th>Form position</th>
<th>Input in form</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaving section type</td>
<td>Roundabout</td>
<td></td>
</tr>
<tr>
<td>Altern/section:</td>
<td>AB</td>
<td>Section which is calculated</td>
</tr>
<tr>
<td>W₁ = 8m</td>
<td></td>
<td>From example text</td>
</tr>
<tr>
<td>W₂ = 9m</td>
<td></td>
<td>From example text</td>
</tr>
<tr>
<td>Wₑ = 8.5m</td>
<td></td>
<td>((\frac{W₁+W₂}{2})), Formulae in Figure A-1:2</td>
</tr>
<tr>
<td>W = 10m</td>
<td></td>
<td>From example text</td>
</tr>
<tr>
<td>Wₑ / W = 8.5 / 10 = 0.85</td>
<td></td>
<td>From example text</td>
</tr>
<tr>
<td>L = 45m</td>
<td></td>
<td>From example text</td>
</tr>
<tr>
<td>W / L = 10 / 45 = 0.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

STEP A-2: ENVIRONMENTAL CONDITIONS

Road environment type Restricted access From example text
Side friction High From example text
City size Large From example text

STEP A-3: TRAFFIC CONDITIONS

Traffic situation

Input data from the text in the example.

Year 2005 From example text
IHCM: WEAVING SECTIONS

<table>
<thead>
<tr>
<th>Hour</th>
<th>PM Peak</th>
<th>From example text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic alternative:</td>
<td>Example</td>
<td>Optional, to give the traffic situation a name</td>
</tr>
</tbody>
</table>

**Traffic flow sketch**

Enter the sketch of the traffic situation to the form.

**Traffic input variables**

<table>
<thead>
<tr>
<th>Traffic flows</th>
<th>veh/h</th>
<th>Flows in veh/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt/sec</td>
<td>AB</td>
<td>Section, which is calculated</td>
</tr>
<tr>
<td>(Q_v)</td>
<td>4500</td>
<td>(A_{LT} + A_{ST} + A_{RT} + D_{ST} + D_{KT} + C_{KT}) = 500 + 1200 + 400 + 1200 + 500 + 700</td>
</tr>
<tr>
<td>(Q_w)</td>
<td>3500</td>
<td>(A_{ST} + A_{RT} + D_{ST} + C_{RT}) = 1200 + 400 + 1200 + 700</td>
</tr>
</tbody>
</table>

\[W\% = \frac{100 \times Q_w}{Q_v} = \frac{100 \times 3500}{4500}\]

| AADT-factor | - | Not needed. Not planning |

**Traffic composition**

<table>
<thead>
<tr>
<th>Alt/sec</th>
<th>AB</th>
<th>Section, which is calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCU(_{LV})</td>
<td>1.0</td>
<td>Default value</td>
</tr>
<tr>
<td>LV%</td>
<td>60</td>
<td>From example text</td>
</tr>
<tr>
<td>pCU(_{HV})</td>
<td>1.3</td>
<td>Default value</td>
</tr>
<tr>
<td>HV%</td>
<td>5</td>
<td>From example text</td>
</tr>
<tr>
<td>PCU(_{HV})</td>
<td>0.5</td>
<td>Default value</td>
</tr>
<tr>
<td>MC%</td>
<td>30</td>
<td>From example text</td>
</tr>
<tr>
<td>pCU(_{UM})</td>
<td>1.0</td>
<td>Default value</td>
</tr>
<tr>
<td>UM%</td>
<td>5</td>
<td>From example text</td>
</tr>
<tr>
<td>(P)</td>
<td>0.87</td>
<td>((1 \times 60 + 1.3 \times 5 + 0.5 \times 30 + 1.0 \times 5) / 100)</td>
</tr>
</tbody>
</table>
**STEP C: CAPACITY**

Input under ANALYSIS

Alt/sect  
AB  
Section, which is calculated

**STEP C-1: BASE CAPACITY C₀**

W-factor (C-1:1)  
$135 \times 10^{1.3} = 2694$  
Or from Figure C-1:1 2700

$W_{E}/W$-factor (C-1:2)  
$(1+0.85)^{1.5} = 2.52$  
Or from Figure C-1:2 approximately 2.52

$W/L$-factor (C-1:3)  
$1 / (1+0.22)^{1.6} = 0.70$  
Or from Figure C-1:3 approximately 0.70

$W/\%$-factor (C-1:4)  
$(1-78/300)^{0.5} = 0.86$  
Or from Figure C-1:4 approximately 0.86.

Base capacity $C₀ (C-1)$  
4086  
$2694 \times 2.52 \times 0.70 \times 0.86$

**STEP C-2: CITY SIZE CORRECTION FACTOR F_CS**

$F_{CS}(C-2)$  
1.0  
Large city, Table C-2:1

**STEP C-3: ROAD ENVIRONMENT TYPE AND SIDE FRICTION CORRECTION FACTOR F_RF**

$C (C-4)$  
4086  
$4086 \times 1.0 \times 1.0$

**STEP D: DEGREE OF SATURATION DS**

$DS (D)$  
0.96  
$Q_p / C = 3915 / 4086$

**STEP E: DELAY D**

$D (E)$  
11 sec / pcu  
From Figure E:1 with DS = 0.96

**STEP F: QUEUE PROBABILITY QP%**

$QP\%$  
34-70%  
From Figure F:1 with DS = 0.96
4.2 SINGLE WEAVING SECTIONS EXAMPLE

Decide capacity, degree of saturation DS, travel speed and travel time for the single weaving section between Jalan S and Jalan C with layout and traffic as in Figure 4.2:1 below. The traffic situation is a PM peak in 2005. The weaving section is located in a city A-KOTA with 800,000 inhabitants on a road in a commercial area with high friction due to short period parking along the south side of the weaving section.

Figure 4.2:1 Example layout and traffic
### GEOMETRIC CONDITIONS

**A:** JL. A  
**B:** JL. B

**Design alternative:** EXAMPLE

**Weaving section sketch:**

![Weaving Section Sketch]

**Traffic flow sketch (optimal):**

![Traffic Flow Sketch]

### TRAFFIC CONDITIONS

**Year:** 2005  
**Hour:** PM PEAK

**Traffic alternative:** EXAMPLE

### GEOMETRY INPUT

<table>
<thead>
<tr>
<th>Weaving section type</th>
<th>Roundabout</th>
<th>X</th>
<th>Single</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altern. Section</td>
<td>W₁, W₂, W₃, W₄, L, W₅/L</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 8.5, 8, 8.25, 15.5, 0.53, 100, 0.155</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### TRAFFIC FLOWS

<table>
<thead>
<tr>
<th>Traffic flows Veh/h</th>
<th>X</th>
<th>AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-</td>
<td>4550</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>3500</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>77</td>
</tr>
</tbody>
</table>

### TRAFFIC COMPOSITION

- Light PCU \( Q_p \) | Heavy PCU \( Q_p \) | Motor cycle PCU \( Q_p \) | Unmotorised PCU \( Q_p \) | PCU Factor | Qp Factor
- 1.0 | 1.3 | 5 | 0.5 | 40 | 1.0 | 5 | 8.82 | 37.30 |

### ENVIRONMENTAL CONDITIONS

- Road environment Type RE: Commercial  
  Side friction SF: Low
- Road environment Type RE: Residential  
  Side friction SF: High
- Road environment Type RE: Restricted acces  
  Side friction SF: Very Large>3M

### DESIGN/PLANNING OBJECTIVES

<table>
<thead>
<tr>
<th>DS</th>
<th>D</th>
<th>QP%</th>
<th>V</th>
<th>TT</th>
</tr>
</thead>
</table>

### ANALYSIS

<table>
<thead>
<tr>
<th>Alt. Dr Section</th>
<th>Geometry Factor</th>
<th>WE/W Factor</th>
<th>WL Factor</th>
<th>Traffic Type</th>
<th>Base Capacity</th>
<th>Environment Capacity</th>
<th>Measures</th>
<th>Roundabout Delay D sec/pc</th>
<th>Queue Prob. QP%</th>
<th>Single weaving section</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1:1</td>
<td>- 4762</td>
<td>1.89</td>
<td>0.77</td>
<td>0.86</td>
<td>5960</td>
<td>0.94</td>
<td>0.94</td>
<td>5270</td>
<td>0.71</td>
<td>-</td>
</tr>
<tr>
<td>C-2:2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-3:3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-4:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### COMMENTS

Analyzing engineer:  
Checking engineer:  
Date: day..... Month..... Year.....  
Date: Day..... Month..... Year.....
SOLUTION

See the filled form WEAV-I and the comments for each position in the form below, which follow the manual steps.

STEP A: INPUT DATA

STEP A-1: GEOMETRIC CONDITIONS

Overview sketch

Record the road names Jalan S and Jalan C and city name A-KOTA. Name the design EXAMPLE SINGLE.

Enter the sketch of the single weaving section with North arrow and denote approaches and exits A, B, C and D starting from west in a clock-wise order.

Geometry input variables

Input geometry variables in the form as follows.

<table>
<thead>
<tr>
<th>Form position</th>
<th>Input in form</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaving section type</td>
<td>Single</td>
<td>Single, only one section</td>
</tr>
<tr>
<td>Altern/section:</td>
<td>-</td>
<td>From example text</td>
</tr>
<tr>
<td>W₁ = 8.5m</td>
<td></td>
<td>From example text. 2m reduction due to parking.</td>
</tr>
<tr>
<td>W₂ = 10-2 = 8</td>
<td></td>
<td>From example text. 2m reduction due to parking.</td>
</tr>
<tr>
<td>Wₑ = 8.25m</td>
<td></td>
<td>Formulae Figure A-1:2.</td>
</tr>
<tr>
<td>W = 17.5-2 = 15.5m</td>
<td></td>
<td>Formulae Figure A-1:2.</td>
</tr>
<tr>
<td>Wₑ/W = 0.53</td>
<td></td>
<td>From example text</td>
</tr>
<tr>
<td>L = 100m</td>
<td></td>
<td>From example text</td>
</tr>
<tr>
<td>W/L = 0.155</td>
<td></td>
<td>From example text</td>
</tr>
</tbody>
</table>

STEP A-2: ENVIRONMENTAL CONDITIONS

<table>
<thead>
<tr>
<th>Road environment type</th>
<th>Commercial</th>
<th>From example text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side friction</td>
<td>High</td>
<td>From example text</td>
</tr>
<tr>
<td>City size</td>
<td>Medium</td>
<td>From example text</td>
</tr>
</tbody>
</table>
IHCM: WEAVING SECTIONS

STEP A:3 TRAFFIC CONDITIONS

Traffic situation

Input data from the text in the example.

Year 2005 From example text
Hour PM Peak From the example text
Traffic alternative: Example Optional, to give the traffic situation a name

Traffic flow sketch

Enter the sketch of the traffic situation to the form.

Traffic input variables

Traffic flows veh/h Flows in veh/h
Alt/sec - Single, only one

$Q_v = 4550$ $A_{NW} + A_w + D_w + D_{NW} = 350 + 1400 + 2100 + 700$
Formulae in Figure A-3:2

$Q_w = 3500$ $A_w + D_w = 1400 + 2100$
Formulae in Figure A-3:2

$W \% = 77$ $100 \times \frac{Q_w}{Q_v} = 3500 / 4550$

AADT-factor - Not needed. Not planning

Traffic composition

Alt/sec - Single

$pcu_{NV} = 1.0$ Default value

$LV\% = 50$ From example text

$pcu_{HV} = 1.3$ Default value

$HV\% = 5$ From example text

$pcu_{MC} = 0.5$ Default value

$MC\% = 40$ From example text

$P_{cu_{UM}} = 1.0$ Default value
UM% 5 From example text
P 0.815 \( \frac{(1 \times 50 + 1.3 \times 5 + 0.5 \times 40 + 1.0 \times 5)}{100} \)
Qr 3730 0.82 x 4550

DESIGN/PLANNING - Analysis. No objectives!

**STEP C: CAPACITY**

**Input under ANALYSIS**

Alt / sect - Single

**STEP C-1: BASE CAPACITY C\(_0\)**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Value</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W_{-})factor (C-1:1)</td>
<td>135 x 15.5(^{1.3}) = 4762</td>
<td>Or from Figure C-1:1 approximately 4800</td>
</tr>
<tr>
<td>( W_{E}/W)-factor (C-1:2)</td>
<td>((1+0.53)^{1.5}) = 1.89</td>
<td>Or from Figure C-1:2 approximately 1.9</td>
</tr>
<tr>
<td>( W/L)-factor (C-1:3)</td>
<td>(1/(1+0.155)^{1.8}) = 0.77</td>
<td>Or from Figure C-1:3 approximately 0.77</td>
</tr>
<tr>
<td>( W%-)factor (C-1:4)</td>
<td>((1-77/300)^{0.5}) = 0.86</td>
<td>Or from Figure C-1:4 approximately 0.86</td>
</tr>
<tr>
<td>Base capacity ( C_0 ) (C-1)</td>
<td>5960</td>
<td>4762 x 1.89 x 0.77 x 0.86</td>
</tr>
</tbody>
</table>

**STEP C-2: CITY SIZE CORRECTION FACTOR F\(_{CS}\)**

\( F_{CS} \) 0.94 Medium city, Table C-2:1

**STEP C-3: ROAD ENVIRONMENT TYPE AND SIDE FRICTION CORRECTION FACTOR F\(_{RF}\)**

\( F_{RF} \) (C-3) 0.94 Commercial, high friction Table C-3:1

**STEP C-4: CAPACITY C**

\( C \) (C-4) 5270 5960 x 0.94 x 0.94

**STEP D DEGREE OF SATURATION DS**

\( DS \) (D) 0.71 \( Q_p / C = 3730 / 5270 \)
IHCM: WEAVING SECTIONS

STEP G: TRAVEL SPEED $V$ – SINGLE WEAVING SECTIONS

STEP G1: FREE FLOW SPEED $V_0$

<table>
<thead>
<tr>
<th>HV%-factor (G-1:1)</th>
<th>39.4</th>
<th>45.2 x (1+5/100)^{-2.8}, or from Figure G-1:1 approximately 39.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>W%-factor (G-1:2)</td>
<td>(1-77/300) = 0.74</td>
<td>Or from Figure G-1:2 approximately 0.742</td>
</tr>
<tr>
<td>$V_0$ (G-1)</td>
<td>29.2 km/h</td>
<td>39.4 x 0.74</td>
</tr>
</tbody>
</table>

STEP G2: TRAVEL SPEED $V$

<table>
<thead>
<tr>
<th>DS-factor (G-2)</th>
<th>0.77</th>
<th>0.5 x (1+(1-0.71)^{0.5})</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V$ (G)</td>
<td>22.5 km/h</td>
<td>29.2 x 0.77</td>
</tr>
</tbody>
</table>

STEP H TRAVEL TIME $TT$

| $TT$ (H)            | 16 sec / pcu | 100 x 3.6 / 22.5 |
5. LITERATURE REFERENCES


W2 Roess, McShane Weaving area - design and analysis


Overviews:


INDONESIAN HIGHWAY CAPACITY MANUAL : FORM UNSIG-I UNSIGNALISED INTERSECTION

### GEOMETRIC CONDITIONS

<table>
<thead>
<tr>
<th>A:</th>
<th>B:</th>
<th>Year:</th>
</tr>
</thead>
<tbody>
<tr>
<td>D:</td>
<td>C:</td>
<td>Hour:</td>
</tr>
</tbody>
</table>

Design alternative:

**Weaving section sketch:**

**Traffic flow sketch (optimal):**

### GEOMETRY INPUT

<table>
<thead>
<tr>
<th>Traffic flows Veh/h</th>
<th>X</th>
<th>AADT</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Weaving section type</th>
<th>Roundabout</th>
<th>Alt / sect</th>
<th>Qv</th>
<th>Qw</th>
<th>W%</th>
<th>AADT factor K</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Altern. Section</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W</th>
<th>We/W</th>
<th>L</th>
<th>W/L</th>
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</thead>
</table>

### ENVIRONMENTAL CONDITIONS

<table>
<thead>
<tr>
<th>Alt. sect</th>
<th>Light PCU</th>
<th>Heavy PCU</th>
<th>Motor cycle PCU</th>
<th>Unmotorised PCU</th>
<th>PCU factor</th>
<th>Qp</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Road environment Type RE</th>
<th>Side friction SF</th>
<th>City size CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Low</td>
<td>Medium 0.3–1M</td>
<td></td>
</tr>
<tr>
<td>Residential High</td>
<td>Large 1-3 M</td>
<td></td>
</tr>
<tr>
<td>Restricted access</td>
<td>Very Large&gt;3M</td>
<td></td>
</tr>
</tbody>
</table>

### DESIGN/PLANNING OBJECTIVES

<table>
<thead>
<tr>
<th>DS</th>
<th>D</th>
<th>QP%</th>
<th>V</th>
<th>TT</th>
</tr>
</thead>
</table>

### ANALYSIS

<table>
<thead>
<tr>
<th>Alt. sect</th>
<th>Geometry Factor</th>
<th>WE/W Factor</th>
<th>W/L Factor</th>
<th>Traffic W% Factor Base Capacity</th>
<th>Environment City Size</th>
<th>Measures Capacity</th>
<th>Degree Of Saturation</th>
<th>Roundabout Delay D sec/sec</th>
<th>Queue Prob. QP%</th>
<th>Single weaving section DS Factor</th>
<th>Travel Speed V Km/h</th>
<th>Travel Time TT Sec</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Co</th>
<th>Fcs</th>
<th>FRF</th>
<th>C</th>
<th>C-2</th>
<th>C-3</th>
<th>C-4</th>
<th>DS</th>
<th>D</th>
<th>F</th>
<th>G-1:1</th>
<th>G-1:2</th>
<th>G-1</th>
<th>G-2</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
</table>

### COMMENTS

Analyzing engineer: ...
Checking engineer: ...

Date: day:... Month:... Year:...
Date: Day:... Month:... Year:...
Chapter 5: URBAN ROADS
CHAPTER 5

URBAN ROADS

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1. INTRODUCTION

1.1 SCOPE AND OBJECTIVES

1.1.1. Facility types

This manual presents procedures for the calculation of capacity and performance measures on urban and suburban roads of the following types:

Urban roads:
- Two-lane two-way roads (2/2)
- Four-lane two-way roads (4/2)
- without median (undivided)
- with median (divided)
- One-way roads (1-3/1)

Urban motorways:
Dual, two-lane carriageways with grade separated junctions.

1.1.2. Application

The road types used in this manual are defined in the Section 2.3. They are not related to the Indonesian functional road classification system (Undang-undang tentang Jalan, No. 13, 1980), which was developed for a different purpose.

For each of the defined road types, the calculation procedure may be applied with confidence only in the following conditions:
- Flat or essentially flat terrain.
- Straight or essentially straight horizontal alignment.
- On segments of roads which are not affected by queuing caused by intersections, nor by severe platooning downstream from signalised intersections.

1.1.3. Road segments

The procedures are applied to calculations for individual segments of a road. A road segment is defined as a length of road:
- between and unaffected by signalised or major unsignalised intersections, and
- having similar characteristics along its length.

Points where road characteristics change significantly automatically become the boundary of a segment even if there is no nearby intersection. The road characteristics of importance in this respect are set out in general in Section 1.2, and in more detail in the Sections of this manual which deal with each road type.
In segmenting an urban motorway, ramps and weaving areas must be separated from road segments. The procedures given in this Section relate to road segments but not to weaving areas and ramps. As ramp areas may be the critical areas for capacity, separate ramp or weaving analysis may be needed, especially in operational analysis of the road. In this case, it is recommended that the procedures for freeway, ramps and weaving sections contained in the 1985 US HCM are used.

1.1.4. Networks

If a network or corridor is being analysed, it should be broken down into its components, as follows:

- Road segments
- Signalised intersections
- Unsignalised intersections
- Weaving Sections

Calculations are then performed separately for each of these facility types: they are then combined to give the capacity and overall measures of performance for the system as a whole.

The procedures set out below for urban and suburban roads apply to segments without intersection effects, and consequently most of the empirical data on which this manual is based were collected on major urban and suburban through-routes and not on city streets. On city streets, where major intersections are frequent, the capacity and performance of the road system will depend mainly on the intersections (and weaving Sections) and not so much on the road segments between them. However, if a network analysis is needed, the calculation procedures for road segments presented below may be applied to city centre street networks in the following way:

- Calculate journey time, using the road segment procedures, as if there was no disturbance from any intersections or weaving areas i.e. do the analysis as if no intersections or weaving areas existed ("unobstructed journey time")

- For each major intersection or weaving area in the network, calculate delay, using appropriate procedures from other parts of this manual

- Add the intersection/weaving delays to the unobstructed journey time, to obtain the overall journey time.
1.2 ROAD CHARACTERISTICS

The main characteristics of a road which will affect its capacity and its performance when loaded with traffic are as follows. Any point on a particular road where there is a significant change in geometric characteristics or in roadside activities becomes the boundary of a road segment.

1.2.1. Geometry

- Road type: roads of different type will perform differently under a given traffic load; for example toll roads and non-toll roads.

- Width of carriageway: capacity increases with carriageway width.

- Shoulder/kerb characteristics: capacity, and speed at a given flow, increase with increasing shoulder width. The capacity of roads with kerbs is less than those with shoulders. Capacity is reduced if there are fixed obstructions close to the edge of the carriageway, whether the road has a kerb or a shoulder.

- Presence or absence of median (divided or undivided): well-designed medians increase capacity.

1.2.2. Flow composition and directional split

- Directional split of traffic: capacity is highest on two-way roads when directional split is 50 - 50: that is to say when the flows are equal in both directions.

- Traffic composition: if flow and capacity are measured in veh/h, traffic composition will affect capacity. However, by measuring flow in passenger car units (pcu), as in this manual, this effect has been accounted for.

1.2.3. Traffic control

- Controls on speeds, heavy vehicle movements, parking, etc will affect the capacity of the road.

1.2.4. Environment

- Roadside environment and activities: the many activities in Indonesia at the roadside often conflict, sometimes severely, with flow of traffic. The effects of these conflicts, ("side friction"), is given extra attention in this manual, in comparison to that given in Western manuals.
The following side-frictional items have been found to affect traffic significantly on Indonesian two-lane two-way roads:

- Pedestrians walking
- Stopping angkot (on roadway or shoulder)
- Stopping big buses (on the roadway)
- Stopping unmotorised vehicles
- Pedestrians crossing the road
- Vehicles entering and leaving roadside premises
- Parking on roadway or shoulder

Of these only pedestrian walking, stopping angkot (on the roadway), pedestrian crossing the road and exit/entry vehicles have been found to be of general significance, the rest are important only at some locations. Friction is generally defined semi-qualitatively as either very low, low, medium, high or very high, in terms of these four generally significant items. A seventh item, parking on the roadway, is included in the carriageway width adjustment factors.

Driver and vehicle population: the size of Indonesia and the diversity and degree of development of its urban areas mean that driver behaviour and vehicle population (the age, power and condition of vehicles, as distinct from vehicle composition) are diverse. These characteristics are incorporated into the calculation procedures indirectly, by means of city size: smaller cities exhibit less urgent driver behaviour and a less modern vehicle fleet, leading to reduced capacities and lower speeds at a given flow, when compared with larger cities.

These characteristics are used in the calculation procedures in this manual. Most of them have also been recognized by and used in other capacity manuals. The magnitude of their effects is however different in Indonesia.
# 1.3 Definitions and Terminology

<table>
<thead>
<tr>
<th>Notation</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance measures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Capacity (pcu/h)</td>
<td>Maximum stable output flow (pcu/h) at which vehicles can be reasonably expected to traverse a uniform segment of roadway during a specified time period (15 minutes) at given geometry, traffic flow pattern and composition, and environmental factors.</td>
</tr>
<tr>
<td>DS</td>
<td>Degree of saturation</td>
<td>Relation between actual total incoming flow (pcu/h) and capacity (pcu/h) at given geometry, traffic flow pattern and composition, and environmental factors.</td>
</tr>
<tr>
<td>V</td>
<td>Travel speed (Journey speed)</td>
<td>Average speed of a traffic stream computed as the length of a road segment divided by the average travel time of vehicles traversing the segment (km/h).</td>
</tr>
<tr>
<td>Vo</td>
<td>Free flow speed</td>
<td>(1) The theoretical speed of traffic when density is zero, i.e., there are no vehicles present (km/h). (2) The average speed of unobstructed vehicles over a road segment at which drivers feel comfortable traveling, under the physical, environmental, and traffic control conditions existing on an uncongested section of road segment.</td>
</tr>
<tr>
<td>TT</td>
<td>Travel time (Journey time)</td>
<td>Average time spent by vehicles traversing a road segment of given length, including all stopped-time delay (sec/pcu).</td>
</tr>
<tr>
<td><strong>Geometric conditions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WC</td>
<td>Carriageway width (m)</td>
<td>The width available for traffic movement.</td>
</tr>
<tr>
<td>WK</td>
<td>Kerb width (m)</td>
<td>Distance from kerb to obstruction.</td>
</tr>
<tr>
<td>WS</td>
<td>Shoulder width (m)</td>
<td>Distance from the edge of roadway to obstruction.</td>
</tr>
<tr>
<td>Wce</td>
<td>Effective carriageway width (m)</td>
<td>The width available for traffic movement after reduction due to on street parking, for example.</td>
</tr>
<tr>
<td>MD</td>
<td>Median</td>
<td>Area separating traffic directions on a road segment.</td>
</tr>
</tbody>
</table>
IHCM: URBAN ROADS

L ROAD LENGTH
Length of road segment, as if there were no disturbance from any intersections or weaving areas.

ROAD TYPE
Road type defines number of lanes and directions on a road segment:
- 2-lane 2-way (2/2)
- 4-lane 2-way undivided and divided (4/2)
- 1-way (1-3/1)
- Motorways.

NUMBER OF LANES
Number of lanes is defined from the effective carriageway width ($W_{ce}$) for the road segment, see Table 1.3:1

<table>
<thead>
<tr>
<th>Effective carriageway width $W_{ce}$ (m)</th>
<th>Number of lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 10.5</td>
<td>2</td>
</tr>
<tr>
<td>10.5 to 16</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 1.3:1 Number of Lanes

Environmental conditions

CS CITY SIZE
City size is the number of inhabitants in the city (M). Four city size classes are defined, see Table 1.3:2:

<table>
<thead>
<tr>
<th>City size (M in h.)</th>
<th>City size class CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.5</td>
<td>Small</td>
</tr>
<tr>
<td>0.5-1.0</td>
<td>Medium</td>
</tr>
<tr>
<td>1.0-3.0</td>
<td>Large</td>
</tr>
<tr>
<td>&gt;3.0</td>
<td>Very large</td>
</tr>
</tbody>
</table>

Table 1.3:2 City size classes
SF  SIDEFRICTION

Side friction is the impact on traffic performance from roadside activities on the road segment as pedestrians walking, along it or crossing, angkutan kota stopping on the roadway and vehicles entering and exiting.

Five side friction classes are used. They are decided quantitatively:
- Very low (especially if frontage road exists)
- Low
- Medium
- High
- Very high (especially if there are many exit/entry of short-term parked vehicles).

Traffic conditions

Q  ACTUAL FLOW

Number of vehicles passing a point on a road per unit of time, expressed in veh/h or pcu/h.

Q_v  TOTAL ACTUAL FLOW (veh/h)

Total incoming flow to the road segment for both directions (veh/h).

Q_p  TOTAL ACTUAL FLOW (pcu/h)

Total incoming flow to the road segment for both directions (pcu/h).

SP  DIRECTIONAL

Flow distribution (pcu) in the two directions of a road.

Six directional split class are used in the manual, i.e, 100/0, 90/10, 80/20, 70/30, 60/40 and 50/50.

P  PCU-FACTOR

Conversion factor to convert a vehicle flow into an equivalent light vehicle flow.

K  AADT-FACTOR

Conversion factor from AADT to peak hour traffic.

Q_d  DESIGN FLOW

Traffic flow (pcu/h) used for planning:

Q_d = AADT x K
**Calculation factors**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_0$</td>
<td>BASE CAPACITY (pcu /h)</td>
<td>Capacity of a road segment for a predetermined (ideal) set of conditions (geometry, traffic flow pattern and environmental factors).</td>
</tr>
<tr>
<td>$F_W$</td>
<td>CARRIAGEWAY WIDTH ADJUSTMENT FACTOR</td>
<td>Adjustment factor for base capacity due to carriageway width.</td>
</tr>
<tr>
<td>$F_{KS}$</td>
<td>KERB AND SHOULDER ADJUSTMENT FACTOR</td>
<td>Adjustment factor for base capacity due to kerb and/or shoulder width.</td>
</tr>
<tr>
<td>$F_{SP}$</td>
<td>DIRECTIONAL SPLIT ADJUSTMENT FACTOR</td>
<td>Adjustment factor for base capacity due to directional split.</td>
</tr>
<tr>
<td>$F_{SF}$</td>
<td>SIDE FRICTION ADJUSTMENT FACTOR</td>
<td>Adjustment factor for base capacity due to side friction.</td>
</tr>
<tr>
<td>$F_{CS}$</td>
<td>CITY SIZE ADJUSTMENT FACTOR</td>
<td>Adjustment factor for base capacity due to city size.</td>
</tr>
</tbody>
</table>
Two-lane, two-way urban road with shoulder and medium side friction conditions.

Two-lane, two-way urban road with shoulder. Public transport vehicles stopping on the roadway result in very high side friction conditions.
Undivided, four-lane, two-way urban road with kerb and very high side friction conditions. On-street parking reduce effective carriageway width.

Two-lane, one-way urban road with shoulder and medium side friction conditions due to pedestrians. The trees reduce the effective shoulder width zero m.
Undivided, four-lane, two-way urban road with kerb and very high side friction conditions. On-street parking reduce effective carriageway width.

Divided, four-lane, two-way urban road with kerb and low side friction conditions. The trees at the edge of the kerbs reduce speed and capacity.
2. METHODOLOGY

2.1 GENERAL APPROACH

2.1.1. Type of calculation

The procedures given in this manual allow the calculation of:

- the performance of a road segment under a given traffic flow and composition;
- the maximum flow of traffic a road segment can carry while maintaining a specified level of performance;
- the capacity of a road segment and thus the degree of saturation (flow/capacity) of the segment

for road segments of different types, and with particular characteristics.

2.1.2. Levels of analysis

Procedures are given in this manual to enable analysis to be carried out at one of three levels:

- **Operational analysis**: The determination of the performance of an existing or proposed road segment under existing or projected traffic demand. The capacity can also be calculated, as can the maximum flow which can be carried while still maintaining a specified level of performance. This is the most detailed level of analysis.

- **Design**: The determination of the number of lanes needed to carry a given flow of traffic while maintaining an acceptable performance level.

- **Planning**: As for design, the objective is to estimate the likely number of lanes needed for a projected road, but the information on flow is likely to be given only as estimated AADT and the details of geometry and other inputs can only be assumed.

The methods used in operation design and planning analyses are related and differ mainly in the level of detail in the inputs, and outputs. In most cases, the steps in analysis for operational and design analyses will be virtually identical. Steps in planning analysis are very much simpler in most cases.

The calculation procedures given in this manual are in most cases similar, at least in general form, to those in the 1985 U.S. Highway Capacity Manual (US HCM). This is intentional, as users of this manual may already be familiar with the US HCM procedures. In detail however, the procedures are not the same; the complex effect of grades are of less importance in urban than in rural areas in determining speeds. This manual also uses some different variables. Where variables are in common, their values for Indonesian conditions are often quite different from those from the US HCM.
2.1.3. Capacity

Capacity is defined as the maximum flow past a point on the road that can be sustained on an hourly basis under prevailing conditions. This is a two-way flow for two-lane and four-lane two-way roads, and a one-way flow for urban motorways and one-way streets.

2.1.4. Measures of road performance

This manual uses journey speed (synonymous with travel speed) as the main measure of performance of road segments as it is easy to understand and to measure. Journey speed is defined in this manual as the space mean speed of motor vehicles over the road segment:

\[ \bar{V} = \frac{L}{TT} \times 3600 \]

where

- \( \bar{V} \) = space mean speed (km/h)
- \( L \) = length of segment (km)
- \( TT \) = mean travel time of motor vehicles over the segment (secs)

The procedures outlined below also allow the degree of saturation (flow/capacity) to be determined. This is a widely used measure to indicate whether a road segment is expected to have capacity problems or not.

Thus on the one hand, speed is a simple measure to which drivers can relate, which can also be used in economic analysis. On the other hand, flow/capacity is a quick indicator of whether capacity problems are likely to exist.

2.1.5. Level of service

In the US HCM road performance is represented by Level of Service (LOS): a qualitative measure reflecting the drivers' perception of the quality of driving. LOS is related in turn to a quantitative proxy measure, such as density, per cent passing opportunities or journey speed. The level of service concept was developed for use in the United States and the LOS definitions do not directly apply to Indonesia. It is also difficult to produce alternative definitions for Indonesia whose meanings would be clear. For this reason, speed and degree of saturation are used in this manual. Speeds, however, are much lower in Indonesia than in the USA at a given degree of saturation (flow/capacity = Q/C).

2.1.6. Traffic flow and composition

Throughout the manual the traffic flow values reflect traffic composition, by expressing flow in passenger car units (pcu).

See Chapter 1 Section 4 for definitions regarding which vehicle types that are included as light vehicles, heavy vehicles, motorcycles and unmotorised vehicles.
2.1.7. Period of analysis

In this Manual, the capacity analysis of roads is performed for a peak one-hour period, and flows and mean speeds are expressed for this period. To use a full day (AADT) analysis period would be too coarse for urban analysis. At the other extreme, to use the peak 15 minutes within the peak hour would imply an unreasonable inability to tolerate short periods of congestion. Throughout the Manual, flow is expressed as an hourly rate (pcu/h), unless otherwise stated. For planning, in which AADT is normally given, tables are provided to convert flows directly from AADT to performance measures and vice versa, under certain assumed conditions.

2.2 BASIC RELATIONSHIPS

2.2.1. Speed-flow relationships

The principle underlying the capacity analysis of road segments is that speed decreases as flow increases. The speed decrease with unit flow increase is small at low flows but becomes greater as flows get higher. Near capacity a small increase in flows results in a large decrease in speed. This is illustrated in Figure 2.2.1:1. This relationship has been quantitatively defined for a 'standard' case, for each type of road. Each standard case has standard geometric and environmental characteristics specified. If the characteristics of the road are "better" than the standard case (e.g. wider than normal carriageway width), the capacity is higher and the curve is moved to the right, with higher speeds at a given flow. If the characteristics are 'worse' than the standard (e.g. high side friction) the curve moves to the left, capacity is less and speed at a given flow is lower. This is illustrated in Figure 2.2.1:2.

![Figure 2.2.1:1 The General shape of a speed – flow relationship.](image-url)
In each section of the manual, relating to a particular road type, the standard case curve for that road type is given. However, the calculations themselves are based on tables and figures, which are of two types:

1. A series of tables with empirically-derived factors which "adjust" the standard case according to the actual geometric, traffic and environmental characteristics of the road under study, to the extent that they differ from the standard case.

2. A figure relating free-flow speed to effective carriageway width for different friction level and city size on all types of road excluding motorway.

The basic equation used in the manual to describe traffic operations is as follows:

- For urban roads: Two-lane two-way (2/2), four-lane two-way (4/2) and one-way road (1-3/1)

\[ C = C_o \times f_1 \times \ldots \times f_n \] ......................................................... (1)

\[ V = V_o \times 0.5 \times [1 + (1 - Q/C)^{0.5}] \] .............................................................. (2)

- For urban motorways:

\[ Q_i = C_o \times (Q/C_o)_i \times f_1 \times \ldots \times f_n \] ......................................................... (3)

where:

- \( C \) = Capacity (pcu/h).
- \( C_o \) = Base capacity (pcu/h).
- \( f_1 \ldots f_n \) = Adjustment factors.
- \( V \) = Speed (km/h) at flow \( Q \).
- \( V_o \) = Free-flow speed (km/h).
- \( Q \) = Actual flow (pcu/h).
- \( Q/C \) = Degree of saturation (DS) or flow/capacity ratio.
- \( Q_i \) = Max. flow which can be sustained while remaining in a particular speed \( i \) (pcu/h).
- \( (Q/C_o)_i \) = Degree of saturation corresponding to the speed \( i \), for the standard case.
2.2.2. Capacity

Referring to Equation (1), (2) and (3), when the road is operating at capacity, \( Q/C = 1.00 \) by definition. If the actual conditions are the same as the standard case, then all the adjustment factors \( f_1 \ldots f_n \) become 1.0 and the capacity becomes equal to the standard capacity, \( C_0 \). But if any characteristics of the road are non-standard, then one or more of the factors \( f_1 \ldots f_n \) become \( \neq 1.0 \) and the resulting "capacity" will be either lower than \( C_0 \) if the product of all the factors < 1.0 (sub-standard road) or higher than \( C_0 \) if the product of all the factors > 1.0 (over-standard road).

2.2.3. Degree of saturation and speed

The degree of saturation (flow/capacity) is used in the manual in two different ways for two different purposes:

1. Speeds are related to flow/capacity ratios.
2. Flow/capacity ratios can be calculated to indicate quickly segments which have capacity problems. The effects of different ways of solving capacity problems can also be estimated. Suppose, for example, a road had a forecast flow of 2600 pcu/h and a calculated capacity of 2900 pcu/h, giving an unacceptably high degree of saturation of 0.9. Alternative solutions could be explored through Equation (1) to (3), for example reducing friction or widening the road, by selecting adjustment factors for desired friction or desired width.

2.3 GEOMETRIC CHARACTERISTICS

2.3.1. Two-lane two-way roads

This road type encompasses all two-way roads with a carriageway width of up to and including 10.5 metres. For wider two-way roads the procedures in Section 2.3.2 (four-lane two-way roads) should be followed. (Note: for roads of 9.5 m to 11.5 m in width, the procedures in this Section and those in Section 2.3.2 should give approximately the same results).

The standard road of this type is defined as follows:

- Seven metre carriageway width
- Shoulders of effective width of at least 2 m on each side
- No median
- Directional traffic split of 50 - 50
- Low side friction
- City size 1.0 - 3.0 M
- Essentially level terrain
- Essentially straight alignment
2.3.2. Four-lane two-way roads

This road type encompasses all two-way roads with a carriageway width greater than 10.5 metres and up to 16.0 metres.

The standard road of this type is defined as follows:

- Fourteen metre carriageway width
- Kerbed: with at least 2 m clearance to roadside obstructions
- No median
- Directional traffic split of 50 - 50
- Low side friction
- City size 1.0 - 3.0 M
- Essentially level terrain
- Essentially straight alignment

2.3.3. One-way roads

This road type encompasses all one-way roads with a carriageway width from 5.0 m up to and including 10.5 metres.

The standard road of this type is defined as follows:

- Seven metre carriageway width
- Kerbed: with at least 2 m clearance to roadside obstructions
- No median
- Low side friction
- City size 1.0 - 3.0 M
- Essentially level terrain
- Essentially straight alignment

2.3.4. Urban motorways

This road type encompasses all urban 4-lane (2 carriageways, each of two lanes) fully grade-separated roads. The standard road of this type is:

- Four lanes, each of 3.6 m width (two 7.2 metre carriageways).
- Effective left shoulder width of 2.0 m.
- City size > 3.0 M.
- Zero side friction (completely restricted access).
- Complete grade separation.
- No motorcycles or unmotorised vehicles in the traffic.
- Essentially level terrain.
- Essentially straight alignment.

To date, all roads in Indonesia of this type are operated as toll roads.
2.4 OVERVIEW OF THE CALCULATION PROCEDURE

A flow chart of the calculation procedure is illustrated in Figure 2.4:1 for urban roads and Figure 2.4:2 for urban motorways. The different steps are described in detail in Section 3 and 4.

Figure 2.4:1 Flow chart for analysis of urban roads
Figure 2.4:2 Flow chart for analysis of urban motorways

The following forms are used for the calculations:

a) **Urban Roads**

ROAD-1 GENERAL, GEOMETRY  
ROAD-2 TRAFFIC, ENVIRONMENT  
ROAD-3 ANALYSIS, RESULTS, COMMENTS

b) **Urban Motorways**

ROAD-4 GENERAL, GEOMETRY, TRAFFIC  
ROAD-5 ANALYSIS, RESULTS, COMMENTS

The forms are presented in Appendix 5:1.
3. CALCULATION PROCEDURE FOR URBAN ROADS

3.1 OPERATIONAL ANALYSIS AND DESIGN

The objectives of operational analysis for a particularly road segment, under an existing or projected set of geometric, traffic and environmental conditions can be:

- to determine capacity;
- to determine the Q/C ratio associated with a projected traffic flow;
- to determine the speed in which the road will operate.

The main objective of design is to determine the number of standard lanes needed, but can also be to estimate the effect of a change in design, such as whether to construct a shoulder or a kerb. The calculation procedures followed for operational analysis and for design are the same.

The general approach is to compute the capacity and speed on the urban roads. These are calculated by using following equation:

\[
C = C_o \times F_W \times F_{KS} \times F_{SD} \times F_{SF} \times F_{CS}
\]

\[
V = V_0 \times 0.5 \times \left[1 + (1 - Q/C)^{0.5}\right]
\]

where:

- \(C\) = Capacity (pcu / h)
- \(C_o\) = Base capacity (pcu / h)
- \(F_W\) = Carriageway width adjustment factor
- \(F_{KS}\) = Kerb and shoulder adjustment factor
- \(F_{SD}\) = Directional split adjustment factor (\(F_{SP}\) is not valid for one-way roads)
- \(F_{SF}\) = Side friction adjustment factor
- \(F_{CS}\) = City size adjustment factor
- \(V\) = Speed (km/h) at flow Q
- \(V_0\) = Free-flow speed (km/h)
- \(Q\) = Actual flow (pcu/h)
- \(Q/C\) = Degree of saturation (DS)

The following steps carried out in operational analysis or design, using the Forms ROAD-1, ROAD-2 and ROAD-3, are given in Appendix 5:1.
STEP A : GENERAL DATA

STEP A-1 : ROAD SEGMENTS

- Divide the road into segments. A road segment is defined as a length of road:
  - between and unaffected by signalised or major unsignalised intersections, and
  - having similar characteristics along its length.

Points where road characteristic change significantly automatically become the boundary of a segment even if there is no nearby intersection. If several geometric alternatives are being explored, each may be entered into a separate form and be identified by case number.

- Fill in road segment identification (site name/section/city) and segment length (L) in separate forms for each segment, in Section GENERAL (Form ROAD-1). Follow the remaining steps for each segment and case.

STEP A-2 : GENERAL INPUT DATA

Fill in date and personnel in Section GENERAL (Form ROAD-1)
STEP B : GEOMETRIC CONDITIONS

Insert the geometric data in the spaces provided in Section GEOMETRY (Form ROAD-1). The geometric terms used are shown in Figure B:1 below.

**Figure B:1 Illustration of the geometric terms used.**

STEP B-1 : INPUT DATA

Enter the following input data in Section GEOMETRY (Form ROAD-1):

- Whether the segment has a shoulder or a kerb, or both.
- Shoulder level: difference between levels of shoulder and carriageway.
- Whether the segment has a median or not for four-lane two-way roads (4/2)
- Effective carriageway width (m) (total both carriageways, even if divided by a median for four-lane two-way roads).
- Effective shoulder width or distance from kerb to obstruction on both sides.
- If the road has a median, determine median width (m) and median continuity (no gaps/few gaps/frequent gaps)
- Few gaps: gap exists, but fewer than an average of one per 500 m Frequent gaps: an average of one or more gaps per 500 m
- If the road has only shoulders on both sides, calculate average effective shoulder width (m).
- If the road has only kerbs on both sides, calculate average distance to roadside obstructions (m).

- Source of geometric data.
STEP C : TRAFFIC CONDITIONS

Insert the traffic data in the boxes provided in Section TRAFFIC (Form ROAD-2) and determine traffic composition, pcu-factor and actual flow in pcu/h.

STEP C-1 : INPUT DATA

Enter the following input data in Section TRAFFIC (Form ROAD-2):

- pcu values
  For simplicity, constant pcu values are used as follow:
  
  Light vehicle (LV) 1.00
  Heavy vehicle (HV) 1.20
  Motorcycle (MC) 0.25
  Unmotorised vehicle (UM) 0.80

- Period (Column 1)

- Total peak hour flow in both directions (existing or forecast) by vehicle type (Column 2 to 5)

- Year of traffic data

- Source of traffic data

STEP C-2: TRAFFIC COMPOSITION, PCU-FACTOR AND ACTUAL FLOW

- Calculate the actual flow (veh/h) and enter the results into Column 6 (Form ROAD2), using following equation:
  \[ Q_V = Q_{LV} + Q_{HV} + Q_{MC} + Q_{UM} \]

- Calculate traffic composition for each vehicle type and enter the results into Column 7 to 10 (Form ROAD-2).

- Calculate pcu-factor and enter the results into Column 11 (Form ROAD-2), using following equation:
  \[ P = \frac{(LV\% \times pcu_{LV} + HV\% \times pcu_{HV} + MC\% \times pcu_{MC} + UM\% \times pcu_{UM})}{100} \]

- Determine the actual flow (pcu/h) and enter the results into Column 12 (Form ROAD-2), using following equation:
  \[ Q_p = Q_V \times P \]
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STEP C-3 : DIRECTIONAL SPLIT CLASS

- Enter directional split class into Column 13 (Form ROAD-2).

Other traffic information (eg. AADT) are used for planning purposes and need not be filled in for operational analysis or design. If necessary, convert classified flow into pcu.
STEP D : ENVIRONMENTAL CONDITIONS

Enter the appropriate environmental data in Section ENVIRONMENT (Form ROAD-2), by deleting inappropriate values.

STEP D-1 : SIDE FRICTION CLASS

Side friction class is determined by classifying each of the 3 components listed below into one of the 5 classes as shown in Table D-1:1. This can be done by an engineer with a knowledge of the road or of the area.

<table>
<thead>
<tr>
<th>Side friction item</th>
<th>Very low (few)</th>
<th>Low (some)</th>
<th>Medium (many)</th>
<th>High (many)</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian movements</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Angkutan kota stopping on the roadway</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Vehicles turning into or out of the segment</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>

Notes:  
- Pedestrian movements including pedestrian walking and pedestrian crossing  
- Very low: especially if frontage road exists (restricted access)  
- Very high: especially if there are many exit/entry of short-term parked vehicles

Table D-1:1 Side friction code

The numbers are then added to get a total score and the side friction class is determined as indicated in Table D-1:2

<table>
<thead>
<tr>
<th>Total score</th>
<th>Side friction class</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1</td>
<td>Very low</td>
</tr>
<tr>
<td>2 - 5</td>
<td>Low</td>
</tr>
<tr>
<td>6 - 11</td>
<td>Medium</td>
</tr>
<tr>
<td>12 - 18</td>
<td>High</td>
</tr>
<tr>
<td>19 - 24</td>
<td>Very high</td>
</tr>
</tbody>
</table>

Table D-1:2 Side friction class based on total score

If there is insufficient information or if looking a long period ahead, medium friction should be assumed.
The actual values for each component of friction, corresponding to the very low, low, medium, high and very high categories, are shown in Table D-1:3:

<table>
<thead>
<tr>
<th>No</th>
<th>Friction item</th>
<th>Side friction quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Very low</td>
</tr>
<tr>
<td>1.</td>
<td>Pedestrian walking (ped/h)</td>
<td>0</td>
</tr>
<tr>
<td>2.</td>
<td>Pedestrian crossing (ped/h/km)</td>
<td>0</td>
</tr>
<tr>
<td>3.</td>
<td>Stopping angkot on the roadway (veh/h/km)</td>
<td>0</td>
</tr>
<tr>
<td>4.</td>
<td>Exit/entry vehicles (veh/h/km)</td>
<td>0</td>
</tr>
</tbody>
</table>

Table D-1:3 Side friction quantity

The values shown in this table could be used as a basis for determination of side friction level as indicated in Table D-1:1.

STEP D-2: CITY SIZE

Enter city size (M inh) at the bottom in Form ROAD-2.
STEP E : ANALYSIS

Select values of each of the factors from the tables indicated in Section ANALYSIS (Form ROAD-3). The values should be appropriate to the geometric, traffic and environmental conditions described in Form ROAD-1 and ROAD-2.

STEP E-1 : BASE CAPACITY

Determine the base capacity ($C_0$) from Table E-1:1 and enter the value into Column 2 (Form ROAD-3).

<table>
<thead>
<tr>
<th>Type of urban roads</th>
<th>2/2</th>
<th>4/2</th>
<th>1-3/1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_0$ (pcu/h)</td>
<td>2900</td>
<td>5700</td>
<td>3200</td>
</tr>
</tbody>
</table>

Table E.1:1 Base capacity ($C_0$) for urban roads.

STEP E-2 : CARRIAGEWAY WIDTH ADJUSTMENT FACTOR

Determine the carriageway width factor ($F_W$) from Table E-2:1 and enter the value into Column 3 (Form ROAD-3).

<table>
<thead>
<tr>
<th>Effective carriageway width $W_{Ce}$ (m)</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_W$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/2</td>
<td>0.66</td>
<td>0.83</td>
<td>1.00</td>
<td>1.07</td>
<td>1.14</td>
<td>1.21</td>
<td>1.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4/2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.58</td>
<td>0.68</td>
<td>0.79</td>
<td>0.90</td>
<td>1.00</td>
</tr>
<tr>
<td>1-3/1</td>
<td>0.66</td>
<td>0.83</td>
<td>1.00</td>
<td>1.05</td>
<td>1.10</td>
<td>1.15</td>
<td>1.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes : Use linear interpolation for intermediate values. Effective carriageway width is the width available for traffic movement. On-street parking for example, reduces effective width 3.0 m.

Table E-2:1 Carriageway width adjustment factors ($F_W$)
STEP E-3 : KERB AND SHOULDER ADJUSTMENT FACTOR

a) **Roads with shoulders**

Determine the shoulder factor from Table E-3:1 which assumes shoulders are level with the carriageway and of firm material, and enter the value into Column 4 (Form ROAD-3). If shoulder level is 10 cm or more different from that of the carriageway it is suggested that the $F_{KS}$ for zero effective width shoulder should be used.

<table>
<thead>
<tr>
<th>Effective shoulder width $W_{Se}$ (m)</th>
<th>0</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>≥2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2/2</td>
<td>0.85</td>
<td>0.89</td>
<td>0.93</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>4/2</td>
<td>0.96</td>
<td>0.99</td>
<td>0.01</td>
<td>1.04</td>
</tr>
<tr>
<td></td>
<td>1-3/1</td>
<td>0.94</td>
<td>0.98</td>
<td>1.02</td>
<td>1.06</td>
</tr>
</tbody>
</table>

Notes:  
1. The table assumes two shoulders of equal effective width; if shoulders on each side have different effective widths, take the average effective width.  
2. Effective width is the width of the available shoulder. For example, a line of trees down the middle of the shoulder would halve the effective width.

Table E-3:1  Effective shoulder width adjustment ($F_{KS}$) factors

b) **Roads with kerbs**

Determine the kerb factor from Table E-3:2 and enter the value into Column 4 (Form ROAD-3). The adjustment factor varies according to the distance of obstructions (solid objects) from the line of the kerb (edge of the carriageway).

<table>
<thead>
<tr>
<th>Distance from kerb to obstruction $W_{Ke}$ (m)</th>
<th>0</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>≥2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2/2</td>
<td>0.85</td>
<td>0.86</td>
<td>0.88</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>4/2</td>
<td>0.96</td>
<td>0.97</td>
<td>0.98</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>1-3/1</td>
<td>0.94</td>
<td>0.96</td>
<td>0.97</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Table E-3:2  Kerb distance to obstruction adjustment ($F_{KS}$) factors

Kerbs have two effects:
- They reduce speed and capacity, even when there is no friction;
- When there is friction, the kerb tends to confine some of it to the carriageway which could otherwise take place on the shoulder.

The kerb adjustment factors in Table E-3:2 include only the former effect. The latter is included in the side friction adjustment factor.
c) **Roads with shoulder and kerb**

If the road has a shoulder on one side and a kerb on the other, take the appropriate shoulder factor from Table E-3:1 and the appropriate kerb factor from Table E-3:2, and make the factor \( F_{KS} \) equal to the average of these two values. The value is then entered into Column 4 (Form ROAD-3).
STEP E-4 : DIRECTIONAL SPLIT OR MEDIAN ADJUSTMENT FACTOR

Determine the directional split or median factor (F_{SP}) from Table E-4:1 or E-4:2 below and enter the value into Column 5 (Form ROAD-3).

Table E-4:1 gives the directional split adjustment factors for two-lane two-way (2/2) and four-lane two-way (4/2) undivided roads.

<table>
<thead>
<tr>
<th>Directional split SP</th>
<th>50-50</th>
<th>60-40</th>
<th>70-30</th>
<th>80-20</th>
<th>90-10</th>
<th>100-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/2</td>
<td>1.00</td>
<td>0.94</td>
<td>0.88</td>
<td>0.82</td>
<td>0.76</td>
<td>0.70</td>
</tr>
<tr>
<td>4/2 undivided</td>
<td>1.00</td>
<td>0.97</td>
<td>0.94</td>
<td>0.91</td>
<td>0.89</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Table E-4:1 Directional split adjustment factors (F_{SP})

For four-lane two-way roads (4/2) with medians (divided), the presence of a median renders the directional split factor inapplicable. A median also removes the possibility of interaction between opposing streams and so increases capacity and performance. Table E-4:2 gives the median adjustment factors (F_{SP}):

<table>
<thead>
<tr>
<th>Median continuity</th>
<th>F_{SP}</th>
</tr>
</thead>
<tbody>
<tr>
<td>No gaps</td>
<td>1.12</td>
</tr>
<tr>
<td>Few gaps (1)</td>
<td>1.05</td>
</tr>
<tr>
<td>Frequent gaps (1)</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Table E-4:2 Median adjustment factors (F_{SP}):

Notes :  
(1) Gaps exist, but fewer than an average of one per 500 m  
(2) An average of one or more gaps per 500 m

The greatest benefits to capacity occur if the median is continuous. (This does not necessarily mean that a continuous median is always preferable to a broken one). A 'gap' is defined as a break big enough for a four-wheeled vehicle and where turning movements or U-turns are permitted. In Indonesia, narrow medians are the norm on non-grade-separated facilities. Consequently, turns and U-turns through gaps in the median disrupt traffic flow and partly negate the beneficial capacity effects of a median. Where gaps are frequent and the median narrow, capacities may be similar to or even below, an otherwise similar undivided road. Medians which are wide enough to contain turning pockets are rare in Indonesia.
STEP E-5 : SIDE FRICTION ADJUSTMENT FACTOR

Determine the side friction factor ($F_{SF}$) Table E-5:1 below and enter the value into Column 6 (Form ROAD-3).

<table>
<thead>
<tr>
<th>Side friction class</th>
<th>Very low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{SF}$</td>
<td>1.00</td>
<td>1.00</td>
<td>0.97</td>
<td>0.90</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Table E-5:1 Side friction adjustment factors ($F_{SF}$)

STEP E-6 : CITY SIZE ADJUSTMENT FACTOR

Determine the city factor ($F_{CS}$) from Table E-6:1 below and enter the value into Column 7 (Form ROAD-3)

<table>
<thead>
<tr>
<th>City size (M inh)</th>
<th>&lt;0.5</th>
<th>0.5-1.0</th>
<th>1.0-3.0</th>
<th>&gt;3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{CS}$</td>
<td>0.80</td>
<td>0.86</td>
<td>1.00</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Table E-6:1 City size adjustment factor ($F_{CS}$)

STEP E-7 : CAPACITY

Calculate capacity $C$ (pcu/h) and enter the results into Column 8 (Form ROAD-3), using following equation:

$$C = C_0 \times F_W \times F_{KS} \times F_{SF} \times F_{CS}$$

STEP E-8 : DEGREE OF SATURATION

Calculate the ratio of existing or forecast volume ($Q_p$ or $Q_d$) with capacity ($C$) to determine the degree of saturation ($DS$) (Column 10) within which the road will operate under the given conditions.

STEP E-9 : TRAVEL SPEED

- Determine the free-flow speed $V_0$ (Column 11) from Figure E-9:1 to E-9:12
- Determine the travel speed of the road (Column 12) by relating free-flow speed $V_0$ (Column 11) and DS (Column 10), using following equation:

$$V = V_0 \times 0.5 \times \left[1 + (1 - DS)^{0.5}\right]$$
STEP E-10 : JOURNEY TIME

- Calculate the average journey time (Column 13) in sec/km if a network analysis is being undertaken, or if the results of several segments of road are to be combined, using following equation:

  \[ \text{Average journey time} = \frac{3600}{V} \]

- Calculate the section journey time TT (Column 14) in sec, using following equation:

  \[ \text{TT} = L \times \text{Average journey time} \]

STEP E-11 : RESULTS

Enter the results from the previous step into Section RESULTS of the worksheet (Form ROAD-3).

STEP E-12 : COMMENTS

Enter any comments into Section COMMENTS of the worksheet (Form ROAD-3).
Figure E-9:1  Free-flow speed ($V_o$) - effective carriageway width ($W_{ce}$) model for different friction level (SF) and city size (CS) > 3.0 M on 2-lane 2-way roads (2/2)

Figure E-9:2  Free-flow speed ($V_o$) - effective carriageway width ($W_{ce}$) model for different friction level (SF) and city size (CS) 1.0 - 3.0 M on 2-lane 2-way roads (2/2)
Figure E-9:3 Free-flow speed \( (V_o) \) - effective carriageway width \( (W_{Ce}) \) model for different friction level (SF) and city size (CS) 0.5 - 1.0 M on 2-lane 2-way roads (2/2).

Figure E-9:4 Free-flow speed \( (V_o) \) - effective carriageway width \( (W_{Ce}) \) model for different friction level (SF) and city size (CS) < 0.5 M on 2-lane 2-way roads (2/2).
Figure E-9:5  Free-flow speed ($V_o$) - effective carriageway width ($W_{Ce}$) model for different friction level (SF) and city size (CS) $> 3.0$ M bn 4-lane 2-way roads (4/2).

Figure E-9:6  Free-flow speed ($V_o$) - effective carriageway width ($W_{Ce}$) model for different friction level (SF) and city size (CS) $1.0 - 3.0$ M on 4-lane 2-way roads (4/2).
Figure E-9:7  Free-flow speed ($V_0$) - effective carriageway width ($W_{ce}$) model for different friction level (SF) and city size (CS) 0.5 - 1.0 M on 4-lane 2-way roads (4/2)

Figure E-9:8  Free-flow speed ($V_0$) - effective carriageway width ($W_{ce}$) model for different friction level (SF) and city size (CS) < 0.5 M on 4-lane 2-way roads (4/2)
Figure E-9:9  Free-flow speed ($V_o$) - effective carriageway width ($W_{Ce}$) model for different friction level (SF) and city size (CS) $> 3.0$ M on 1-way roads (1-3/1)

Figure E-9:10  Free-flow speed ($V_o$) - effective carriageway width ($W_{Ce}$) model for different friction level (SF) and city size (CS) $1.0 - 3.0$ M on 1-way roads (1-3/1)
Figure E-9:11  Free-flow speed ($V_o$) - effective carriageway width ($W_{Ce}$) model for different friction level (SF) and city size (CS) 0.5 - 1.0 M on 1-way roads (1-3/1)

Figure E-9:12  Free-flow speed ($V_o$) - effective carriageway width ($W_{Ce}$) model for different friction level (SF) and city size (CS) < 0.5 M on 1-way roads (1-3/1)
STEP F : RE-ANALYSIS

If the performance of the road segment is found to be inadequate, in terms of expected speed or expected Q/C ratio, then improvements to the road geometry, or measures to reduce friction, should be considered. The effects of these changes may be assessed by repeating the analysis, using the new values of geometry, etc, on a fresh worksheet. This would be given a new case number.
3.2 PLANNING

For planning, the design of the road and the traffic and environmental data would be known in general, but not in detail, and forecast traffic flow would be given in AADT, rather than as peak hour flow. Consequently, certain assumptions about geometric design, traffic and environment have to be made. The relationship between the flow in the peak hour or design flow ($Q_d$) and AADT must also be assumed. This relationship is normally expressed as 'AADT-factor', as follows: $Q = AADT \times K$

3.2.1 Two-lane two-way roads

The assumptions used for planning two-lane two-way roads are as follows:

- **Geometry:** 7 m carriageway, 2 m effective shoulder width
- **Traffic:** 60-40 directional split
- **Environment:** Medium friction
- **City size:** 1.0 - 3.0 M
- **AADT-factor ($K$):** 0.095

On the basis of these assumptions, the procedures used in operation and design have been applied to produce Table 3.2.1:1 which relates AADT to road performance as measured by peak hour speeds and Q/C ratios.

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>39</th>
<th>35</th>
<th>31</th>
<th>27</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q/C</td>
<td>0.24</td>
<td>0.54</td>
<td>0.76</td>
<td>0.91</td>
<td>1.00</td>
</tr>
<tr>
<td>AADT (pcu)</td>
<td>6,800</td>
<td>15,000</td>
<td>21,200</td>
<td>25,400</td>
<td>27,800</td>
</tr>
</tbody>
</table>

Table 3.2.1:1 Maximum AADT vs speed and Q/C ratio for planning two-lane two-way roads (2/2)

3.2.2 Four-lane two-way roads

The assumptions used for planning four-lane two-way roads are as follows:

- **Geometry:** Kerbed 14 m carriageway, no median, at least 2 m from kerb to roadside obstructions.
- **Traffic:** 60-40 directional split
- **Environment:** Medium friction
- **City size:** 1.0 - 3.0 M
- **AADT-factor ($K$):** 0.095
On the basis of these assumptions, the procedures used in operation and design have been applied to produce Table 3.2.2:1 which relates AADT to road performance as measured by peak hour speeds and Q/C ratios.

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>53</th>
<th>48</th>
<th>42</th>
<th>37</th>
<th>28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q/C</td>
<td>0.26</td>
<td>0.53</td>
<td>0.77</td>
<td>0.91</td>
<td>1.00</td>
</tr>
<tr>
<td>AADT (pcu)</td>
<td>14,500</td>
<td>29,800</td>
<td>43,700</td>
<td>51,400</td>
<td>56,500</td>
</tr>
</tbody>
</table>

Table 3.2.2:1 Maximum AADT vs speed and Q/C ratio for planning four-lane two-way roads (4/2)

### 3.2.3 One-way roads

The assumptions used for planning one-way roads are as follows:

**Geometry:** Kerbed 7 m carriageway, at least 2 m from kerb to roadside obstructions.

**Environment:** Medium friction

**AADT-factor(K):** 0.095

On the basis of these assumptions, the procedures used in operation and design have been applied to produce Table 3.2.3:1 which relates AADT to road performance as measured by peak hour speeds and Q/C ratios.

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>53</th>
<th>48</th>
<th>42</th>
<th>37</th>
<th>28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q/C</td>
<td>0.26</td>
<td>0.53</td>
<td>0.77</td>
<td>0.91</td>
<td>1.00</td>
</tr>
<tr>
<td>AADT (pcu)</td>
<td>8,400</td>
<td>17,300</td>
<td>25,300</td>
<td>29,700</td>
<td>32,700</td>
</tr>
</tbody>
</table>

Table 3.2.3:1 Maximum AADT vs speed and Q/C ratio for planning one-way roads (1-3/1)

Thus, estimates of AADT may be made directly from a selected speed or Q/C ratio using Table 3.2.1:1, 3.2.2:1 or 3.2.3:1. Alternatively, with a given AADT, the speed and Q/C ratio at which the planned road will operate, can immediately be estimated.

The performance of a planned road, in terms of speed or Q/C ratio, resulting from a given AADT may be obtained directly from Table 3.2.1:1, 3.2.2:1 or 3.2.3:1. This table can also be used to estimate the AADT which could be carried while maintaining speed or Q/C ratio within given limits. No worksheet is needed. However, if conditions are known to be very different from the assumed conditions given in Section 3.2.1, 3.2.2 or 3.2.3 then appropriate value(s) should be used and an operational/design analysis performed instead. This would first require conversion of AADT to peak hour, using AADT-factor (default: K = 0.095). Examples of cases where an operational analysis would be needed are:

- if the K is expected to be quite different from 0.095; put the new K value into Section TRAFFIC of the worksheet (Form ROAD-2)
- if it is known that the facility will have a kerb rather than a shoulder.
4. CALCULATION PROCEDURE FOR URBAN MOTORWAYS

The Indonesian empirical data used in this Section are based on one urban freeway, so the adjustment factors are based on those in the US HCM (TRB, 1985). The small amount of data on which this Section is based means that less confidence can be placed on results of calculations for this type of road than for those in Section 3.

For urban motorways, all operational and design analysis is done separately by direction. For planning, both directions are combined. As in Sections 3, analysis is by total carriageway width and not by the number of lanes. This is because, in Indonesia, as capacity is approached the two-lane carriageway begins to operate as a three-lane carriageway, with moving traffic utilizing the shoulder. This behavioural characteristic also makes it difficult to extrapolate from the dual-two lane to the dual-three lane case.

4.1 OPERATIONAL ANALYSIS AND DESIGN

The objectives of operational analysis for a particularly road segment, under an existing or projected set of geometric, traffic and environmental conditions can be:

- to determine capacity
- to determine the Q/C ratio associated with a projected traffic flow
- to determine the speed in which the motorway will operate

The main objective of design is to determine the number of standard lanes needed, but can also be to estimate the effect of a change in design. The calculation procedures followed for operational analysis and for design are the same.

The general approach is to compute the flow rates, by direction, for each speed and compare these with the existing or projected flow rate for each direction on the motorway. The flow rates in one direction for each speed values are calculated using following equation:

\[ Q_i = 4600 \times \left( \frac{Q}{C_0} \right)_i \times F_W \]

where:
- \( Q_i \) = Maximum one-way flow that can be sustained while speeds remain in speed \( i \) (pcu/h)
- \( \left( \frac{Q}{C_0} \right)_i \) = Ratio of flow to ideal capacity for speed \( i \) (\( C_0 = 4600 \) pcu/h)
- \( F_W \) = Factor for narrow lanes and effective shoulder width
The Q / C₀ equivalent to the various speed values are shown in Table 4.1:1

<table>
<thead>
<tr>
<th>Speed Vᵢ (km/h)</th>
<th>(Q / C₀)ᵢ</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>0.40</td>
</tr>
<tr>
<td>70</td>
<td>0.61</td>
</tr>
<tr>
<td>65</td>
<td>0.75</td>
</tr>
<tr>
<td>58</td>
<td>0.89</td>
</tr>
<tr>
<td>45</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 4.1:1 Speed and (Q / C₀) equivalencies

The following steps are followed in operational analysis or design, using the Form ROAD-4 and ROAD-5.
STEP A : GENERAL DATA

STEP A-1 : ROAD SEGMENTS

- Divide the road into segments. A road segment is defined as a length of road:
  - between and unaffected by signalised or major unsignalised intersections, and
  - having similar characteristics along its length.

Points where road characteristics change significantly automatically become the boundary of a segment even if there is no nearby intersection. If several geometric alternatives are being explored, each may be entered into a separate form and be identified by case number.

In segmenting an urban motorway, ramps and weaving areas must be separated from road segments. The procedures given in this Section relate to road segments but not to weaving areas and ramps. As ramp areas may be the critical areas for capacity, separate ramp or weaving analysis may be needed, especially in operational analysis of the road. In this case, it is recommended that the procedures for freeway, ramps and weaving Sections contained in the 1985 US HCM are used.

- Fill in road segment identification (site name/section/city) and segment length (L) in separate forms for each segment, in Section GENERAL (Form ROAD-4). Follow the remaining steps for each segment and case.

STEP A-2 : GENERAL INPUT DATA

Fill in date personnel in section GENERAL (Form ROAD-4)
STEP B : GEOMETRIC CONDITIONS

Insert the geometric data in the spaces provided in Section GEOMETRY (Form ROAD-4).

STEP B-1 : INPUT DATA

Enter the following input data in Section GEOMETRY (Form ROAD-4):

- Effective carriageway width (m) of both carriageways
- Effective shoulder width (m) of both left shoulders
- Median width (m)
- Source of geometric data
STEP C : TRAFFIC CONDITIONS

Insert the traffic data in the boxes provided in Section TRAFFIC (Form ROAD-4) and determine traffic composition, pcu-factor and actual flow in pcu/h.

STEP C-1 : INPUT DATA

Enter the following input data in Section TRAFFIC (Form ROAD-4):

- pcu values
  
  For simplicity, constant pcu values are used as follow:
  
  Light vehicle (LV) 1.00
  Heavy vehicle (HV) 1.20

- Period (Column 2)

- Total peak hour flow, separately by direction, (existing or forecast) by vehicle type (Column 3 and 4).

- Year of traffic data

- Source of traffic data

STEP C-2: TRAFFIC COMPOSITION, PCU-FACTOR AND ACTUAL FLOW

- Calculate the actual flow (veh/h) and enter the results into Column 5 (Form ROAD-4), using following equation:

  \[ Q_V = Q_{LV} + Q_{HV} \]

- Calculate traffic composition for each vehicle type, and enter the results into Column 6 and 7 (Form ROAD-4).

- Calculate pcu-factor and enter results into Column 8 (Form ROAD-4), using following equation:

  \[ P = \frac{(LV\% \times pcu_{LV} + HV\% \times pcu_{HV})}{100} \]

- Determine the actual flow (pcu/h) and enter the results into Column 9 (Form ROAD-4), using following equation:

  \[ Q_p = Q_V \times P \]

- Other traffic information (eg. AADT) are used for planning purposes and need not be filled in for operational analysis or design. If necessary, convert classified flow into pcu.
STEP D : ANALYSIS

Select values of each of the following factors for each speed values from the tables indicated in Section ANALYSIS (Form ROAD-5). The values should be appropriate to the geometric and environmental data described in Form ROAD-4.

STEP D-1: CARRIAGEWAY WIDTH AND EFFECTIVE LEFT SHOULDER WIDTH ADJUSTMENT FACTOR

Determine the carriageway width and effective left shoulder width factor ($F_W$) from Table D1:1 and enter the value into Column 5 (Form ROAD-5).

<table>
<thead>
<tr>
<th>Effective left shoulder width (m)</th>
<th>Obstructions on one side of carriageway</th>
<th>Obstructions on both sides of carriageway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Carriageway width $W_C$ (m)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>7.2</td>
</tr>
<tr>
<td>&gt; 2.0</td>
<td>0.99</td>
<td>1.00</td>
</tr>
<tr>
<td>1.5</td>
<td>0.98</td>
<td>0.99</td>
</tr>
<tr>
<td>1.0</td>
<td>0.97</td>
<td>0.98</td>
</tr>
<tr>
<td>0.5</td>
<td>0.94</td>
<td>0.95</td>
</tr>
<tr>
<td>0</td>
<td>0.89</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Note: These values are based directly on the US HCM (TRB, 1985)

Table D-1:1 Carriageway width and effective left shoulder width adjustment factor ($F_W$)

STEP D-2 : CAPACITY

- Calculate $Q$ (Column 2) for each speed values, separately for each direction, using following equation:

$$Q_i = 4600 \times \left(\frac{Q}{C_0}\right) \times F_W$$

- The capacity ($C$) of each carriageway is the value of $Q$ (Column 3) corresponding a $Q/C_0$ ratio (Column 4) of 1.0.
STEP D-3 : DEGREE OF SATURATION

Calculate the ratio of existing or forecast volume (Qp or Qd) with capacity (C) to determine the degree of saturation (DS) within which the road will operate under the given conditions.

STEP D-4 : TRAVEL SPEED

Determine the travel speed by comparing the existing or forecast volume with the various calculated values of Q (Column 2), separately for each direction.

STEP D-5 : JOURNEY TIME

- Calculate the average journey time in sec/km if a network analysis is being undertaken, or if the results of several segments of road are to be combined, separately for each direction, using following equation:

  \[
  \text{Average journey time} = \frac{3600}{V}
  \]

- Calculate the section journey time (TT) in sec, separately for each direction, using following equation:

  \[
  TT = L \times \text{Average journey time}
  \]

STEP D-6 : RESULTS

Enter the results from the previous step into Section RESULTS of the worksheet (Form ROAD-5), separately for each direction.

STEP D-7 : COMMENTS

Enter any comments into Section COMMENTS of the worksheet (Form ROAD-5).
STEP E: RE-ANALYSIS

If the performance of the road segment is found to be inadequate, in terms of expected speed or expected Q/C ratio, then improvements to the road geometry should be considered. The effects of these changes may be assessed by repeating the analysis, using the new values of geometry, on a fresh worksheet. This would be given a new case number.
4.2 PLANNING

For planning, the design of the road and the traffic and environmental data would be known in general; but not in detail, and forecast traffic flow would be given in AADT, rather than as peak hour flow. Consequently, certain assumptions about geometric design and environment have to be made. The relationship between the flow in the peak hour or design flow \(Q_d\) and AADT must also be assumed. This relationship is normally expressed as AADT-factor, \(Q_d = AADT \times K\).

The assumptions used for planning urban motorways are as follows:

**Geometry:**
- 2 x 7.2 m carriageways, 2.0 m left effective shoulder width.

**Environment:**
- City size > 3.0 M

**AADT-factor (K):** 0.095

On the basis of these assumptions, the procedures used in operation and design have been applied to produce Table 4.2:1 which relates AADT to road performance as measured by peak hour speeds and Q/C ratios.

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>75</th>
<th>70</th>
<th>65</th>
<th>58</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q/C ratio</td>
<td>0.40</td>
<td>0.61</td>
<td>0.75</td>
<td>0.89</td>
<td>1.00</td>
</tr>
<tr>
<td>AADT (pcu)</td>
<td>37,600</td>
<td>57,300</td>
<td>70,450</td>
<td>83,600</td>
<td>93,900</td>
</tr>
</tbody>
</table>

Note: In order to construct Table 4.2:1 a peak hour directional split is needed. This was assumed to be 60 - 40.

Table 4.2:1 Two-directional AADT vs speed and Q/C ratio

Thus, estimates of AADT can be made directly from a selected speed or Q/C ratio, or vice versa. The performance of a planned road, in terms of speed or Q/C ratio, resulting from a given total two-directional AADT may be obtained directly from Table 4.2:1. This table can also be used to estimate the AADT which could be carried while maintaining speed or Q/C ratio within given limits. No worksheet is needed. However, if conditions are known to be very different from the assumed conditions given in Section 4.2 or if the AADT-factor (K) is expected to be very different from the default value of 0.095 (which was used to compile Table 4.2:1), then appropriate value(s) should be used and an operational/design analysis performed instead.

Though urban motorways have medians, a directional distribution has to be assumed to construct Table 4.2:1. If the expected that the directional distribution is significantly different from the assumed 60 - 40, then an operational /design analysis should be carried out instead.
5. WORKED EXAMPLES

5.1 EXAMPLE 1: OPERATIONAL ANALYSIS OF A TWO-LANE TWO-WAY ROAD

Geometry :

- 6.0 m effective carriageway width
- 1.0 m effective shoulder on both sides (level with road)

Traffic :

Directional split of 70 - 30

Environment :

City size 700,000 inh.
Many angkutan kota
Many pedestrians
Some traffic using roadside accesses.

Questions:

1. What is the capacity (pcu/h) of the segment?

2. What is the maximum flow (pcu/h) of traffic that can be carried at a speed of 30 km/h?

Solution:

See Figure 5.1:1 to 5.1:3.
**URBAN ROADS**
**Form ROAD-1 : GENERAL GEOMETRY**

**GENERAL**(1)

Road segment identification (site name/section/city):

*JL. R1 BETWEEN KM. 3,2 AND KM. 6,1 KOTA K1*

<table>
<thead>
<tr>
<th>Segment length (L)</th>
<th>2.9 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzing engineer</td>
<td>NOVARA</td>
</tr>
<tr>
<td>Date: day</td>
<td>17 month</td>
</tr>
<tr>
<td>Checking engineer</td>
<td>MARLER</td>
</tr>
<tr>
<td>Date: day</td>
<td>20 month</td>
</tr>
<tr>
<td>Case</td>
<td>A</td>
</tr>
</tbody>
</table>

**GEOMETRY**(2)

Shoulder / kerb / shoulder and kerb (**)

Difference between levels of shoulder and carriageway:
- ≤ 10 cm; considered as shoulder
- > 10 cm; considered as shoulder = 0 m

Median / no-median (**): only considered for four-lane two-way roads

**Dimensions:**

<table>
<thead>
<tr>
<th>Side A</th>
<th>Effective shoulder width (Wse)</th>
<th>1.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Or distance from kerb to obstruction (Wke)</td>
<td>- m</td>
</tr>
<tr>
<td></td>
<td>Effective carriageway width (Wce)</td>
<td>6.0 m</td>
</tr>
<tr>
<td>Side B</td>
<td>Effective shoulder width (Wse)</td>
<td>1.0 m</td>
</tr>
<tr>
<td></td>
<td>Or distance from kerb to obstruction (Wke)</td>
<td>- m</td>
</tr>
</tbody>
</table>

If median:
- Median width (Wm) | - m |
- Median continuity: no gaps / few gaps / frequent gaps (**)

If shoulder:
- Average effective shoulder width (Wse) | 1.0 m |

If kerb:
- Average distance from kerb to obstruction (Wke): - m

Source of geometric data:

**EXAMPLE 1**

**Notes and symbols used on this page:**
- * delete as appropriate
- (1) Step A Section 3.1
- (2) Step B Section 3.1
Traffic (3)

\[ p_{cuLV} = \frac{- p_{cuHV}}{p_{cuUM}} = \frac{-}{-} \]

\[ P = \frac{(LV\% \times p_{cuLV} + HV\% \times p_{cuHV} + MC\% \times p_{cuMC} + UM\% \times p_{cuUM})}{100} \]

<table>
<thead>
<tr>
<th>Period</th>
<th>Total peak hour flow of traffic (veh/h)</th>
<th>Traffic composition</th>
<th>pcu factor</th>
<th>Qp (pcu/h)</th>
<th>Directional split class SP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LV (2)</td>
<td>HV (3)</td>
<td>MC (4)</td>
<td>UM (5)</td>
<td>Qp (6)</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

AADT: \( - \) pcu\(^{(4)}\)

AADT-factor (K\(^{(4)}\)): \( - \) Design flow (Q\(_d\)): \( - \) pcu/h\(^{(4)}\)

Year of traffic data: \(1992\)

Source of traffic data:

**EXAMPLE 1**

Environment

Side friction class (SF\(^{(5)}\)): *Very Low / Low / Medium / High / Very High*

City size (M inh\(^{(6)}\)): \(>3.0 \text{ to } 1.0 \text{ to } 0.5 \text{ to } 1.0 \text{ to } <0.5\)

Notes and symbols used on this page:

* delete as appropriate

(3) Step C section 3.1 (4) Section 3.2 (5) Step D-1 Section 3.1 (6) Step D-2 Section 3.1
### Analysis

**C** = \( CO \times FW \times FKS \times FSP \times FSF \times FCS \)

\[ V = V_O \times 0.5 \times [1 + (1 - DS)^{0.5}] \]

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Base capacity ( CO ) (pcu/h)</th>
<th>Carriageway with adjustment factor ( FW )</th>
<th>Kerb and shoulder adjustment factor ( FKS )</th>
<th>Directional split or median adjustment factor ( FSP )</th>
<th>Side friction adjustment factor ( FSF )</th>
<th>City size adjustment factor ( FCS )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2900</td>
<td>0.83</td>
<td>0.93</td>
<td>0.88</td>
<td>0.90</td>
<td>0.86</td>
</tr>
</tbody>
</table>

**Capacity**

\( Q_o = Q_d \) (pcu/h)

<table>
<thead>
<tr>
<th>Capacity ( Q_o ) (pcu/h)</th>
<th>Degree of saturation ( DS )</th>
<th>Free flow speed ( V_o ) (km/h)</th>
<th>Travel speed ( V ) (km/h)</th>
<th>Average journey time ( TT ) (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1525</td>
<td>0.49</td>
<td>35</td>
<td>30</td>
<td>-</td>
</tr>
</tbody>
</table>

### Results

**Actual or design flow** (Qp or Qd) (pcu/h) : 747

Capacity (C) (pcu/h) : 1525

Ratio of flow to capacity (DS) : 0.49

Estimated average speed (km/h) : 30

Estimated average journey time (sec/km) : -

Section journey time (sec) : -

### Comments

Notes and symbols used on this page:

1. Step E Section 3.1
2. Step E-7 Section 3.1
3. Step E-8 Section 3.1
4. Step E-9 Section 3.1
5. Step E-10 Section 3.1
6. Step E-11 Section 3.1
7. Step E-12 Section 3.1
5.2 EXAMPLE 2: OPERATIONAL ANALYSIS OF A TWO-LANE TWO-WAY ROAD

Geometry: 6.0 m effective carriageway width
           1.0 m effective shoulder on both sides (level with road)

Traffic: Directional split of 70 - 30

Environment: City size 700,000 inh.
             Many angkutan kota Many pedestrians
             Some traffic using roadside accesses.

A peak hour volume is predicted of:

<table>
<thead>
<tr>
<th>Q_{LV}</th>
<th>Q_{HV}</th>
<th>Q_{NC}</th>
<th>Q_{UM}</th>
</tr>
</thead>
<tbody>
<tr>
<td>610</td>
<td>80</td>
<td>1200</td>
<td>0</td>
</tr>
</tbody>
</table>

Questions:

1. What peak hour speed will the road operate at?

2. What is the flow/capacity ratio?

Solution:

See Figure 5.2:1 to 5.2:3.
## GENERAL

Road segment identification (site name/section/city):

**JL. R2 BETWEEN KM. 4.1 AND KM. 7.3 KOTA K2**

<table>
<thead>
<tr>
<th>Segment length (L)</th>
<th>3.2 km</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Analyzing engineer</th>
<th>NOVARA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>day 17 month 11 year 1992</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Checking engineer</th>
<th>MARLER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>day 20 month 11 year 1992</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Case</th>
<th>A+B</th>
</tr>
</thead>
</table>

## GEOMETRY

**Shoulder / kerb / shoulder and kerb (⋆)**

Difference between levels of shoulder and carriageway:
- ≤ 10 cm; considered as shoulder
- > 10 cm; considered as shoulder = 0 m

**Median / no-median (⋆):** only considered for four-lane two-way roads

### Dimensions:

<table>
<thead>
<tr>
<th>Side A</th>
<th>Effective shoulder width (W_se)</th>
<th>1.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Or distance from kerb to obstruction (W_ke)</td>
<td>- m</td>
</tr>
<tr>
<td></td>
<td>Effective carriageway width (W_ce)</td>
<td>6.0 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Side B</th>
<th>Effective shoulder width (W_se)</th>
<th>1.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Or distance from kerb to obstruction (W_ke)</td>
<td>- m</td>
</tr>
</tbody>
</table>

**If median:**

<table>
<thead>
<tr>
<th>Median width (W_M)</th>
<th>- m</th>
</tr>
</thead>
</table>

**Median continuity:** no gaps / few gaps / frequent gaps (⋆)

**If shoulder:**

Avarage effective shoulder width (W_se): 1.0 m

**If kerb:**

Avarage distance from kerb to obstruction (W_ke): - m

Source of geometric data:

**EXAMPLE 2**

### Notes and symbols used on this page:

- * delete as appropriate
- (1) Step A Section 3.1
- (2) Step B Section 3.1
TRAFFIC

Traffic values used:

\[
\begin{align*}
\text{pcu}_{LV} &= \frac{1.0}{0.25} \quad \text{pcu}_{HV} = \frac{1.2}{0.8} \\
\text{pcu}_{MC} &= \frac{0.25}{0.8} \\
\text{pcu}_{UM} &= \frac{0.8}{0.8}
\end{align*}
\]

\[
P = \frac{(LV\% \times \text{pcu}_{LV} + HV\% \times \text{pcu}_{HV} + MC\% \times \text{pcu}_{MC} + UM\% \times \text{pcu}_{UM})}{100}
\]

<table>
<thead>
<tr>
<th>Period</th>
<th>Total peak hour flow of traffic (veh/h)</th>
<th>Traffic composition</th>
<th>pcu factor</th>
<th>(Q_p) (pcu/h)</th>
<th>Directional split class SP (13)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LV</td>
<td>HV</td>
<td>MC</td>
<td>UM</td>
<td>Qv</td>
</tr>
<tr>
<td>1</td>
<td>610</td>
<td>80</td>
<td>1200</td>
<td>0</td>
<td>1890</td>
</tr>
</tbody>
</table>

AADT: _____ pcu

AADT-factor (K): _____ Design flow (Q_d): _____ pcu/h

Year of traffic data: 1992

Source of traffic data: EXAMPLE 2

ENVIRONMENT

Side friction class (SF): Very Low / Low / Medium / High / Very High

City size (M inh): >3.0 / 1.0 – 3.0 / 0.5 – 1.0 / <=0.5

Notes and symbols used on this page:

* delete as appropriate

(3) Step C section 3.1 (4) Section 3.2 (5) Step D-1 Section 3.1 (6) Step D-2 Section 3.1
### IHCM: URBAN ROADS

**INDONESIAN HIGHWAY CAPACITY MANUAL**  
Form ROAD-3

- **Analyzing engineer:** NOVARA  
  **Date:** 17 / 11 / 1992
- **Analyzing engineer:** MARLER  
  **Date:** 20 / 11 / 1992
- **Road segment:** JL . R2 (KM. 4.1 – KM. 7.3) KOTA K2

### ANALYSIS
C = CO x FW x FKS x FSP x FSF x FCS

\[ V = V_0 \times 0.5 \left[ 1 + \left( 1 - DS \right)^{0.5} \right] \]

### Table E-1:1
- **Base capacity (CO)** (pcu/h)
- **Carriageway width adjustment factor (FW)**
- **Kerb and shoulder adjustment factor (FKS)**
- **Directional split or median adjustment factor (FSP)**
- **Side friction adjustment factor (FSF)**
- **City size adjustment factor (FCS)**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Base capacity CO (pcu/h)</th>
<th>Carriageway width adjustment factor FW</th>
<th>Kerb and shoulder adjustment factor FKS</th>
<th>Directional split or median adjustment factor FSP</th>
<th>Side friction adjustment factor FSF</th>
<th>City size adjustment factor FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2900</td>
<td>0.83</td>
<td>0.93</td>
<td>0.88</td>
<td>0.90</td>
<td>0.86</td>
</tr>
</tbody>
</table>

### Table E-2:1
- **Actual or design flow Qd (pcu/h)**

<table>
<thead>
<tr>
<th>Capacity C (pcu/h)</th>
<th>Degree of saturation DS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1525</td>
<td>0.66</td>
</tr>
</tbody>
</table>

### Table E-9:1 to E-9:12
- **Free flow speed VO (km/h)**
- **Travel speed V (km/h)**
- **Avarage journey time (sec/km)**
- **Section journey time (sec)**

<table>
<thead>
<tr>
<th>Capacity C (pcu/h)</th>
<th>Degree of saturation DS</th>
<th>Free flow speed VO (km/h)</th>
<th>Travel speed V (km/h)</th>
<th>Avarage journey time (sec/km)</th>
<th>Section journey time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1525</td>
<td>0.66</td>
<td>35.1</td>
<td>27.8</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### RESULTS

- **Actual or design flow (Qp or Qd) (pcu/h):** 1006
- **Capacity (C) (pcu/h):** 1525
- **Ratio of flow to capacity (DS):** 0.66
- **Estimated average speed (km/h):** 28
- **Estimated average journey time (sec/km):** -
- **Section journey time (sec):** -

### COMMENTS

- Notes and symbols used on this page:

  7) Step E Section 3.1  
  8) Step E-7 Section 3.1  
  9) Step E-8 Section 3.1  
  10) Step E-9 Section 3.1  
  11) Step E-10 Section 3.1  
  12) Step E-11 Section 3.1  
  13) Step E-12 Section 3.1
5.3 EXAMPLE 3: OPERATIONAL ANALYSIS OF A TWO-LANE TWO-WAY ROAD

Geometry: 6.0 m effective carriageway width
1.0 m effective shoulder on both sides (level with road)

Traffic: Directional split of 70 - 30

Environment: City size 700,000 inh.
Many angkutan kota
Many pedestrians
Some traffic using roadside accesses.

This is the same road as the Example-2 but a large new shopping and office development is being built nearby. When it is finished the predicted peak hour volume (two-way) will be:

\[
\begin{align*}
Q_{LV} & = 1000 \\
Q_{HV} & = 100 \\
Q_{MC} & = 1500 \\
Q_{UM} & = 0
\end{align*}
\]

Questions:

1. What peak hour speed will the road now operate at?
2. What will the peak hour Q/C ratio be now?
3. What action would you take?

Solution:

See Figure 5.2:1, 5.3:1 to 5.3:3.
TRAFFIC (3)

pcu values used:

\[

c_{\text{LV}} = \frac{1.0}{pcu_{\text{LV}}} \quad \text{pcu}_{\text{HV}} = \frac{1.2}{pcu_{\text{HV}}} \\
\quad c_{\text{MC}} = \frac{0.25}{pcu_{\text{MC}}} \quad \text{pcu}_{\text{UM}} = \frac{0.8}{pcu_{\text{UM}}}
\]

\[
P = \left( L V \% \times pcu_{\text{LV}} + HV \% \times pcu_{\text{HV}} + MC \% \times pcu_{\text{MC}} + UM \% \times pcu_{\text{UM}} \right) / 100
\]

<table>
<thead>
<tr>
<th>Period</th>
<th>Total peak hour flow of traffic (veh/h)</th>
<th>Traffic composition</th>
<th>pcu factor</th>
<th>Q_p (pcu/h)</th>
<th>Directional split class SP (13)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LV (2)</td>
<td>HV (3)</td>
<td>MC (4)</td>
<td>UM (5)</td>
<td>Q_v (6)</td>
</tr>
<tr>
<td>1</td>
<td>1000</td>
<td>100</td>
<td>1500</td>
<td>0</td>
<td>2600</td>
</tr>
</tbody>
</table>

AADT : \(-\) pcu \(^{(4)}\)

AADT-factor (K) \(^{(4)}\) : \(-\) \quad Design flow (Q_d) : \(-\) pcu/h \(^{(4)}\)

Year of traffic data : 1992

Source of traffic data :

EXAMPLE 3

ENVIRONMENT

Side friction class (SF) \(^{(5)}\) : Very Low / Low / Medium / High / Very High (*)

City size (M inh) \(^{(6)}\) : >3.0 / 1.0 – 3.0 / 0.5 – 1.0 / <0.5 (*)

Notes and symbols used on this page :

* delete as appropriate

(3) Step C section 3.1 (4) Section 3.2 (5) Step D-1 Section 3.1 (6) Step D-2 Section 3.1

5 - 63
**IHCM: URBAN ROADS**

**INDONESIAN HIGHWAY CAPACITY MANUAL**

Form ROAD-3: ANALYSIS

### Analysis

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Base capacity $C_O$ (pcu/h)</th>
<th>Carriageway width adjustment factor $F_W$</th>
<th>Kerb and shoulder adjustment factor $F_{KS}$</th>
<th>Directional split or median adjustment factor $F_{SP}$</th>
<th>Side friction adjustment factor $F_{SF}$</th>
<th>City size adjustment factor $F_{CS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2900</td>
<td>0.83</td>
<td>0.93</td>
<td>0.88</td>
<td>0.90</td>
<td>0.86</td>
</tr>
<tr>
<td>2</td>
<td>2900</td>
<td>0.83</td>
<td>1.00</td>
<td>0.88</td>
<td>0.90</td>
<td>0.86</td>
</tr>
<tr>
<td>3</td>
<td>2900</td>
<td>1.00</td>
<td>0.93</td>
<td>0.88</td>
<td>0.90</td>
<td>0.86</td>
</tr>
</tbody>
</table>

### Results

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Actual or design flow $Q_o$ or $Q_d$ (pcu/h)</th>
<th>Degree of saturation $DS$</th>
<th>Free flow speed $V_O$ (km/h)</th>
<th>Travel speed $V$ (km/h)</th>
<th>Average journey time $TT$ (sec/km)</th>
<th>Section journey time $TT$ (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1525</td>
<td>1495</td>
<td>0.98</td>
<td>35.1</td>
<td>20.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1639</td>
<td>1495</td>
<td>0.91</td>
<td>35.1</td>
<td>22.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1837</td>
<td>1495</td>
<td>0.81</td>
<td>37.5</td>
<td>26.9</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Comments

- **alt.1**: existing conditions
- **alt.2**: widen shoulder to 2.0 m
- **alt.3**: widen carriageway width to 7.0 m

**Notes and symbols used on this page:**

- (7) Step E Section 3.1
- (8) Step E-7 Section 3.1
- (9) Step E-8 Section 3.1
- (10) Step E-9 Section 3.1
- (11) Step E-10 Section 3.1
- (12) Step E-11 Section 3.1
- (13) Step E-12 Section 3.1
**ANALYSIS**

\[ C = C_O \times F_W \times F_{KS} \times F_{SP} \times F_{SF} \times F_{CS} \]

\[ V = V_O \times 0.5 \left[ 1 + \left( 1 - DS \right)^{0.5} \right] \]

**RESULTS**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Actual or design flow (Qb or Qd) (pcu/h)</th>
<th>Degree of saturation (DS)</th>
<th>Free flow speed (km/h)</th>
<th>Travel speed (km/h)</th>
<th>Avarage journey time (sec/km)</th>
<th>Section journey time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>2900</td>
<td>0.83</td>
<td>38.5</td>
<td>25.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3200</td>
<td>0.83</td>
<td>45.8</td>
<td>35.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**COMMENTS**

*alt. 4 : remove fricton (high -> low)*

*alt. 5 : make it one-way road*
5.4 EXAMPLE 4: OPERATIONAL ANALYSIS OF A FOUR-LANE TWO-WAY ROAD

Geometry:
- 12.5 m carriageway
- 2 m shoulders on both sides
- 0.5 m median width
- Median with frequent gaps (av. 1 gap per 500 m)

Environment:
- Some pedestrians
- Many angkutan kota stopping
- Some vehicles entering and leaving roadside premises.
- City size 900,000 inh.

There are warungs selling fruit along both sides of the road, right up to the edge of the carriageway.

The peak hour flow of traffic is:

\[
\begin{align*}
Q_{LV} & = 3000^{(1)} \\
Q_{HV} & = 300 \\
Q_{MC} & = 1300 \\
Q_{UM} & = 120
\end{align*}
\]

\(^{(1)}\text{incl. 400 angkutan kota, most of which stop on the segment}

(Assume pcu value of angkutan kota = 1.0)

Questions:

1. What speed and Q/C ratio does the road operate?

2. (a) If:
   a. The warungs were moved;
   b. All angkutan kota were moved to another parallel route nearby;
   c. All gaps in the median were closed;
   d. The road was widened to 14 m.

   What would the speed and Q/C ratio be for each action separately?

   (b) What would the speed and Q/C ratio be if all these were done together?

Solution:

See Figure 5.4:1 to 5.4:4.
### GENERAL

Road segment identification (site name/section/city):

**JL. R4 BETWEEN KM. 5.7 AND KM. 8.3 KOTA K4**

<table>
<thead>
<tr>
<th>Segment length (L)</th>
<th>Date: day 3 month 12 year 1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.6 km</td>
<td></td>
</tr>
</tbody>
</table>

Analyzing engineer: NOVARA
Checking engineer: MARLER
Case: A+B

### GEOMETRY

- **Shoulder / kerb / shoulder and kerb**
  - Difference between levels of shoulder and carriageway:
    - ≤ 10 cm; considered as shoulder
    - > 10 cm; considered as shoulder = 0 m
  - Median / no-median: only considered for four-lane two-way roads

#### Dimensions:

<table>
<thead>
<tr>
<th>Side</th>
<th>Effective shoulder width (W_{se})</th>
<th>Or distance from kerb to obstruction (W_{ke})</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.0 m</td>
<td>- m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Side</th>
<th>Effective carriageway width (W_{ce})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12.5 m</td>
</tr>
</tbody>
</table>

If median:
- Median width (W_{m}): 0.5 m
- Median continuity: no gaps / few gaps / frequent gaps

If shoulder:
- Average effective shoulder width (W_{se}): 1.0 m

If kerb:
- Average distance from kerb to obstruction (W_{ke}): 2.0 m

Source of geometric data:

**EXAMPLE 4**

Notes and symbols used on this page:
- * delete as appropriate
- (1) Step A Section 3.1
- (2) Step B Section 3.1
### TRAFFIC (3)

**pcu values used:**

\[
p_{cuv}^{LV} = \frac{1.0}{0.25}, \quad p_{cuv}^{HV} = \frac{1.2}{0.8}, \quad p_{cuv}^{MC} = \frac{0.25}{0.8}
\]

\[
P = \frac{(LV\% \times p_{cuv}^{LV} + HV\% \times p_{cuv}^{HV} + MC\% \times p_{cuv}^{MC} + UM\% \times p_{cuv}^{UM})}{100}
\]

<table>
<thead>
<tr>
<th>Period</th>
<th>Total peak hour flow of traffic (veh/h)</th>
<th>Traffic composition</th>
<th>pcu factor</th>
<th>Q_P (pcu/h)</th>
<th>SP (13)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LV (2)</td>
<td>HV (3)</td>
<td>MC (4)</td>
<td>UM (5)</td>
<td>Q_v (6)</td>
</tr>
<tr>
<td>1</td>
<td>3000</td>
<td>300</td>
<td>1300</td>
<td>120</td>
<td>4720</td>
</tr>
</tbody>
</table>

**AADT :** \(\text{-}\) pcu(4)

**AADT-factor (K)(4) :** \(\text{-}\) Design flow (Q_d): \(\text{-}\) pcu/h(4)

**Year of traffic data :** 1992

**Source of traffic data :** EXAMPLE 4

### ENVIRONMENT

**Side friction class (SF)(5) :** Very Low / Low / Medium / High / Very High

**City size (M inh)(6) :** >3.0 / 1.0 – 3.0 / 0.5 – 1.0 / <0.5

Notes and symbols used on this page :

* delete as appropriate

(3) Step C section 3.1 (4) Section 3.2 (5) Step D-1 Section 3.1 (6) Step D-2 Section 3.1
## ANALYSIS

\[ C = C_0 \times F_W \times F_{KS} \times F_{SP} \times F_{SF} \times F_{CS} \]

\[ V = V_0 \times 0.5 \left[ 1 + \left( 1 - DS \right)^0.5 \right] \]

### Capacity

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Base capacity ( C_0 ) (pcu/h)</th>
<th>Carriageway width ( F_W ) adjustment factor</th>
<th>Kerb and shoulder adjustment factor ( F_{KS} )</th>
<th>Directional split or median adjustment factor ( F_{SP} )</th>
<th>Side Friction adjustment ( F_{SF} )</th>
<th>City size adjustment ( F_{CS} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5700</td>
<td>0.85</td>
<td>0.96</td>
<td>0.98</td>
<td>0.97</td>
<td>0.86</td>
</tr>
<tr>
<td>2</td>
<td>5700</td>
<td>0.85</td>
<td>0.96</td>
<td>0.98</td>
<td>0.97</td>
<td>0.86</td>
</tr>
<tr>
<td>3</td>
<td>5700</td>
<td>0.85</td>
<td>0.96</td>
<td>0.98</td>
<td>0.97</td>
<td>0.86</td>
</tr>
</tbody>
</table>

### Results

<table>
<thead>
<tr>
<th>Capacity ( C_0 ) (pcu/h)</th>
<th>Actual or design flow ( Q_b = Q_d ) (pcu/h)</th>
<th>Degree of saturation ( DS )</th>
<th>Free flow speed ( V_0 ) (km/h)</th>
<th>Travel speed ( V ) (km/h)</th>
<th>Average journey time ( TT ) (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3802</td>
<td>3781</td>
<td>0.99</td>
<td>51.5</td>
<td>28.3</td>
<td>-</td>
</tr>
<tr>
<td>4199</td>
<td>3781</td>
<td>0.90</td>
<td>51.5</td>
<td>33.9</td>
<td>-</td>
</tr>
<tr>
<td>3802</td>
<td>3381</td>
<td>0.89</td>
<td>51.5</td>
<td>34.3</td>
<td>-</td>
</tr>
</tbody>
</table>

### Comments

- **Alt. 1**: existing conditions
- **Alt. 2**: the warungs were removed
- **Alt. 3**: all angkutan kota were moved to another parallel route

Notes and symbols used on this page:

- (7) Step E Section 3.1
- (8) Step E-7 Section 3.1
- (9) Step E-8 Section 3.1
- (10) Step E-9 Section 3.1
- (11) Step E-10 Section 3.1
- (12) Step E-11 Section 3.1
- (13) Step E-12 Section 3.1
## ANALYSIS

\[ C = C_O \times F_W \times F_{KS} \times F_{SP} \times F_{SF} \times F_{CS} \]

\[ V = V_O \times 0.5 \left[ 1 + \left( 1 - DS \right)^{0.5} \right] \]

### Case: a

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Base capacity ( C_O ) (pcu/h)</th>
<th>Carriageway width adjustment factor ( F_W )</th>
<th>Kerb and shoulder adjustment factor ( F_{KS} )</th>
<th>Directional split or median adjustment factor ( F_{SP} )</th>
<th>Side Friction adjustment factor ( F_{SF} )</th>
<th>City size adjustment factor ( F_{CS} )</th>
<th>Capacity ( C ) (pcu/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>5700</td>
<td>0.85</td>
<td>0.96</td>
<td>1.12</td>
<td>0.97</td>
<td>0.86</td>
<td>4346</td>
</tr>
<tr>
<td>5</td>
<td>5700</td>
<td>1.00</td>
<td>0.96</td>
<td>0.98</td>
<td>0.97</td>
<td>0.86</td>
<td>4473</td>
</tr>
<tr>
<td>6</td>
<td>5700</td>
<td>1.00</td>
<td>1.06</td>
<td>1.12</td>
<td>0.97</td>
<td>0.86</td>
<td>5645</td>
</tr>
</tbody>
</table>

### RESULTS

<table>
<thead>
<tr>
<th>Actual or design flow ( Q_p ) (pcu/h)</th>
<th>Degree of saturation ( DS )</th>
<th>Free flow speed ( V_O ) (km/h)</th>
<th>Travel speed ( V ) (km/h)</th>
<th>Average journey time ( TT ) (sec)</th>
<th>Section journey time ( TT ) (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3781</td>
<td>0.87</td>
<td>51.5</td>
<td>35.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3781</td>
<td>0.85</td>
<td>53.6</td>
<td>37.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3381</td>
<td>0.60</td>
<td>53.6</td>
<td>43.7</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### COMMENTS

- **alt. 4**: all gaps in the median were closed
- **alt. 5**: widen the road to 14 m
- **alt. 6**: combined alt. 2.3.4 and 5

### Notes and symbols used on this page:

- (7) Step E Section 3.1
- (8) Step E-7 Section 3.1
- (9) Step E-8 Section 3.1
- (10) Step E-9 Section 3.1
- (11) Step E-10 Section 3.1
- (12) Step E-11 Section 3.1
- (13) Step E-12 Section 3.1
5.5 EXAMPLE 5: ANALYSIS OF FOUR-LANE TWO-WAY ROAD, FOR USE IN A NETWORK ANALYSIS

**Geometry:**
- 14 m
- Kerbed, no obstructions within 2.0 m on either side
- No median
- Segment length: 2 km

**Traffic:**
- Directional split of 70 - 30

**Environment:**
- Few pedestrians
- Few angkutan kota
- Few vehicles entering/leaving premises
- City size < 500,000 in h.

The peak traffic flow is expected to be 3000 pcu/h

**Questions:**

1. What is the average travel time along the segment?
   a. in sec
   b. in sec/km

**Solution:**

See Figure 5.5:1 to 5.5:3.
### INDONESIAN HIGHWAY CAPACITY MANUAL  
Form ROAD-1  

**URBAN ROADS**  
Form ROAD-1: **GENERAL**  

**GEOMETRY**

Road segment identification (site name/section/city):

<table>
<thead>
<tr>
<th>JL. R5 BETWEEN KM. 5.3 AND KM. 7.3 KOTA K5</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Segment length (L):</th>
<th>2.0 km</th>
</tr>
</thead>
</table>

Analyzing engineer: NOVARA  
Date: day 12 month 1 year 1993

Checking engineer: MARLER  
Date: day 17 month 1 year 1993

Case: A

**GEOMETRY**

Shoulder / kerb / shoulder and kerb (*)

Difference between levels of shoulder and carriageway:

- ≤ 10 cm; considered as shoulder
- > 10 cm; considered as shoulder = 0 m

Median / no-median (*) : only considered for four-lane two-way roads

**Dimensions:**

<table>
<thead>
<tr>
<th>Side A</th>
<th>Effective shoulder width (W_{Se})</th>
<th>Or distance from kerb to obstruction (W_{Ke})</th>
<th>Side B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&gt; 2 m</td>
<td></td>
</tr>
</tbody>
</table>

If median:

Median width (W_{M}) :  
Median continuity: no gaps / few gaps / frequent gaps (*)

If shoulder:

Average effective shoulder width (W_{Se}) :  

If kerb:

Average distance from kerb to obstruction (W_{Ke}) :  

Source of geometric data:

**EXAMPLE 5**

Notes and symbols used on this page:

* delete as appropriate

(1) Step A Section 3.1
(2) Step B Section 3.1
# Traffic and Environment Analysis

### Traffic

<table>
<thead>
<tr>
<th>Period</th>
<th>Total peak hour flow of traffic (veh/h)</th>
<th>Traffic composition</th>
<th>pcu factor</th>
<th>Qp (pcu/h)</th>
<th>Directional split class SP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LV (2)</td>
<td>HV (3)</td>
<td>MC (4)</td>
<td>UM (5)</td>
<td>Qv (6)</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- **AADT:** __________ pcu
- **AADT-factor (K):** __________
- **Design flow (Qd):** __________ pcu/h

- **Year of traffic data:** 1992
- **Source of traffic data:** EXAMPLE 5

### Environment

- **Side friction class (SF):** Very Low / Low / Medium / High / Very High
- **City size (Min):** >3.0 / 1.0 / 3.0 / <0.5

### Notes and Symbols

* delete as appropriate

(3) Step C section 3.1 (4) Section 3.2 (5) Step D-1 Section 3.1 (6) Step D-2 Section 3.1
### ANALYSIS

\[ C = C_0 \times F_w \times F_{KS} \times F_{SP} \times F_{SF} \times F_{CS} \]

\[ V = V_0 \times 0.5 \left[ 1 + \left(1 - DS\right)^{0.5}\right] \]

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Base capacity ( C_0 ) (pcu/h)</th>
<th>Carriageway width adjustment factor ( F_w )</th>
<th>Kerb and shoulder adjustment factor ( F_{KS} )</th>
<th>Directional split or median adjustment factor ( F_{SP} )</th>
<th>Side Friction adjustment factor ( F_{SF} )</th>
<th>City size adjustment factor ( F_{CS} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>5700</td>
<td>1.00</td>
<td>1.00</td>
<td>0.94</td>
<td>1.00</td>
<td>0.80</td>
</tr>
</tbody>
</table>

### Capacity

\[ Q_0 = q_0 \quad \text{or} \quad Q_d \quad \text{(pcu/h)} \]

<table>
<thead>
<tr>
<th>Capacity (8)</th>
<th>Actual or design flow ( Q_0 = q_0 ) (pcu/h)</th>
<th>Degree of saturation ( S )</th>
<th>Free flow speed ( V_0 ) (km/h)</th>
<th>Travel speed ( V ) (km/h)</th>
<th>Avarage journey time ( TT ) (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(8)</td>
<td>4286</td>
<td>0.70</td>
<td>56.4</td>
<td>43.6</td>
<td>82.5</td>
</tr>
</tbody>
</table>

### RESULTS

<table>
<thead>
<tr>
<th>Actual or design flow (( Q_0 ) or ( q_0 )) (pcu/h)</th>
<th>Capacity (C) (pcu/h)</th>
<th>Ratio of flow to capacity (DS)</th>
<th>Estimated average speed (km/h)</th>
<th>Estimated average journey time (sec/km)</th>
<th>Section journey time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000</td>
<td>4286</td>
<td>0.70</td>
<td>44</td>
<td>83</td>
<td>165</td>
</tr>
</tbody>
</table>

### COMMENTS

Notes and symbols used on this page:

1. (7) Step E Section 3.1
2. (8) Step E-7 Section 3.1
3. (9) Step E-8 Section 3.1
4. (10) Step E-9 Section 3.1
5. (11) Step E-10 Section 3.1
6. (12) Step E-11 Section 3.1
7. (13) Step E-12 Section 3.1
5.6 EXAMPLE 6: DESIGN OF A NEW ROAD

A new at-grade road of standard design is to be built in Sukabumi. The predicted peak hour flow for the design year is 1700 pcu.

Standard design:
- 3.5 metre lanes
- Kerb or shoulder (your choice)
  (distance to obstructions/effective shoulder width > 2.0 m)
- A median or no median (your choice)

Questions:

1. How many standard lanes are needed?

   Assume

   - Directional split of 60 - 40
   - Medium friction
   - A Q/C ratio of 0.6 or lower is required for the design year

Solution:

See Figure 5.6:1 to 5.6:3.
## GENERAL

Road segment identification (site name/section/city):

**JL. R6 BETWEEN KM. 13.2 AND KM. 15.7 KOTA SUKABUMI**

<table>
<thead>
<tr>
<th>Segment length (L):</th>
<th><strong>2.5 km</strong></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Analyzing engineer:</th>
<th>NOVARA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>4 month 12 year 1993</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Checking engineer:</th>
<th>MARLER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>10 month 12 year 1993</td>
</tr>
</tbody>
</table>

| Case:               | A |

## GEOMETRY

**Shoulder / kerb / shoulder and kerb (*)**

- Difference between levels of shoulder and carriageway:
  - ≤ 10 cm; considered as shoulder
  - > 10 cm; considered as shoulder = 0 m

**Median / no-median (**)**:
- only considered for four-lane two-way roads

### Dimensions:

<table>
<thead>
<tr>
<th>Side</th>
<th>Effective shoulder width (W_{Se})</th>
<th>Or distance from kerb to obstruction (W_{Ke})</th>
<th>Effective carriageway width (W_{Ce})</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td>3x3.5 m</td>
</tr>
</tbody>
</table>

If median:
- Median width (W_{M}): [ ] m
- Median continuity: no gaps / few gaps / frequent gaps (*)

If shoulder:
- Average effective shoulder width (W_{Se}): ≥ 2 m

If kerb:
- Average distance from kerb to obstruction (W_{Ke}): [ ] m

Source of geometric data:

**EXAMPLE 6**

---

**Notes and symbols used on this page:**

- * delete as appropriate
- (1) Step A Section 3.1
- (2) Step B Section 3.1
## TRAFFIC (3)

pcu values used:

\[
\text{pcu}_{LV} = \quad \text{pcu}_{HV} = \quad \\
\text{pcu}_{MC} = \quad \text{pcu}_{UM} = \quad \\
\]

\[
P = \left( \text{LV}\% \times \text{pcu}_{LV} + \text{HV}\% \times \text{pcu}_{HV} + \text{MC}\% \times \text{pcu}_{MC} + \text{UM}\% \times \text{pcu}_{UM} \right) / 100
\]

<table>
<thead>
<tr>
<th>Period</th>
<th>Total peak hour flow of traffic (veh/h)</th>
<th>Traffic composition</th>
<th>pcu factor</th>
<th>( Q_P ) (pcu/h)</th>
<th>Directional split class SP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LV (2)       HV (3)      MC (4)      UM (5)</td>
<td>Qv (6)</td>
<td>LV% (7)</td>
<td>HV% (8)</td>
<td>MC% (9)</td>
</tr>
<tr>
<td>1</td>
<td>-            -           -           -</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

AADT: \( \text{pcu}^{(4)} \)

AADT-factor (K)\(^{(4)} \): \( \text{Design flow (Qd)}: \text{pcu/h}^{(4)} \)

Year of traffic data: 1992

Source of traffic data: EXAMPLE 6

## ENVIRONMENT

Side friction class (SF)\(^{(5)} \): Very Low / Low / Medium / High / Very High

City size (M inh)\(^{(6)} \): >3.0 / 1.0 – 3.0 / 0.5 – 1.0 / < 0.5

Notes and symbols used on this page:

* delete as appropriate

(3) Step C section 3.1 (4) Section 3.2 (5) Step D-1 Section 3.1 (6) Step D-2 Section 3.1
**ANALYSIS**

\[ C = C_O \times F_W \times F_{KS} \times F_{SP} \times F_{SF} \times F_{CS} \]

\[ V = V_O \times 0.5 \times [1 + (1 - DS)^{0.5}] \]

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Base capacity ( C_O ) (pcu/h)</th>
<th>Carriageway width adjustment factor ( F_W )</th>
<th>Kerb and shoulder adjustment factor ( F_{KS} )</th>
<th>Directional split or median adjustment factor ( F_{SP} )</th>
<th>Side Friction adjustment factor ( F_{SF} )</th>
<th>City size adjustment factor ( F_{CS} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Table E-1:1</td>
<td>Table E-2:1</td>
<td>Table E-3:1 or E-3:2</td>
<td>Table E-4:1 or E-4:2</td>
<td>Table E-5:1</td>
<td>Table E-6:1</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
</tr>
<tr>
<td>1</td>
<td>5700</td>
<td>0.63</td>
<td>1.06</td>
<td>0.97</td>
<td>0.97</td>
<td>0.80</td>
</tr>
</tbody>
</table>

**RESULTS**

<table>
<thead>
<tr>
<th>Capacity ( C_O ) (pcu/h)</th>
<th>Actual or design flow ( Q_b = Q_d ) (pcu/h)</th>
<th>Degree of saturation ( DS )</th>
<th>Free flow speed ( V_O ) (km/h)</th>
<th>Travel speed ( V ) (km/h)</th>
<th>Avarage journey time ( TT ) (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(8)</td>
<td>(9)</td>
<td>(10)</td>
<td>(11)</td>
<td>(12)</td>
<td>(13)</td>
</tr>
<tr>
<td>2865</td>
<td>1700</td>
<td>0.59</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**COMMENTS**

Three lanes will therefore carry the traffic at the required Q/C ratio of 0.6 or less, but three – lane roads may be dangerous, so four-lane road may be better.

Notes and symbols used on this page:

(7) Step E Section 3.1  (8) Step E-7 Section 3.1  (9) Step E-8 Section 3.1  (10) Step E-9 Section 3.1  (11) Step E-10 Section 3.1  (12) Step E-11 Section 3.1  (13) Step E-12 Section 3.1
5.7 EXAMPLE 7: PLANNING

A new road is being planned. The predicted AADT is 30,000 pcu. The road must operate at a Q/C ratio of 0.6 or less in the design year.

Questions:

1. Will a 4-lane road be sufficient?

   Assume:
   - Standard lane width of 3.5 m
   - Kerb width > 2.0 m to obstructions
   - No median
   - Directional split of 60 – 40
   - Medium friction
   - City size 1.0 – 3.0 M

Solution:

The assumptions used for planning four-lane two-way roads are the same as the assumed conditions given in Section 3.2.2, so no worksheet is needed. Relating the predicted AADT (30,000 pcu) to the corresponding values shown in Table 3.2.2:1 gives the Q/C ratio is about 0.53, so a four-lane road will be sufficient.
5.8 EXAMPLE 8: OPERATIONAL ANALYSIS OF URBAN MOTORWAYS

Geometry: 7.5 m carriageway width (both side)  
1.0 m effective shoulder on side A  
2.0 m effective shoulder on side B  
2.0 m median width

Traffic:  
- Side A: \( Q_{LV} = 2700 \text{ veh/h} \)  
  \( Q_{HV} = 800 \text{ veh/h} \)  
- Side B: \( Q_{LV} = 3200 \text{ veh/h} \)  
  \( Q_{HV} = 600 \text{ veh/h} \)

Environment: City size > 3.0 M

Questions:  
1. What peak hour speed will be the road operate at?  
2. What is the flow/capacity ratio?

Solution:  
See Figure 5.8:1 and 5.8:2.
URBAN ROADS
Form ROAD-1: GENERAL
GEOMETRY
TRAFFIC

GENERAL
Road segment identification (site name/section/city):
JL. M.T Haryono between km 5.7 and km 9.2 kota Jakarta

Segment length (L): 3.5 km

Analyzing engineer: NOVARA Date: day 17 month 11 year 1993
Checking engineer: MARLER Date: day 20 month 11 year 1993

Case: a

GEOMETRY

Dimensions:

Side A:
Effective left shoulder width (W_{Se}): 1.0 m
Effective carriageway width (W_{Ce}): 7.5 m
Median width (W_M): 2.0 m

Side B:
Effective carriageway width (W_{Ce}): 7.5 m
Effective left shoulder width (W_{Se}): 2.0 m

Source of geometric data:
EXAMPLE 8

TRAFFIC

pcu values used: pcu_{LV} = 1.0 pcu_{HV} = 1.2
P = (LV\% \times pcu_{LV} + HV\% \times pcu_{HV}) / 100

<table>
<thead>
<tr>
<th>Side</th>
<th>Period</th>
<th>Total peak hour flow of traffic (veh/h)</th>
<th>Traffic composition</th>
<th>pcu factor (P)</th>
<th>Design flow (Q_d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LV (3)</td>
<td>HV (4)</td>
<td>Q_r (5)</td>
<td>LV% (6)</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>2700</td>
<td>800</td>
<td>3500</td>
<td>77.1</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>3200</td>
<td>600</td>
<td>3800</td>
<td>84.2</td>
</tr>
</tbody>
</table>

AADT: - pcu (4)
AADT-factor (K): - Design flow (Q_d): - pcu/h (4)
Year of traffic data: 1992
Source of traffic data: EXAMPLE 8

Notes and symbols used on this page:
* delete as appropriate
(1) Step A Section 4.1 (2) Step B Section 4.1 (3) Step C Section 4.1 (4) Section 4.2
IHCM: URBAN ROADS

INDONESIAN HIGHWAY CAPACITY MANUAL  Form ROAD-5

URBAN ROADS
Form ROAD-3 : ANALYSIS RESULT COMMENTS
Analyzing engineer : NOVARA Date: 4 / 12 / 1992
Analyzing engineer : MARLER Date: 10 / 12 / 1992
Road segment: Jl.M.T.Haryono (km 5.7-km 9.2) Jakarta
Case: a

ANALYSIS

<table>
<thead>
<tr>
<th>Side A :</th>
<th>Q_i</th>
<th>=</th>
<th>4600</th>
<th>x</th>
<th>(Q/C_o)i</th>
<th>x</th>
<th>F_W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>V_i (km/h)</td>
<td>(1)</td>
<td>pcu/h</td>
<td>(2)</td>
<td>Table 4.1:1 (3)</td>
<td>Table D-1:1 (4)</td>
<td>(5)</td>
</tr>
<tr>
<td>75</td>
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<td></td>
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<tr>
<td>70</td>
<td>=</td>
<td>4600</td>
<td>0.61</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
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<td>0.99</td>
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<td></td>
</tr>
<tr>
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<td>0.99</td>
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<td></td>
</tr>
<tr>
<td>45</td>
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<td>4600</td>
<td>1.00</td>
<td>0.99</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Side B :

<table>
<thead>
<tr>
<th>Speed</th>
<th>V_i (km/h)</th>
<th>(1)</th>
<th>pcu/h</th>
<th>(2)</th>
<th>Table 4.1:1 (3)</th>
<th>Table D-1:1 (4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>=</td>
<td>4600</td>
<td>0.40</td>
<td></td>
<td></td>
<td></td>
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<td>=</td>
<td>4600</td>
<td>0.61</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>=</td>
<td>4600</td>
<td>0.75</td>
<td>1.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>=</td>
<td>4600</td>
<td>0.89</td>
<td>1.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>=</td>
<td>4600</td>
<td>1.00</td>
<td>1.01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RESULTS

Actual or design flow (Q_p or Q_d) (pcu/h) : Side A Side B
3660 3920
Capacity (C) (pcu/h) (6) : 4554 4646
Ratio of flow to capacity (DS) (7) : 0.80 0.84
Estimated average speed (km/h) (8) : 62 60
Estimated average journey time (sec/km) (9) : - -
Section journey time (sec) (10) : - -

COMMENTS

Notes and symbols used on this page:
* delete as appropriate
(5) Step D Section 4.1 (6) Step D-2 Secton 4.1 (7) Step D-3 Section 4.1
(8) Step D-4 Section 4.1 (9) Step D-5 Section 4.1 (10) Step D-6 Section 4.1
(11) Step D-7 Section 4.1
## 6. LITERATURE REFERENCE

<table>
<thead>
<tr>
<th>Reference</th>
<th>Author/Group</th>
<th>Title</th>
</tr>
</thead>
</table>


R17. Government of Indonesia Peraturan Pemerintah Republik Indonesia No. 8 Tahun 1990 tentang Jalan Tol.
## GENERAL(1)

Road segment identification (site name/section/city):

<table>
<thead>
<tr>
<th>Segment length (L):</th>
<th>Analyzing engineer:</th>
<th>Date: day ___ month ___ year</th>
<th>Checking engineer:</th>
<th>Date: day ___ month ___ year</th>
</tr>
</thead>
<tbody>
<tr>
<td>______km</td>
<td></td>
<td>1993</td>
<td></td>
<td>1993</td>
</tr>
</tbody>
</table>

Case: __________________

## GEOMETRY(2)

Shoulder / kerb / Shoulder and kerb (*)

Difference between levels of shoulder and carriageway:  
- $\leq 10$ cm; considered as shoulder  
- $> 10$ cm; considered as shoulder = 0 m

Median / no-median (*) : only considered for four-lane two-way roads

### Dimensions:

- **Side A**:  
  - Effective shoulder width ($W_{Se}$): ______ m  
  - Or distance from kerb to obstruction ($W_{Ke}$): ______ m  

- **Side B**:  
  - Effective carriageway width ($W_{Ce}$): ______ m  
  - Effective shoulder width ($W_{Se}$): ______ m  
  - Or distance from kerb to obstruction ($W_{Ke}$): ______ m

**If median:**  
- Median width ($W_{M}$): ______ m  
- Median continuity: no gaps / few gaps / frequent gaps (*)

**If shoulder:**  
- Average effective shoulder width ($W_{Se}$): ______ m

**If kerb:**  
- Average distance from kerb to obstruction ($W_{Ke}$): ______ m

Source of geometric data:

**Notes and symbols used on this page:**  
* delete as appropriate
(1) Step A Section 3.1  
(2) Step B Section 3.1
### TRAFFIC

pcu values used:

\[
p_{\text{LV}} = \quad p_{\text{HV}} = \\
p_{\text{MC}} = \quad p_{\text{UM}} = \\
\]

\[
P = \left( \text{LV}\% \times p_{\text{LV}} + \text{HV}\% \times p_{\text{HV}} + \text{MC}\% \times p_{\text{MC}} + \text{UM}\% \times p_{\text{UM}} \right) / 100
\]

<table>
<thead>
<tr>
<th>Period</th>
<th>Total peak hour flow of traffic (veh/h)</th>
<th>Traffic composition</th>
<th>pcu factor P (pcu/h)</th>
<th>Q&lt;sub&gt;P&lt;/sub&gt; (pcu/h)</th>
<th>Directional split class SP (13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>LV</td>
<td>HV</td>
<td>MC</td>
<td>UM</td>
<td>Q&lt;sub&gt;v&lt;/sub&gt;</td>
<td>LV%</td>
</tr>
</tbody>
</table>

AADT : \(____ \) pcu<sup>(4)</sup>

AADT-factor (K)<sup>(4)</sup> : \(____ \) Design flow \(Q_d\) : \(____ \) pcu/h<sup>(4)</sup>

Year of traffic data :  
Source of traffic data :  

### ENVIRONMENT

Side friction class (SF)<sup>(5)</sup> : Very Low / Low / Medium / High / Very High <sup>(*)</sup>

City size (M inh)<sup>(6)</sup> : > 3.0 / 1.0 – 3.0 / 0.5 – 1.0 / < 0.5 <sup>(*)</sup>

Notes and symbols used on this page :

* delete as appropriate

(3) Step C section 3.1 (4) Section 3.2 (5) Step D-1 Section 3.1 (6) Step D-2 Section 3.1
IHCM: URBAN ROADS

Appendix 5:1

INDONESIAN HIGHWAY CAPACITY MANUAL

Form ROAD-3

<table>
<thead>
<tr>
<th>ANALYSIS</th>
<th>RESULT</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Analyzing engineer:**

**Date:**

**Analyzing engineer:**

**Date:**

**Road segment:**

**Case:**

**ANALYSIS**

\[ C = C_O \times F_W \times F_{KS} \times F_{SP} \times F_{SF} \times F_{CS} \]

\[ V = \frac{V_O}{0.5} \times \left[ 1 + \left( 1 - DS \right)^{0.5} \right] \]

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Base capacity ( C_O ) (pcu/h)</th>
<th>Carriageway width adjustment factor ( F_W ) (3)</th>
<th>Kerb and shoulder adjustment factor ( F_{KS} ) (7)</th>
<th>Directional split or median adjustment factor ( F_{SP} ) (5)</th>
<th>Side Friction adjustment factor ( F_{SF} ) (4)</th>
<th>City size adjustment factor ( F_{CS} ) (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(7)</td>
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<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Capacity ( C_O ) (pcu/h)</th>
<th>Actual or design flow ( Q_D = Q_D ) (pcu/h)</th>
<th>Degree of saturation ( DS ) (9)</th>
<th>Free flow speed ( V_O ) (km/h)</th>
<th>Travel speed ( V ) (km/h)</th>
<th>Avarage journey time ( TT ) (sec)</th>
<th>Section journey time ( TT ) (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(8)</td>
<td>(9)</td>
<td>(10)</td>
<td>(11)</td>
<td>(12)</td>
<td>(13)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RESULTS**

Actual or design flow (Qp or qt) (pcu/h) | Alternative _ | Alternative _ | Alternative _

Capacity (C) (pcu/h) | Alternative _ | Alternative _ | Alternative _

Ratio of flow to capacity (DS) | Alternative _ | Alternative _ | Alternative _

Estimated average speed (km/h) | Alternative _ | Alternative _ | Alternative _

Estimated average journey time (sec/km) | Alternative _ | Alternative _ | Alternative _

Section journey time (sec) | Alternative _ | Alternative _ | Alternative _

**COMMENTS**

Notes and symbols used on this page:

(7) Step E Section 3.1    (8) Step E-7 Section 3.1    (9) Step E-8 Section 3.1    (10) Step E-9 Section 3.1
(11) Step E-10 Section 3.1  (12) Step E-11 Section 3.1  (13) Step E-12 Section 3.1
## URBAN ROADS
Form ROAD-1: GENERAL

### GEOMETRY

Road segment identification (site name/section/city):

<table>
<thead>
<tr>
<th>Segment length (L):</th>
<th>______ km</th>
</tr>
</thead>
</table>

Analyzing engineer: ____________________________ Date: day ___ month ___ year ______

Checking engineer: ____________________________ Date: day ___ month ___ year ______

### TRAFFIC

pcu values used: pcu\(_{LV}\) = 1.0 pcu\(_{HV}\) = 1.2

\[ P = (LV\% \times pcu_{LV} + HV\% \times pcu_{HV}) / 100 \]

<table>
<thead>
<tr>
<th>Side</th>
<th>Periode</th>
<th>Total peak hour flow of traffic (veh/h)</th>
<th>Traffic composition</th>
<th>pcu factor (P)</th>
<th>Q(_p) (pcu/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LV (3)</td>
<td>HV (4)</td>
<td>Q(_v) (5)</td>
<td>LV% (6)</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**AADT:** __________ pcu \(^{(4)}\)

**AADT-factor (K)** \(^{(4)}\): __________ Design flow (Q\(_d\)): __________ pcu/h \(^{(4)}\)

Year of traffic data: __________

Source of traffic data: __________

---

Notes and symbols used on this page:
* delete as appropriate

(1) Step A Section 4.1 (2) Step B Section 4.1 (3) Step C Section 4.1 (4) Section 4.2
### ANALYSIS

#### Side A

<table>
<thead>
<tr>
<th>Speed $V_i$ (km/h)</th>
<th>$Q_i =$ 4600 $x$ $(Q/C_o)i$ $x$ $F_W$</th>
<th>pcu/h</th>
<th>Table 4.1:1</th>
<th>Table D-1:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>4600</td>
<td>0.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>4600</td>
<td>0.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>4600</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>4600</td>
<td>0.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>4600</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Side B

<table>
<thead>
<tr>
<th>Speed $V_i$ (km/h)</th>
<th>$Q_i =$ 4600 $x$ $(Q/C_o)i$ $x$ $F_W$</th>
<th>pcu/h</th>
<th>Table 4.1:1</th>
<th>Table D-1:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>4600</td>
<td>0.40</td>
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<tr>
<td>45</td>
<td>4600</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### RESULTS

- Actual or design flow ($Q_p$ or $Q_d$) (pcu/h) : Side A [ ] Side B [ ]
- Capacity (C) (pcu/h) \(^{(5)}\) : Side A [ ] Side B [ ]
- Ratio of flow to capacity (DS) \(^{(7)}\) : Side A [ ] Side B [ ]
- Estimated average speed (km/h) \(^{(8)}\) : Side A [ ] Side B [ ]
- Estimated average journey time (sec/km) \(^{(9)}\) : Side A [ ] Side B [ ]
- Section journey time (sec) \(^{(9)}\) : Side A [ ] Side B [ ]

### COMMENTS

Notes and symbols used on this page:

* delete as appropriate

- \(^{(5)}\) Step D Section 4.1
- \(^{(6)}\) Step D-2 Section 4.1
- \(^{(7)}\) Step D-3 Section 4.1
- \(^{(8)}\) Step D-4 Section 4.1
- \(^{(9)}\) Step D-5 Section 4.1
- \(^{(10)}\) Step D-6 Section 4.1
- \(^{(11)}\) Step D-7 Section 4.1