Capacity Analysis on Highway
Based on JKR traffic census

By

Mohamad Faizal Radzi Bin Md Ehsan
Civil Engineering
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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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in partial fulfilment of the requirement for the
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Approved by,

_____
(Assoc. Prof. Dr. Madzlan Bin Napiah)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MOHAMAD FAIZAL RADZI BIN MD EHSAN

ABSTRACT

When designed road approach its demand, we started to experience lower speed and congestion. In Malaysia, the capacity of road was designed based on Jabatan Kerja Raya (JKR) design standard. JKR traffic census is the survey done twice a year to check the traffic volume. The data collection of current traffic will be combined with other known data such as population, employment, trip rates, zones , travel cost , etc. to enable us to forecast the future demand. The current data also helpful in determining whether the current road was sufficient or further development was needed in the future. The scope of this research is at Perak where the government plans to make Perak a high-income state with a viable economy. With the future development plan, the existing roads within Perak will be affected. The new transportation plans are needed to meet those demands. New analysis on the highway capacity and design should be done, to check the current level of service while compare it with designed capacity. The capacity analysis will based on the Highway Capacity Manual (HCM2000) to determine the performance of current facilities and compared with expected annual traffic growth.

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CHAPTER 1: INTRODUCTION

1.1 Project Background

Transport infrastructure in Malaysia has been growing at a phenomenal rate. This has essentially been in the form of roads in new residential, industrial and commercial developments. In addition, numerous townships have mushroomed and these have had to be comprehensively planned in terms of road and rail transport, transport terminals, bus routes, taxi stands, parking, pedestrian network and of late bicycle networks.

Existing cities and townships have also been affected in terms of demand for transport. This has resulted in traffic congestion in the cities, huge demand for bus services which cannot be met adequately. All this have had to be addressed and major transport studies and implementation work has taken place in the last few years.

A study called traffic impact assessment need to be done to analyze traffic generated by proposed developments with new access or increased use of an existing access. The traffic impact assessment generally includes a description of the scope and intensity of the proposed project, a summary of the projected impacts and any required mitigation measures, and helps ensure that the highway can safely accommodate a proposed subdivision/ development.

Traffic flows are fairly well when the capacity is greater than the demand. However, when demand approaches capacity, we begin to experience lower speeds and congestion. Thus in planning and design of highways we are interested in designing facilities that will operate below capacity. We need a good estimate of capacity for this. Capacity analysis involves the quantitative evaluation of the capability of a freeway section to carry traffic. Through this research project the level of service particular

highway and recalculation for designing the highway to operate at an acceptable Level of Service (LOS) will be determined.

The design will be based on JKR manual while the traffic data are based on JKR traffic census. The data collection of current traffic will be combined with other known data such as population, employment, trip rates, zones , travel cost , etc. to enable us to forecast the future demand. The current data also helpful in determining whether the current road was sufficient or further development was needed in the future.

The JKR traffic censuses are carried out by the respective District Public Works Department (JKR) staff, coordinated by the Highway Planning Unit (HPU). The censuses were done in the month of March/April and September/October from 1993 to 2010. For this research the data will based on 2001 to 2010 censuses. The censuses include the 24-hours traffic, 16-hour traffic, peak hour traffic, percentage of vehicle classification and also annual growth.

1.2 Problem Statement

Perak Development Plan which targeted to be a high-income state with a viable economy needed a new development plan for its transportation system. Transportation sector is an important component of the economy impacting on development and the welfare of populations. When transport systems are efficient, they provide economic and social opportunities and benefits that result in positive multipliers effects such as better accessibility to markets, employment and additional investments.

The impact of transportation on economy can be direct or indirect. The direct cost related to accessibility change where transport enables larger markets and enables to save time and costs. While, indirect impact related to the economic multiplier effects such as the price of commodities, goods or services drop or their variety increases. To ensure the transportation system are efficient, the first step which is traffic survey need to done periodically. Based on the traffic survey, we can evaluate the performance of the existing road and determine the traffic demand for the future.

The capacity analysis of road is the preliminary study of traffic impact assessment. The designed road should be able to meet the current and future demand as new development area are been proposed. The capacity analysis is related to the volume, density and speed of the traffic. A proper designed road will have optimum value in term of cost and speed. Basically the road design will be based on the traffic demand forecast. This demand forecast is a complex study which involves a lot of parameter and cause uncertainty for some factors. Therefore some forecast may inaccurate and cause some loss in term of land use and investment.

1.3 Objectives

The objectives of this research project are:

1) To **study the accuracy of forecasted traffic volume with the current traffic in determining capacity or road compared to HCM approach.** With new study on current traffic volume, a new forecast can be done for further investment or expansion of roads.

1.4 Scope of Study

The study revolves the capacity analysis on highway within Perak state. Based on JKR traffic census, reassessment of the highway capacity will be done and compared to the forecasted highway capacity.

New development area at Perak will give impact on traffic within the state. The study will determine the impact of the development area on traffic performance for future investment and development.

1.5 Relevancy of Project

In term of relevancy of the project, it poses a great deal of significance to transportation planning around Perak state. With the increasing land value and population, efficient transportation system is a must. Annual traffic assessment needs to be done to ensure the roads are able meet the traffic demand. Any further development to improve the traffic flow can also be evaluated with this study.

1.6 Feasibility of Project

All the objectives stated earlier are achievable and feasible in terms of this project duration and time frame. With the limited timeframe, no traffic survey will be done. The data will be based on JKR census while calculation on the designed capacity based on JKR traffic manual. The study will be more on reassessment or re-evaluation or existing highway, which focus on the design calculation.

CHAPTER 2: LITERATURE REVIEW AND THEORY

2.1 Literature Review

Public Work Department (PWD) or Jabatan Kerja Raya (JKR) is the bodies that responsible for the set the standard for the design of road in Malaysia. Road design is important in transportation planning to ensure the good service and its safety. To achieve their objective, schedule maintenance and providing acceptable level of service need to be done. Therefore, annual traffic survey coordinated by Highway Planning Unit (HPU) by respective JKR staff has been done. The survey or census varies according to the census types which are 7-day, 24 hour manual counting, 7-day, 16 hour manual counting and 1-day, 16 hour manual counting which include directional counts. Changes in ground condition due to upgrading works of major and minor routes causes the revision of formula used for the capacity analysis.

For this research, capacity analysis will be based on Highway Capacity Manual which published by Transportation Research Board (TRB) in the United States. This HCM was published to provide transportation practitioners and researchers with a consistent system of techniques for the evaluation of the quality of service on highway and street facilities. The category of road for this research is highways. They constitute the interstate national network and complement the expressway network. They usually link up directly or indirectly with Federal Capitals, State Capitals and point of entry/exit to the country. Speed service is not so important as in an expressway but relatively high to medium speed is necessary. [1] The design of the road should be based on the traffic data for a road section of road or section of road. In this case, the JKR census is the set of data that used. The data was obtained by the surveys that have been done by JKR.

Traffic data such as average daily traffic (ADT) is important for many purposes, such as determining the annual usage as justification for expenditures. However direct use of ADT for design purposes is not appropriate because it does not indicate the

significant variations in the traffic occurring during various months of the year, days of the week and hours of the days. The capacity requirement of the road is more accurate if it measured by hourly volume.[3] The design may be wasteful if it based on the peak hour traffic of the year and would be in adequate design if using the average hourly traffic.[1] Based on the reasoning it shows the importance of valid traffic data to ensure the design can cope with the demand.

Traffic forecast are very important for planning process. Traffic forecasts provide essential input for the appraisal of transport investment projects and public policies. For road projects, forecasts are more accurate and balanced, although for 50% of the projects the difference between actual and forecasted traffic was more than ±20%.[9] Differences in these performance measures between the base year and the forecast year are indications of changes in congestion and the ability of the highway system capacity to support traffic demand in the future. The project profitability is highly dependent on predicted traffic flow, uncertainty has to be quantified and accounted for in project evaluation. In my scope, the capacity analysis was used of the steps to check the traffic forecast accuracy. Highway capacity analysis measures include traffic volume, travel time, link delay, congested speed, and service to flow ratio. the capacity and performance results can be used to generate thematic maps that show highway links with capacity problems. The performance measures can also be aggregated to identify those congested highway links.

2.1.1 Definition of capacity analysis

Highway capacity is defined as the maximum hourly rate at which vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions.[2] While capacity analysis is the study of the number of traffic can be accommodate by the road. [3] Capacity and level of service (LOS) are two related term where LOS are qualitative measure while capacity is quantitative measure of a facility.

2.1.2 Factor affecting capacity

There are four major factors that affecting the capacities which are roadway condition, traffic condition, control condition and weather condition.

1) Roadway condition
    - The type of facility and its development environment,
    - Lane width
    - Number of lanes
    - Design speed
    - Surface condition
    - Number of intersections
    - Lateral clearance and width of shoulders
    - Presence of kerb
    - Type of median in case of divided facility
    - Horizontal and vertical alignment of road.
2) Traffic condition
    - Physical and operating conditions of the vehicles
    - Composition of traffic stream
    - Directional distribution
    - Pedestrian conditions

3) Control Condition
    - Driver characteristics and behavior

4) Weather Condition
    - Other factors such as rain, snow and fog badly affect the visibility condition, which reduces the capacity of a lane or roadway.

2.1.3 Importance of capacity analysis

Capacity analysis is fundamental to planning, design and operation of roads. It provides the basis for determining the number of traffic lanes to be provided for different road sections having regard to volume, composition, and other parameters of traffic. [9] For existing road network, it provides a means of assessing the traffic carrying ability of the number of traffic lanes provided for a given road link under the prevailing roadway and traffic conditions. For future planning, capacity analysis can provide a forecast when additional investment needed.

2.1.4 Benefit of capacity analysis

Capacity analysis is beneficial in term of qualitative measure. Qualitative measure which are related to the level of service (LOS) are very important in road design.[6] Level of service is define as "a qualitative measure describing operational conditions within a traffic stream and their perception by motorists and/or passengers in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety".[4] Travel speed and volume by capacity ratio (v/c ratio) to distinguish between various level of service. [3] Depending upon the travel speed and v/c ratio, six levels of service, level A to level F based on a graph between operating speed and v/c ratio are referred.

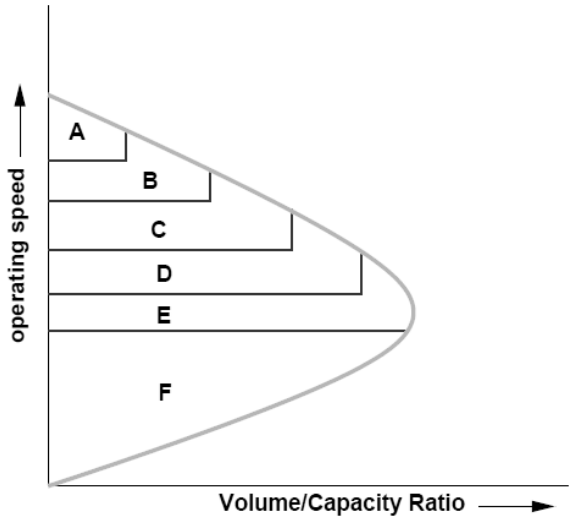


Figure 1 : Graph of operating speed vs volume/capacity ratio

After determination of the LOS, we can determined the design standard and forecast studies if traffic impact assessment need to be done later. Until the level of service is acceptable, no expansions are needed. In term of cost for which crucial in construction stage and maintenance purpose, based interpretation of data it would be helpful reduce unnecessary investments. For example, the construction for road will have the design period longer especially at new development area, the over design road capacity may cause problems not only in term of financial but also in term of safety. By providing too high operating speed the risk of accident occurs also getting higher. Thus, transportation planning should also consider human factor and not based on data and design only.

2.1.5 Level of Service Concept

Level of Service A free-flow conditions. Individual users are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to maneuver within the traffic stream is extremely high. The general level of comfort and convenience provided to drivers is excellent.

Level of Service B allows speeds at or near free-flow speeds, but the presence of other users in the traffic stream begins to be noticeable. Freedom to select desired speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within the traffic stream relative to LOS A.

Level of Service C speeds at or near free-flow speeds, but the freedom to maneuver is noticeably restricted (lane changes require careful attention on the part of drivers). The general level of comfort and convenience declines significantly at this level. Disruptions in the traffic stream, such as an incident (for example, vehicular accident or disablement), can result in significant queue formation and vehicular delay. In contrast, the effect of incidents at LOS A or LOS B are minimal, and cause only minor delay in the immediate vicinity of the event.

Level of Service D conditions where speeds begin to decline slightly with increasing flow. The freedom to maneuver becomes more restricted and drivers experience reductions in physical and psychological comfort. Incidents can generate lengthy queues because the higher density associated with this LOS provides little space to absorb disruption in the traffic flow.

Level of Service E represents operating conditions at or near the roadway's capacity. Even minor disruptions to the traffic stream, such as vehicles entering from a ramp or 2 vehicles changing lanes, can cause delays as other vehicles give way to allow such maneuvers. In general, maneuverability is extremely limited and drivers experience considerable physical and psychological discomfort.

Level of Service F describes a breakdown in vehicular flow. Queues form quickly behind points in the roadway where the arrival flow rate temporarily exceeds the departure rate, as determined by the roadway's capacity. Vehicles typically operate at low speeds in these conditions and are often required to come to a complete stop,

usually in a cyclic fashion. The cyclic formation and dissipation of queues is a key characterization of LOS F.

Figure 2 : The Condition in different LOS

2.1.6 Volume and Flow Rate

Volume – The total number of vehicles that pass over the given point or section of a lane or roadways during a given time interval. Volume can be expressed in term of annual, daily, hourly or sub-hourly period.

Flow rate – the equivalent hourly rate at which vehicles pass over a given point or section of lane or roadways during given time interval less than 1 hour, usually 15 minutes.

Volume and flow are variables that quantify demand, which is the number of vehicles, desire to use the facility during specific time period. Congestion can influence demand and observed volumes sometimes reflect the capacity constraint rather than true demand. Consideration of peak flow rates is important in capacity analysis. Peak hour rates and hourly volumes produce the

peak-hour factor (PHF), the total hourly volume to the peak flow rate within the hour, computed by the Equation 1-1:

PHF = Hourly volume / Peak flow rate (within the hour) (1-1)

If 15-min periods are used, the PHF may be computed by equation 1-2

$$PHF = V / 4*V_{15} \quad (1\text{-}2)$$

Where

PHF = peak-hour factor

V = hourly volume (veh/h), and

V_{15} = volume during the peak 15 min of the peak hour (veh/15min)

When the PHF is known, it can convert a peak-hour volume to a peak flow rate, as in Equation 1-3

$$v = V/PHF \quad (1\text{-}3)$$

Where

v = flow rate for a peak 15-min period (veh/h),

V = peak-hour volume (veh/h), and

PHF = peak-hour factor

2.1.7 Speed

Speed is an important measure of the traffic survey provided. Speed is defined as rate of motion expressed as distance per unit of time, generally as miles per hour (mi/h). Average travel speed is used as the speed measure because it is easily computed from observation of individual vehicles within the traffic stream and the most statically relevant measure in relationship with other variables.

2.1.8 Density

Density is the number of vehicles occupying a given length of a lane or roadway at a particular instant. For the computations in this manual, density is averaged over time and usually expressed as vehicles per mile (veh/mi) or passenger cars per mile (pc/mi). Equation 1-4 is used for under saturated traffic condition.

$$D = v/S \qquad (1\text{-}4)$$

Where

v = flow rate (veh/hour),

S = average travel speed (mi/h), and

D = density (vehicle/mile)

Density is a critical parameter for uninterrupted-flow facilities because it characterizes the quality of the traffic operations. It describes the freedom to maneuver within the traffic stream.

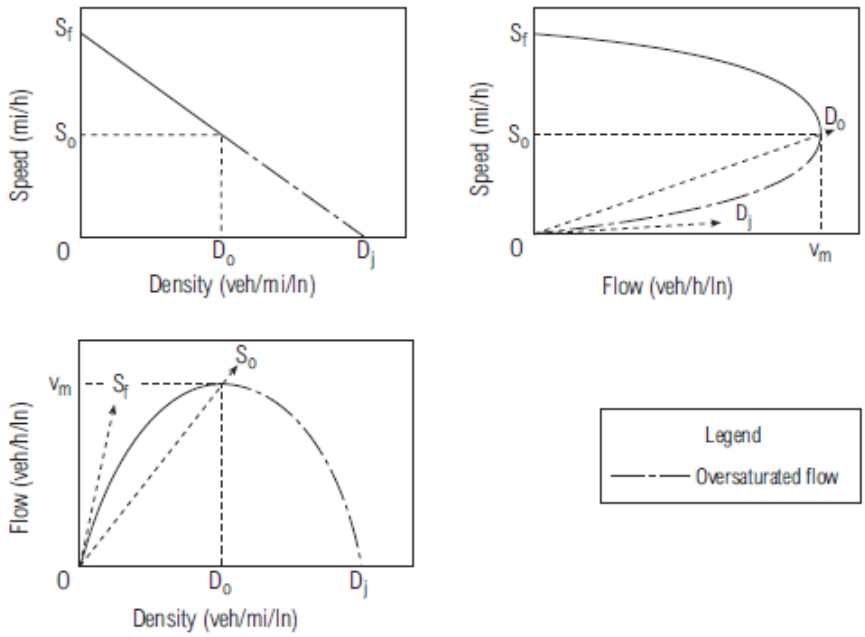


Figure 3 : Relationship between flow rate, speed and density

2.1.9 Type of highway

There are two types of highway for this research; Two Way Two Lane Highway (TWTL) and Multilane Highway. TWTL also known as single carriageway while Multilane as the dual carriageway. The difference for single carriageway is the road is undivided and no separation for opposing flows of traffic. Road traffic safety for single carriageway is generally worse than dual carriageway due to lack of separation between opposing traffic.

2.1.9.1 Two Lane Highway

Two-Lane highways or single carriageway are defined in the Highway Capacity Manual (HCM) as undivided roadway with two lanes, one for use by traffic in each direction and are classified as:

- Class I – These are two-lane, two-way highways on which motorists expect to travel at relatively high speeds. Two-lane, two-way highways

that are major intercity routes, primary arterials connecting major traffic generators, daily commuter routes, or primary links in state or national highway networks generally are assigned to Class I. Class I facilities most often serve long distance trips or provide connecting links between facilities that serve long distance trips.

- Class II – These are two-lane, two-way highways on which motorists do not necessarily expect to travel at high speeds. Two-lane, two-way highways that function as access routes to Class I facilities, serve as scenic or recreational routes that are not primary arterials, or pass through rugged terrain generally are assigned to Class II. Class II facilities most often serve relatively short trips, the beginning and ending portions of longer trips, or trips for which sightseeing plays a significant role.

The analysis for this class of highway is different. The Level of Service (LOS) for Class I highway, based on the Percent Time-spent-following (PTSF) and Average Travel Speed (ATS) while for Class II, it only based on Percent Time-spent-following (PTSF). Basically the factor affecting the flow rate in single carriageway is the heavy vehicles. The volume of the number of trucks, buses and recreational vehicles (RVs) are converted into an equivalent number of passenger car. The heavy vehicle factor is important especially when analyzing the section with grade. On level terrain the heavy vehicle tend to operate like passenger car so the equivalent factor approaches 1.

Next is the percentage of no-passing zone. At no-passing zone, it means that no vehicle are possible to maneuver therefore, it reduce the average travel speed. For different terrain, different default values are used. 20% for flat, 50% for rolling and 80% for mountainous terrain. The default values are used for any unavailable data based on HCM 2000. With no-passing zone also, the percent time following also increase. Time spent

following is define as the percentage time taken to follow other vehicle due to limited area to pass the vehicles. The condition will getting worse if the large percentage of heavy vehicle on traffic which will cause significant reduction of level of service.

2.1.9.2 Multilane Highway

Multilane highways usually have a total of four or six lanes, counting both directions, with medians and also may be undivided. This type of highways typically located in suburban communities, connecting two cities or two significant activities that generate substantial number of daily trips.

Multilane analysis method is different from single carriageway or two lane highway as it depends on the density of vehicles. The density of traffic represented by total vehicle per kilometer per lane (pc/km/ln). Due to availability for passing lane, the factors affecting the travel speed are reduced. Percent time-spent-following also not become a major issue in this type of highway. The factors that most likely to affect the flow of traffic is the access point density. It defines as the total number of intersections within the segment. It will reduce the travel speed as it will stop the traffic and cause queuing of traffic. The large number of vehicle also will cause significant effect as it accelerates slower than passenger car.

CHAPTER 3: METHODOLOGY

Methodology

In general, research methodology refers to a set of procedures used to conduct a research project. In here, the methodology includes:

- Research Methodology
- Project Activities
- Key Milestone
- Gantt Chart
- Tools

1.1 Research Methodology

1.1.1 Project Planning and Feasibility Study

For this phase it involve the review of related journals, books, research papers and developers forum to increase the familiarity, better understanding and also to get a clear view about the research scope that will be carried out. The main information resources are from the website scopus.com and also IEEE.org. After the reading has been done, a Gantt chart has been drawn which consist of several milestone and project activities so that the time will be allocated in the right way.

1.1.2 Data Gathering

The data for JKR traffic census need to be obtain from Jabatan Kerja Raya Perak. The data of designed road need which include the width of lanes, number of lanes, shoulder width etc. need to be gathered through survey. Other option is by using the standard road design for the geometric data.

1.1.3 Design Capacity

The design of road which including the forecast traffic volume are used. The design will be based on the JKR traffic manual which has been implemented on highway design in Malaysia. Default value will be used for any absence data.

1.1.4 Implementation

Based on the data from survey, calculation of current design capacity will be done.

1.1.5 Analysis

After the calculation, the level of service (LOS) of the current road will be obtained. Based on the current road performance, the expected volume for the road facility to fail can be forecasted. Using the annual growth, the number of years for the facilities can support the volume of vehicles can be obtained.

1.2 Project Activities

In the beginning of the project, everything is focused on the theoretical reading and understanding the project scope. In this stage, critical analysis of the existing features of identified highway need to be done. The JKR traffic census also needs to be obtained earlier for saving time as design period will consume more time.

Survey on the highway should be done to determine the parameters for the recalculation works. The parameters are various with the location therefore it can improve the accuracy of this research.

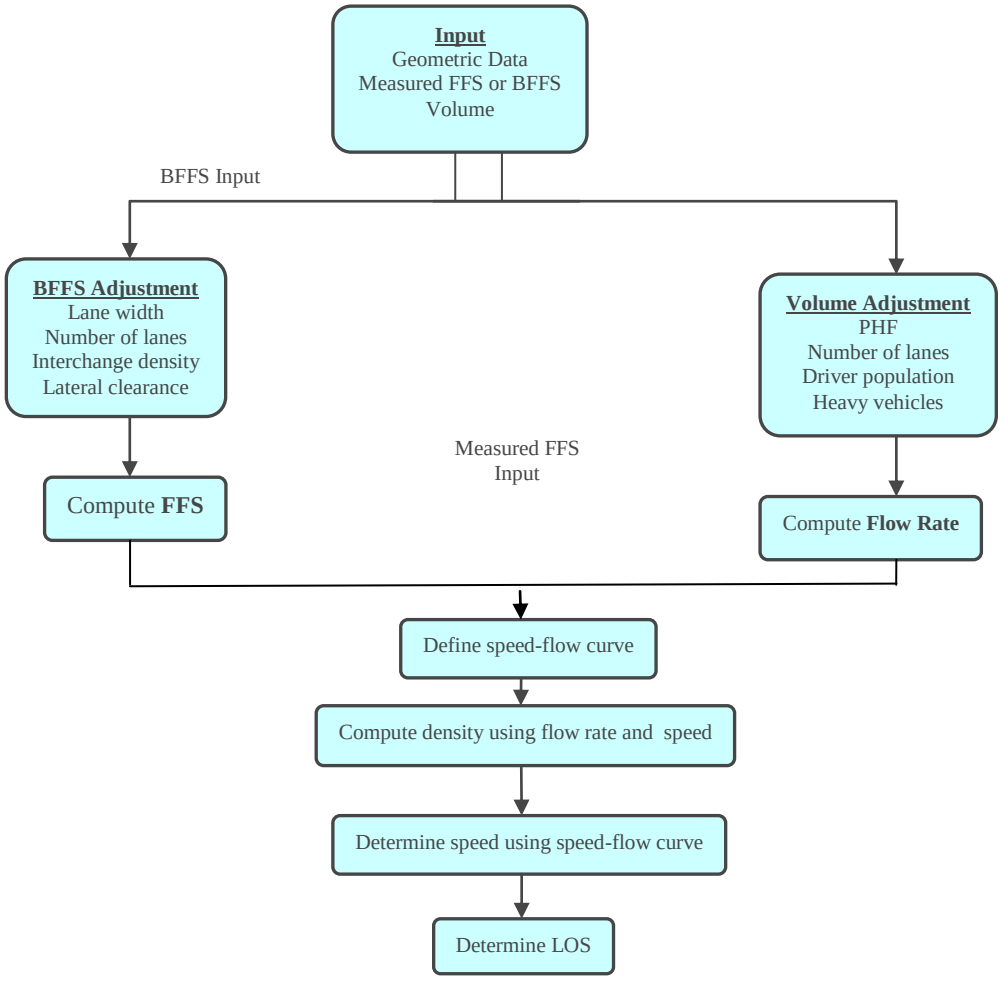
The study for road design should follow the JKR design manual. With various parameters, the process of design will be easier with an assist of spreadsheet. The development of the spreadsheet may consume time but it may be helpful for future used. Analysis of the result will be done to determine the level of service (LOS) and we can compare the accuracy of JKR traffic forecast.

After completion of the analysis, design improvement can be done to maintain the level of service of the current roads to meet the demands. It also helps to determine the time taken for the facilities to reduce their level of service. An option to provide alternative routes can overcome this problem and avoid unnecessary investment of facilities especially in restricted available space area.

1.2.1 Data Calculation Method

The flowchart below shows the method to calculate the level of service and formula used for the calculation

1.2.1.1 Multilane Highway



- **Determining FFS**

Use a baseline and adjust it (BFFS)

$$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID}$$

FFS = free-flow speed

BFFS = base free-flow speed

f_{LW} = adjustment for lane width

f_{LC} = adjustment for right-shoulder lateral clearance

f_{N} = adjustment for number of lanes

f_{A} = adjustment for access density

- **Determining Flow Rate**

Adjust hourly volumes to get pc/ln/hr

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

V = hourly volume (veh/hr)

PHF = peak hour factor

N = number of lanes in one direction

f_{HV} = heavy-vehicle adjustment factor

f_{P} = driver population adjustment factor

- Determine Heavy Vehicle Factor (f_{HV})

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

f_{HV} = Heavy vehicle adjustment factor

E_T, E_R = Passenger-car equivalents for trucks/buses and RVs

P_T, P_R = Proportion of trucks/buses and RVs in traffic stream

- Determine Density (D)

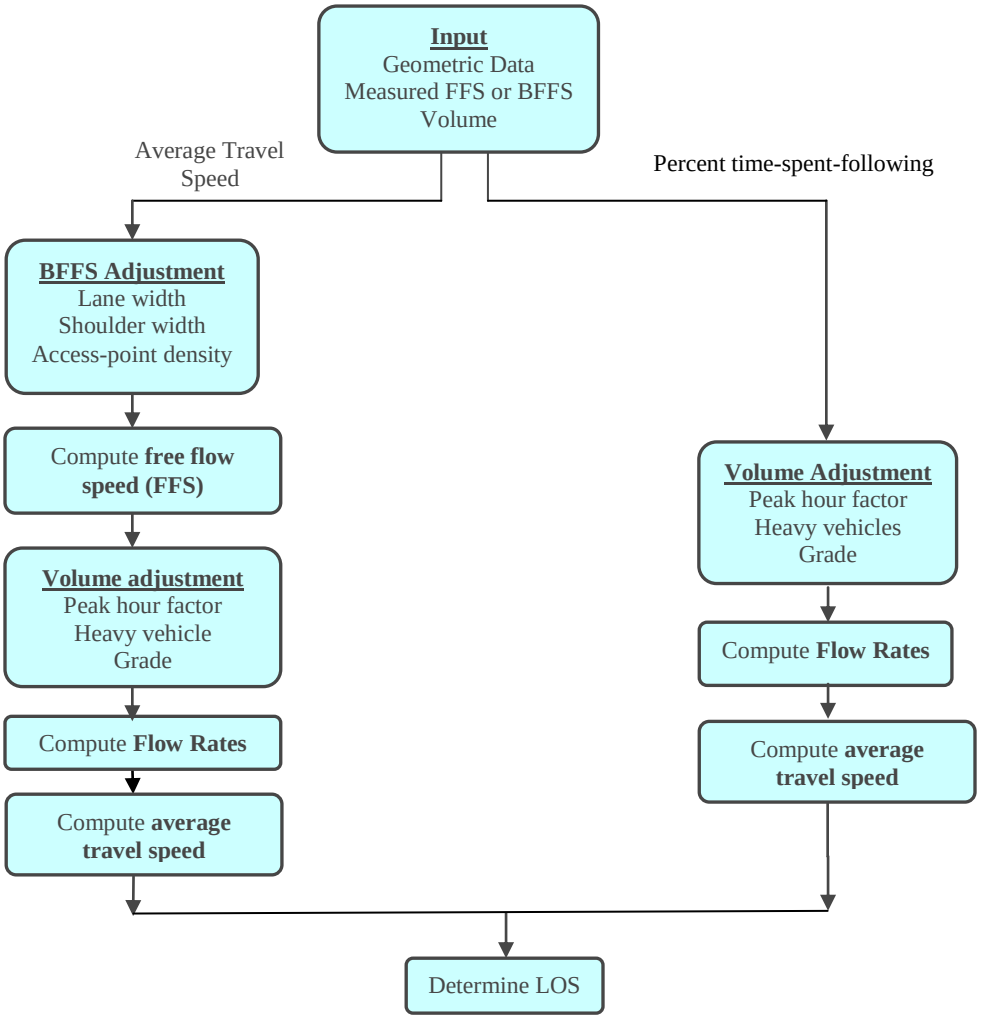
$$D = \frac{v_p}{S}$$

D = density (pc/km/ln)

v_p = flow rate (pc/hr/ln)

S = average passenger-car speed

1.2.1.2 Two-Lane Highway



Average Travel Speed (ATS)

$$ATS = FFS - 0.0125v_p - f_{np}$$

ATS = Average travel Speed

FFS = Free Flow Speed

v_p = Flow rate

f_{np} = Adjustment for no-passing zone

Percent Time-spent-following(PTSF)

$$BPTSF = 100(1-e^{-0.00087vp})$$

$$PTSF = BPTSF - f_{d/np}$$

BPTSF = Base Percent Time-spent –following

v_p = flow rate (pc/hr/ln)

$f_{d/np}$ = combined effect of directional distribution and no-passing zones

1.3 Key Milestone

Below are the key milestone that need to be achieve throughout both of the semester of final year project 1 (FYP I) final year project 2 (FYP II).

Table 1 : Key Milestone

Milestone FYP I	**Week**
Project Proposal	Week 3
Extended proposal (10%)	Week 6
Proposal Defense (40%)	Week 9
Interim Report (50%)	Week 11
Milestone FYP II	Week
Progress Report (10%)	Week 7
Pre-SEDEX (10%)	Week 10
Dissertation (40%)	Week 12
VIVA (30%)	Week 13
Technical Report (10%)	Week 14

1.4 Gantt Chart

Table 2: Gantt chart FYP I

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**Selection of Final Year Project topic**															
2	**Preliminary Research**															
	i) Meeting and discussion with supervisor															
	ii) Searching relevant literatures															
	iii) Preliminary research planning and structuring															
	iv) Preparing Extended Proposal															
3	**Submission of Extended Proposal**															
4	**Proposal defence**															
5	**Continuation Of Research**															
	i) Identification of roads															
	ii) Data gathering															
	iii) Analysis of data obtained															
6	**Submission Of Interim Draft Report**															
7	**Submission Of Interim Report**															

Table 3 : Gantt chart FYP II

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**Continuation Of Research**															
	i) Design Calculation															
2	**Submission of Progress Report**															
3	**Continuation Of Research**															
	ii) Analysis of result															
	Pre-EDX															
4																
	Submission of Draft report															
5																
	Submission of Dissertation (soft-bound)															
6																
	Submission of Technical Paper															
7																
	Oral presentation															
8																
	Submission Of Dissertion (hard-bound)															
9																

CHAPTER 4: RESULT AND DISCUSSION

6.1 Result

The highways selected are based on JKR forecast in 2003. The road classified into three part which depend on the expected year to reach its capacity. For this cases, the duration selected are between 4 year; 2004-2008,2009-2013 and 2014-2018.

Table 4 : Location Description For Traffic Census Stations

Station Number	Survey Type	Route Number	KM	Description of Locations
AR101	0	1	106.6	Ipoh-Tanjong Malim (Slim River toll house)
AR102	0	1	70.8	Ipoh-Tanjong Malim (south of Bidor)
AR301	3	1	35.9	Ipoh-Kampar
AR302	1	1	22.5	Ipoh-Kampar(100m south of Kota Bharu junction)
AR311	3	A8	15.3	Batu Gajah Route I (100m from Route I junction)
AR402	1	1	111.1	Ipoh-Bagan Serai-Butterworth
AR503	3	76	56.4	Ipoh-Kuala Kangsar-Lenggong
AR103	3	1	62.8	Ipoh-Tapar-Bidor
AR105	0	58	68.4	Ipoh-Bidor-Telok Anson
AR107	3	59	4.8	Tapah-Cameron Highlands
AR202	3	18	95.8	Ipoh-Simpang Ampat-Lumut
AR309	3	73	22.5	Ipoh-Siputeh-Parit
AR106	3	70	56.4	Ipoh-Kampar-Changkat Jering
AR203	3	60	86.9	Ipoh-Batu Hampar-Damar Laut
AR401	0	1	98.2	Ipoh-Bagan Serai
AR602	3	60	96.6	Ipoh-Batu Hampat-Changkat Jering
AR603	3	1	82.1	Ipoh-Changkat Jering-Semanggol
AR501	3	1	30.4	Ipoh-Kuala Kangsar (500m north of Sungai Siput town)
AR702	3	69	117.5	Ipoh-Simpang Ampat-Bagan Datoh
AR901	3	5	49.1	Ipoh-Pusing-Bota Kiri-Sitiawan

Based on road traffic volume in Road Traffic Volume Malaysia (RTVM), the levels of service are determined and default values in Highway Capacity Manual (HCM2000) were used for any unavailable data. The road classified into 3 parts based on the traffic forecast in 2003. Calculation based on 2003 and 2010 data was used to determine and compare the result for different year.

Table 5 : Level of Service on 2003

Census Stations	Highway type	Peak Hour Volume, pc/hr	Heavy Vehicles ,%	Free Flow Speed,km/h	Flow Rate, pc/hr/ln	Density, pc/km/ln	Average Travel Speed, km/h	Percent time spent following, %	Level of Service	Normal Growth Rate	year(s) to reach capacity	Remarks
2004-2008												
AR101	TWTL	934	11.6	84.3	1074	13	69	66.3	C	6.74	15	no
AR102	TWTL	835	30.1	84.3	977	12	70	66.1	C	5.73	19	no
AR301	TWTL	1945	22.2	84.3	2259	27	55	87.3	E	3.96	6	no
AR302	TWTL	1824	22.9	84.3	2120	25	57	86.1	E	5.12	6	no
AR311	TWTL	755	22.7	84.3	877	10	71	59.6	C	12.08	10	no
AR402	TWTL	1434	20.3	84.3	1663	20	63	79.1	D	4.17	13	no
AR503	TWTL	564	12	84.3	649	8	74	53.6	B	6.97	22	no
2009-2013												
AR103	TWTL	1129	29	84.3	1320	16	67	73.3	D	6.59	12	no
AR105	TWTL	784	18.8	84.3	924	11	71	61.6	C	7.18	16	no
AR107	TWTL	443	17.9	72.2	639	9	59	59.8	C	5.21	25	no
AR202	Multilane	2733	5	92.9	1592	17			D	4.9	10	no
AR309	Multilane	653	14.4	92.9	398	4			A	9.2	21	no
2014-2018												
AR106	TWTL	494	25.6	84.3	662	8	74	51.2	B	3.92	38	no
AR203	TWTL	673	20	84.3	795	9	72	57.2	C	5.02	26	no
AR401	TWTL	1224	20.3	84.3	1056	13	69	76.2	D	5.27	19	no
AR602	TWTL	713	28.9	84.3	857	10	71	59.5	C	3.83	31	no
AR603	Multilane	1573	31.8	92.9	1036	11			C	6.6	14	yes
AR501	Multilane	1398	19.5	92.9	872	9			B	2.78	40	no
AR702	TWTL	1002	13.9	84.3	1154	14	68	69.5	C	1.89	47	no
AR901	Multilane	1456	16.6	92.9	896	10			B	4.19	26	no

Table 6 : Level of Service in 2010

Census Stations	Highway type	Peak Hour Volume, pc/hr	Heavy Vehicles ,%	Free Flow Speed,km/h	Flow Rate, pc/hr/ln	Density, pc/km/ln	Average Travel Speed, km/h	Percent time spent following, %	Level of Service	Normal Growth Rate	year(s) to reach capacity, yr	Remarks
2004-2008												
AR101	TWTL	1335	15.9	84.3	1541	18	64	76.9	D	5.2	12	no
AR102	Multilane	1054	18.6	92.9	655	7			B	0.84	165	upgraded
AR301	Multilane	2707	14.2	92.9	1647	18			D	0.79	58	upgraded
AR302	TWTL	2139	15.9	84.3	1824	22	61	91.2	E	1.03	42	no
AR311	Multilane	648	17.5	92.9	400	4			A	-1.07	*	
AR402	Multilane	1561	19.7	92.9	974	10			B	-0.68	*	
AR503	Multilane	782	4.9	92.9	455	5			A	6.92	26	upgraded
2009-2013												
AR103	TWTL	1266	18.8	84.3	1419	17	66	75	D	1.23	56	no
AR105	TWTL	583	11.7	84.3	717	9	73	56	C	-2.95	*	
AR107	TWTL	608	7.8	72	739	10	58	66.6	E	1.67	80	no
AR202	Multilane	3615	3.2	92.9	2087	22			E	3.75	6	no
AR309	Multilane	628	14.2	92.9	382	4			A	-3.65	*	
2014-2018												
AR106	TWTL	653	21.4	84.3	774	9	72	56.2	C	3.12	42	no
AR203	TWTL	845	20.2	84.3	999	12	70	67.3	C	1.6	65	no
AR401	TWTL	1250	17.9	84.3	1446	17	67	75.3	D	0.07	944	no
AR602	TWTL	891	22.8	84.3	1059	13	69	67.4	B	-4.5	*	
AR603	Multilane	1582	24.7	92.9	1010	11			B	-6.52	*	
AR501	Multilane	1774	13.4	92.9	1075	12			C	2.38	38	no
AR702	TWTL	1069	10	84.3	1239	15	68	70.7	D	2.25	37	no
AR901	Multilane	1516	16.7	92.9	933	10			B	0.67	153	no

Table 4: Comparison of v/c ratio and Growth rate

Census Stations	V/C Ratio (2003)	V/C Ratio (2010)	Growth Rate (2003)	Growth Rate (2010)
2004-2008				
AR101	0.38	0.55	6.74	5.2
AR102	0.21	0.25	5.73	0.84
AR301	0.46	0.62	3.96	0.79
AR302	**0.76**	**0.9**	5.12	1.03
AR311	0.32	0.15	**12.08**	**-1.07**
AR402	**0.61**	**0.37**	**4.17**	**-0.68**
AR503	0.23	0.17	6.97	6.92
2009-2013				
AR103	0.47	0.51	6.59	1.23
AR105	0.36	0.26	**7.18**	**-2.95**
AR107	0.21	0.26	5.21	1.67
AR202	**0.60**	**0.78**	4.9	3.75
AR309	0.15	0.14	**9.2**	**-3.65**
2014-2018				
AR 106	0.21	0.28	3.92	3.12
AR203	0.28	0.36	5.02	1.6
AR401	0.51	0.52	5.27	0.07
AR602	0.31	0.26	**3.83**	**-4.5**
AR603	0.39	0.38	**6.6**	**-6.52**
AR501	0.33	0.4	2.78	2.38
AR702	0.42	0.44	1.89	2.25
AR901	0.34	0.35	4.19	0.67

Based on the table above, the reduction in growth rate can be clearly seen for the entire road. The reduction in AR311 (Batu Gajah Route I) is most significant which drop from 12.08% to -1.07.For AR302(. The other road for 2004-2008 forecast also show decrement although some of the road already upgraded. The most crucial road needed an upgrade is AR302(Ipoh-Kampar, 100m south of Kota Bharu Junction). While AR402(Ipoh-Bagan Serai-Butterworth) shows a high reduction in its v/c ratio.

For 2009-2013 forecast, the most significant drop in AR309(Ipoh-Siputeh-Parit) and AR105(Ipoh-Bidor-Teluk Anson) with 12.85% and 10.13% reduction respectively. While AR202(Ipoh-Simpang Ampat-Lumut) road almost reach its capacity. For 2014-2018 forecast, both AR602(Ipoh-Batu Hampar-Changkat Jering) and AR603(Ipoh-Changkat Jering-Semanggol) show negative growth rate in 2010 which unable the time of the road to reach its capacity forecast to be made.

2004-2008

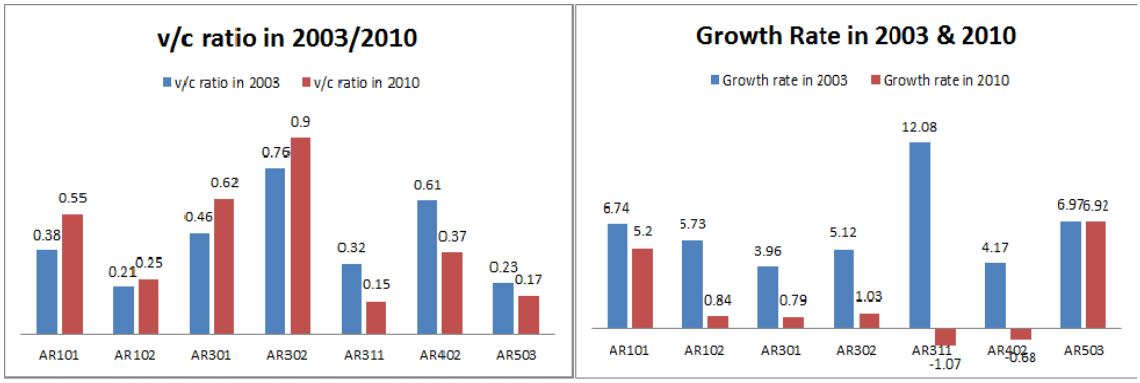


Figure 4:Comparison of v/c ratio and growth rate

2009-2013

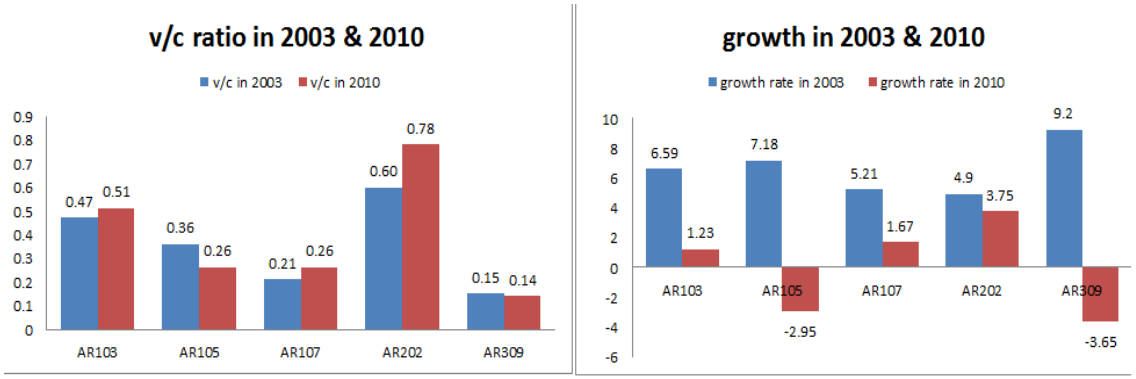


Figure 5: Comparison of v/c ratio and growth rate

2014-2018

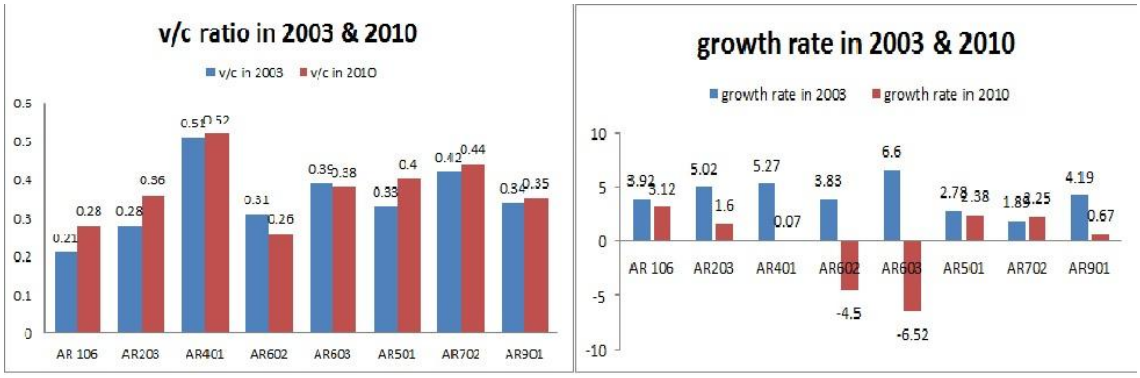


Figure 6: Comparison of v/c ratio and growth rate

Figure 4, 5 and 6 shows the graph to shows the comparison of the v/c ratio and growth rate in 2003 and 2010. By using graphical method the differences can be clearly seen compared by tabulation of data.

4.2 Discussion

The result of this research for current progress is on the current level of service of the selected road. The road selected based on the forecast by JKR in Road Traffic Volume Malaysia 2003 (RTVM 2010). We classify the road into three which is 2004-2008, 2009-2013 and 2014-2018. Most of the road in 2004-2008 already upgraded to dual carriageway in 2010. Therefore, we can check how the upgrading works improve the level of service. Based on the result, we can see most of the multilane highways are on good level of service (LOS) of A and B. It is the result of the upgrade from single carriageway to dual carriageway in recent years. Some of the multilane also was operating at LOS D.

For the single carriageway, mostly it operates in LOS C and D. In this level of service, increasing and unstable traffic flows are observed. Any obstruction on road can cause significant traffic jam. The single carriageways are mostly located in small population area which small in trip generation. Commonly it connect the small town area or as an alternative route. The type of terrain such as mountainous and rolling may cause difficulties for road expansion and upgrade. Therefore alternative of route are considered when increasing volume of traffic produce and safety of road users become and issues. The safety issues mostly involve the mountainous area with a lot of curve and low passing zone. The presence of heavy vehicle will reduce the level of service as it travel in low speed and limited passing distance.

Based on the result, we can observed that the growth rate for each road influence the traffic volume. Significant drop in volume cause the level of service to increase but unnecessary upgrade have been invested. As for example the AR311 v/c ratio in 2003 is 0.32 but the growth rate is 12.08% which is quite high and the road already upgraded by 2010. The problem occurred in 2010 where the growth rate reduces to -1.07 which means the volume reduce within the period. For most of other road, the growth rates are decrease and which means the facilities can carry the traffic volume in longer period. In RTVM 2010, no forecast had been made because some of roads are on upgrading process; therefore study only shows the current level of

service and its expected time to reach its capacity. There are some roads that shows a negative growth and no forecast can be done until the growth rate are positive.

The increases or decreases of traffic in selected highways are the result of new alternative routes. New road were built to increase the accessibility of road users and also to ensure the current road can operating in acceptable level of service without any upgrade. Other possible factors are the development of commercial or housing areas which diverged the route taken by road user. Development of new area are good in term of economic growth for the state and also road planning as in some restricted space which no upgrade can be done.

In traffic forecast, we may experience some uncertainty especially for long term planning. Some factors such as petrol and diesel price, Gross Domestic Product (GDP) and toll price. Petrol and diesel price are being a concern for people because most of their vehicles are using this natural resources. New technology developed to reduce the usage of natural resources such as hybrid vehicles. The reduction in market price for hybrid vehicle may able to maintain the traffic growth in steady state. Other alternative if the petrol and diesel price increase are the increase in public transport usage. Efficient public transport system can reduce the volume of traffic especially passenger car which improve the level of service. For Gross Domestic Product (GDP), it basically shows the economic growth for country. Increase in GDP means expected increase in traffic volume especially for heavy vehicle to transfer goods. For toll price factor, it about the expressway or highway usage. The reduction in toll price may increase the usage of the facilities which reduction in other alternative roads.

CHAPTER 5: CONCLUSION

5.1 Conclusion

The main objective of this research is to study about the accuracy of traffic forecast based on current traffic data. The objective can be achieved with the available data from Ministry of Works from about 10-20 years ago. Based on the latest available data, we computed the level of service and the expected years to reach the capacity. Some of the roads are not even existed before and the forecasted traffic may become different. The result shows that only some of the forecast are accurate.

The factor that may affect these results is the uncertain traffic growth. Construction of new and minor roads also may reduce the traffic in older highway. Significant traffic reduction helps to maintain the level of service and extend the road service's years. Developments of new area are one of the factors which may affect the accuracy of the forecasted traffic. It generates trips to the new area and resulting in change in demand. It can be seen by uncertain traffic growth rate within 10-20 years. The study will help as a tool to determine whether the current facilities can provide acceptable service for coming years in increasing population and traffic. It also can provide the v/c ratio which one of the parameter to determine the capacity of the road.

5.2 Recommendations

The result mostly shows that JKR forecast are inaccurate when compared using HCM approach. In some previous edition of Road Traffic Volume Malaysia, they provide details on the average road width, v/c ratio and time to reach capacity. Based on the RTVM 2003 and 2010, there are no specific details on the parameters where we can compare the result. Comparison only made based on JKR forecast and not on current road performance. Some assumptions need to be done to enable the author to calculate the result of this study due to unavailable data on the RTVM. Assumption was done based on HCM default value to avoid significant differences of the result. The result can be improve if less assumption can be done with more raw data available

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Figure A : TRAFFIC CENSUS STATIONS

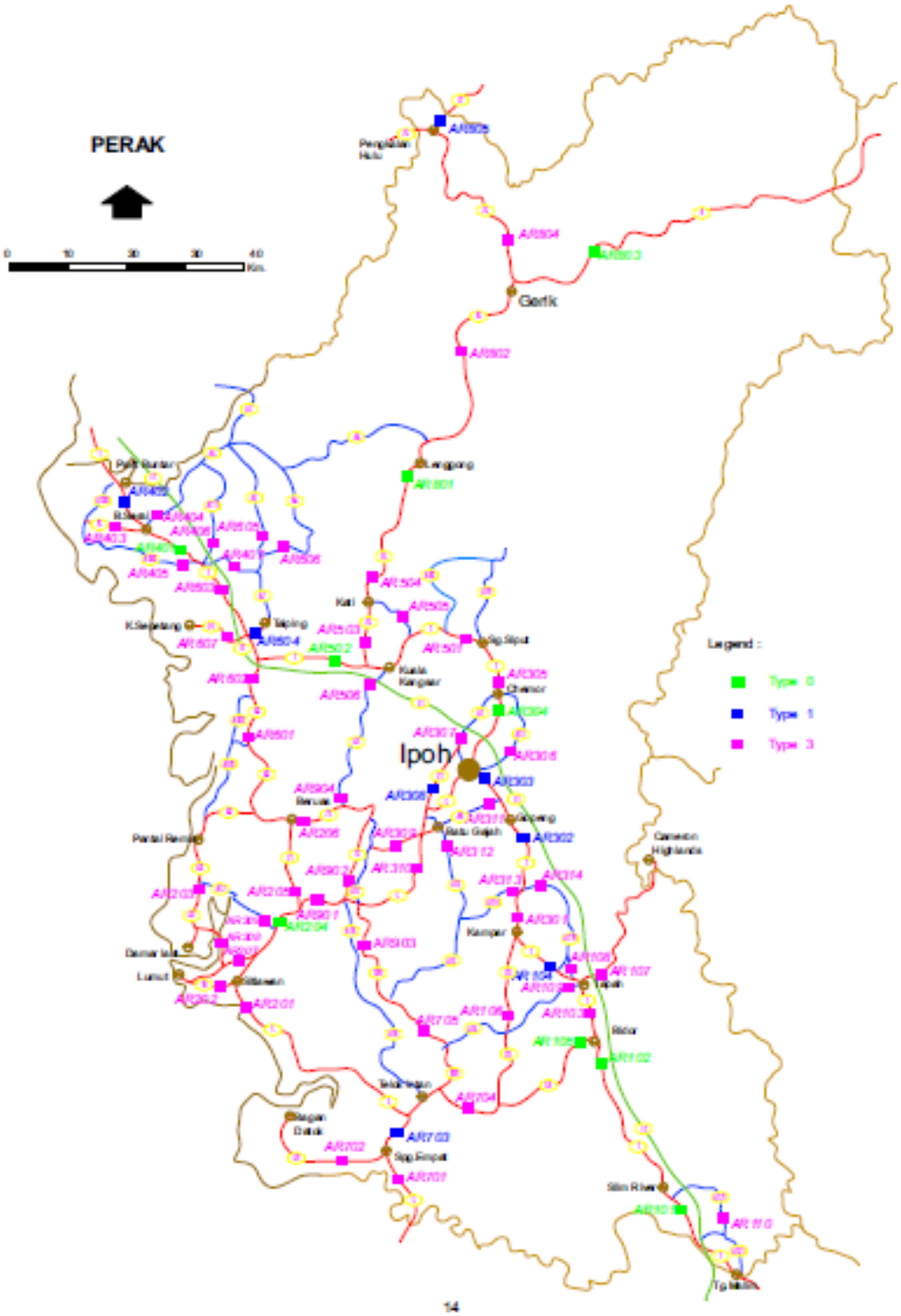

Figure A1 : AVERAGE 16 HOUR TRAFFIC VOLUME

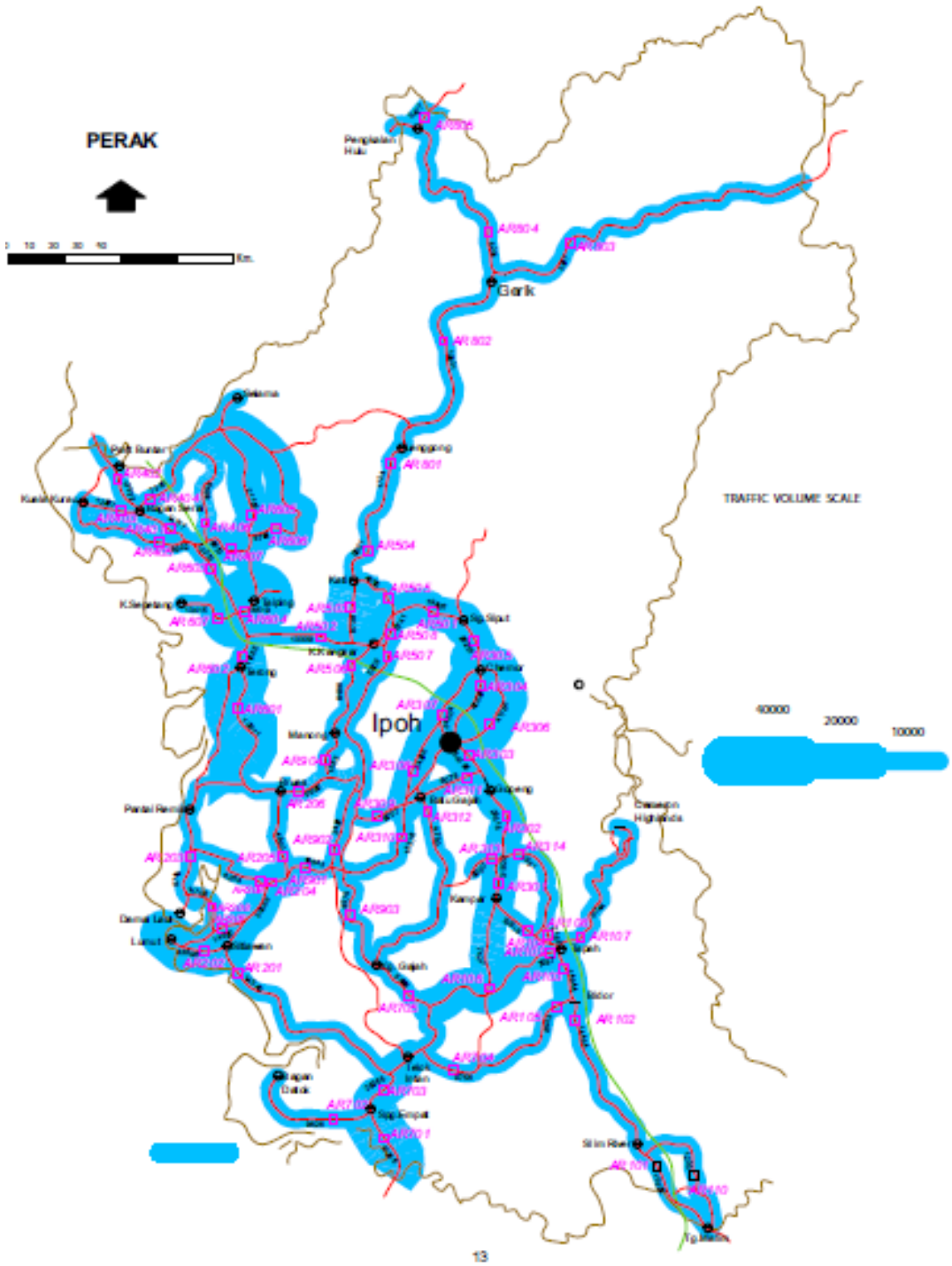

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Figure B 1:2003 Capacity Forecasts

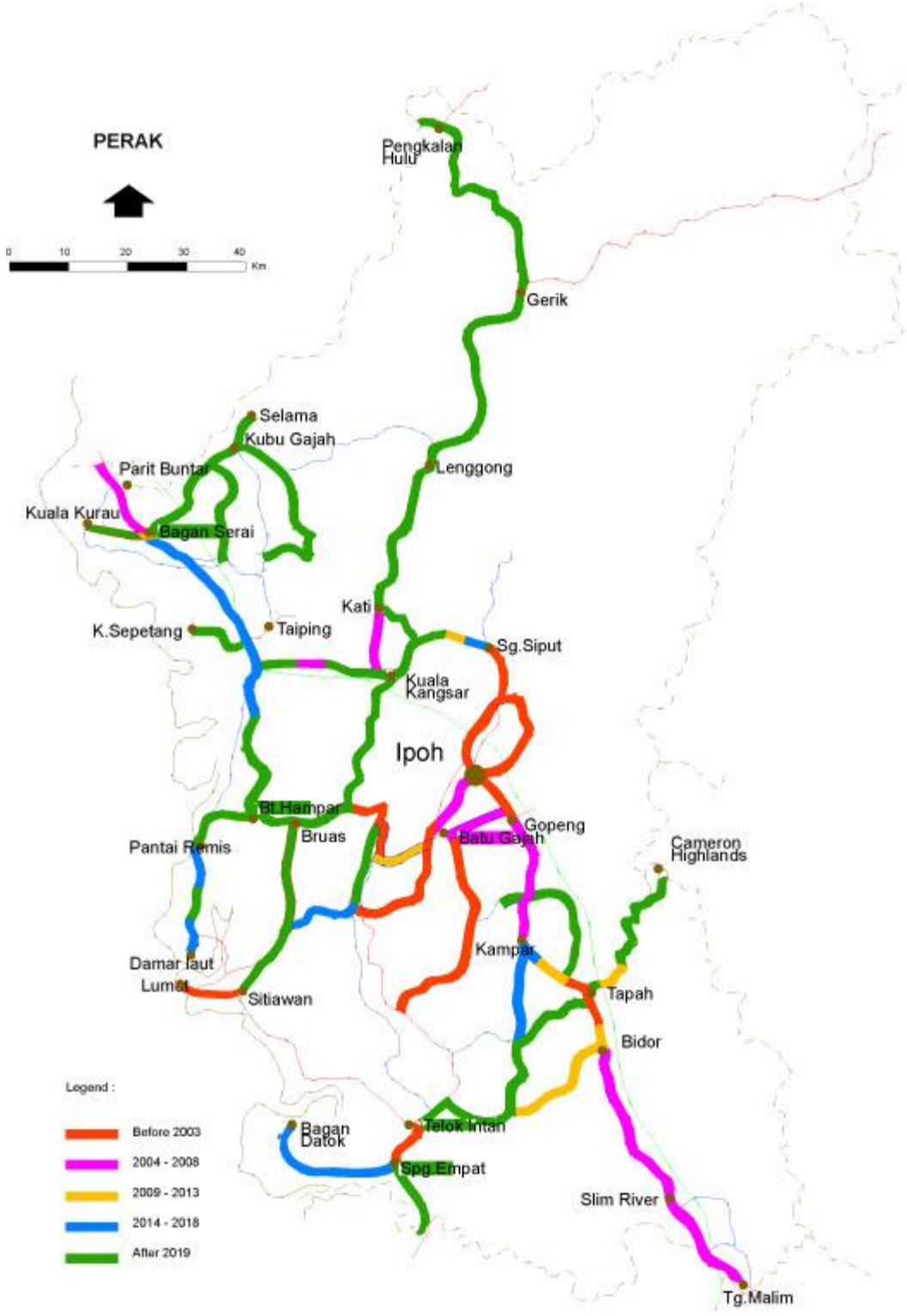

Figure B 2 : 2003 Traffic Census Stations

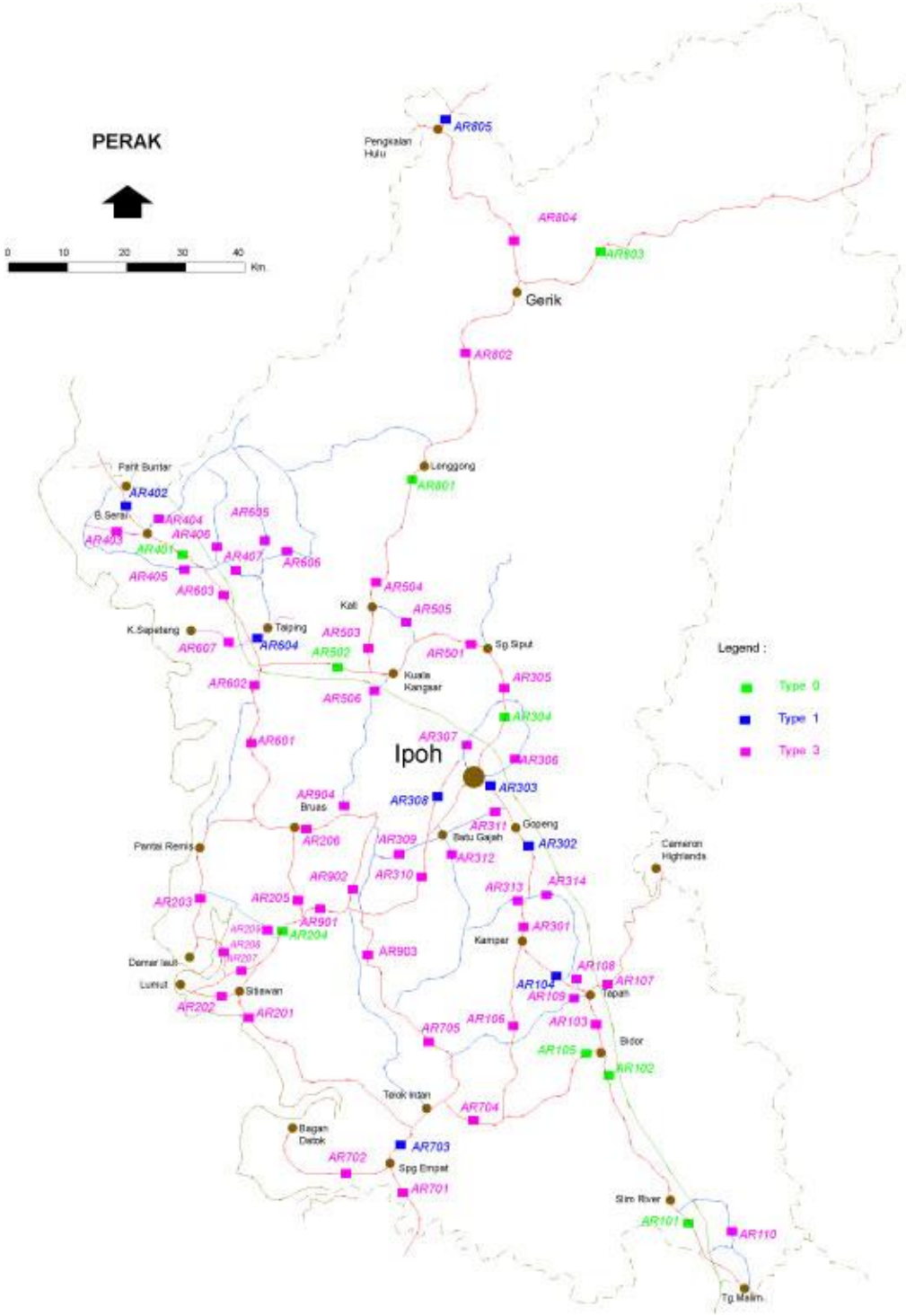

Figure B 3 : 2003 Average Traffic Volume

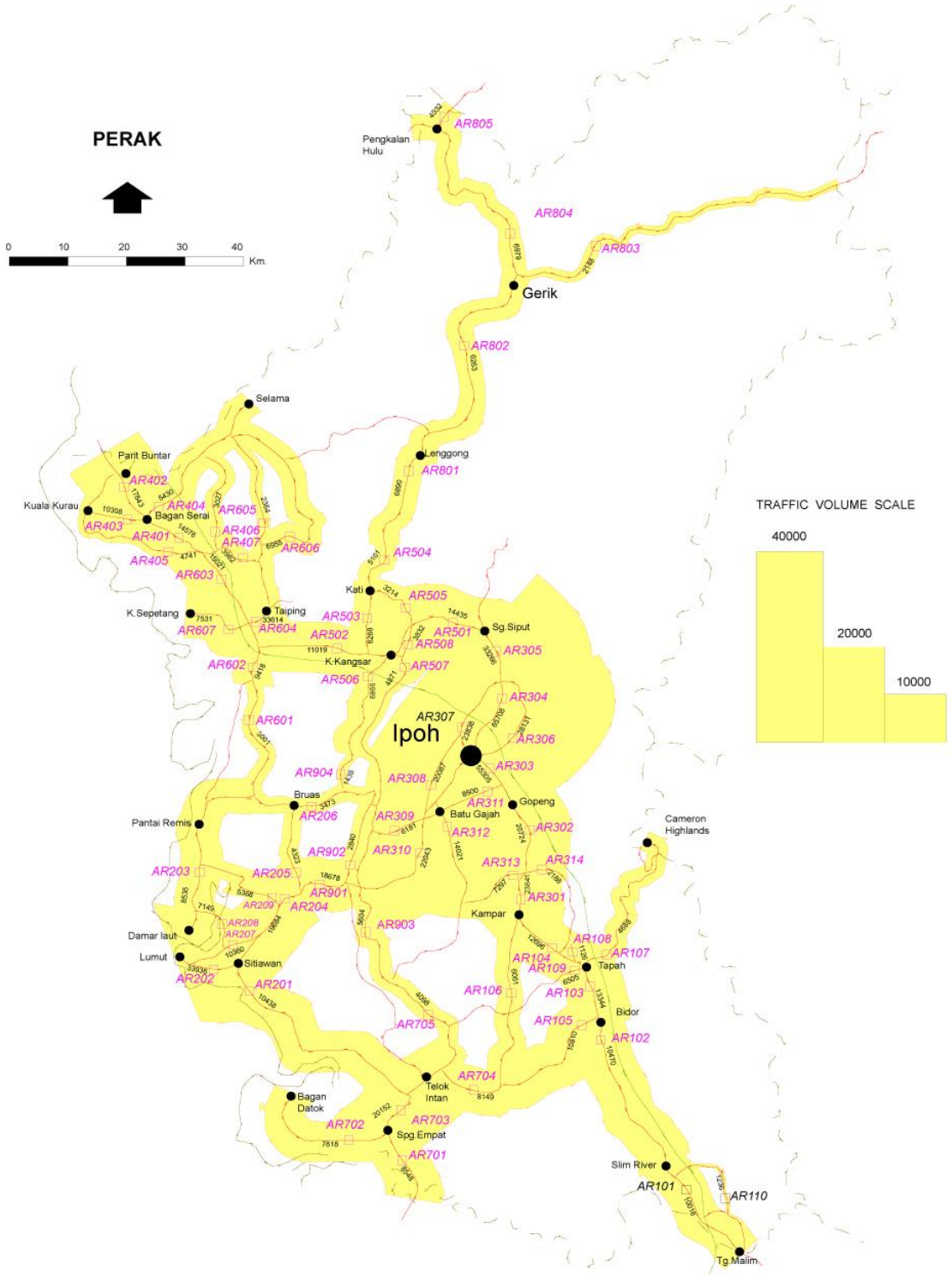

Table B-2

Level of Service Criteria for Multilane Highways

LOS	60 mph Free-Flow Speed				55 mph Free-Flow Speed				50 mph Free-Flow Speed			
	Density[a] (pc/mi/ln)	Speed[b] (mph)	Maximum[c] V/C	MSF[d] (pcphpl)	Density[a] (pc/mi/ln)	Speed[b] (mph)	Maximum[c] V/C	MSF[d] (pcphpl)	Density[a] (pc/mi/ln)	Speed[b] (mph)	Maximum[c] V/C	MSF[d] (pcphpl)
A	≤ 12	≥ 60	0.33	720	≤ 12	≥ 55	0.31	660	≤ 12	≥ 50	0.30	600
B	≤ 20	≥ 60	0.55	1,200	≤ 20	≥ 55	0.52	1,100	≤ 20	≥ 50	0.50	1,000
C	≤ 28	≥ 59	0.75	1,650	≤ 28	≥ 54	0.72	1,510	≤ 28	≥ 50	0.70	1,400
D	≤ 34	≥ 51	0.89	1,940	≤ 34	≥ 53	0.86	1,800	≤ 34	≥ 49	0.84	1,670
E	≤ 40	≥ 55	1.00	2,200	≤ 41	≥ 51	1.00	2,100	≤ 43	≥ 47	1.00	2,000
F	> 40[e]	< 55[e]	-[e]	-[e]	> 41[e]	< 51[e]	-[e]	-[e]	> 43[e]	< 47[e]	-[e]	-[e]

[a] Density in passenger cars per mile per lane.
[b] Average travel speed in miles per hour.
[c] Maximum volume-to-capacity ratio.
[d] Maximum service flow rate under ideal conditions in passenger cars per hour per lane.
[e] Highly variable, unstable.

≤ less than or equal to
≥ greater than or equal to

Source: Transportation Research Board, *Highway Capacity Manual*, Special Report 209 (Washington, D.C., 1994), pp. 7-8.

Table B-3

Level of Service Criteria for General Two-Lane Highway Segments

LOS	% Time Delay	V/C Ratio[a] Level Terrain Avg.[b] Speed	Level Terrain % No-Passing Zone 0	20	40	60	80	100	Rolling Terrain Avg.[b] Speed	Rolling Terrain % No-Passing Zone 0	20	40	60	80	100	Mountainous Terrain Avg.[b] Speed	Mountainous Terrain % No-Passing Zone 0	20	40	60	80	100
A	≤ 30	≥ 58	0.15	0.12	0.09	0.07	0.05	0.04	≥ 57	0.15	0.10	0.07	0.05	0.04	0.03	≥ 56	0.14	0.09	0.07	0.04	0.02	0.01
B	≤ 45	≥ 55	0.27	0.24	0.21	0.19	0.17	0.16	≥ 54	0.26	0.23	0.19	0.17	0.15	0.13	≥ 54	0.25	0.20	0.16	0.13	0.12	0.10
C	≤ 60	≥ 52	0.43	0.39	0.36	0.34	0.33	0.32	≥ 51	0.42	0.39	0.35	0.32	0.30	0.28	≥ 49	0.39	0.33	0.28	0.23	0.20	0.16
D	≤ 75	≥ 50	0.64	0.62	0.60	0.59	0.58	0.57	≥ 49	0.62	0.57	0.52	0.48	0.46	0.43	≥ 45	0.58	0.50	0.45	0.40	0.37	0.33
E	> 75	≥ 45	1.00	1.00	1.00	1.00	1.00	1.00	≥ 40	0.97	0.94	0.92	0.91	0.90	0.90	≥ 35	0.91	0.87	0.84	0.82	0.80	0.78
F	100	< 45	--	--	--	--	--	--	< 40	--	--	--	--	--	--	< 35	--	--	--	--	--	--

[a] Ratio of flow rate to an ideal capacity of 2,800 passenger cars per hour in both directions.
[b] Average travel speed of all vehicles (in mph) for highways with design speed ≥ 60 mph; for highways with lower design speeds, reduce speed by 4 mph for each 10-mph reduction in design speed below 60 mph; assumes that speed is not restricted to lower values by regulation.

≤ less than or equal to
≥ greater than or equal to

Source: Transportation Research Board, *Highway Capacity Manual, Special Report 209* (Washington, D.C., 1994), pp. 8-5.

Table 7 : Geometric Design Cateria for road in rural areas

DESIGN CONTROL & CRITERIA	1	Design Standard		R6			R5			R4			R3			R2			R1			R1A		
	2	Access Control		Full			Partial			Partial			Partial			Nil			Nil			Nil		
	3	Terrain		F	R	M	F	R	M	F	R	M	F	R	M	F	R	M	F	R	M	F	R	M
	4	Design Speed	km/h	120	100	80	100	80	60	90	70	60	70	60	50	60	50	40	40	30	20	40	30	20
CROSS SECTION ELEMENTS	5	Lane Width	m	3.50			3.50			3.25			3.00			2.75								
	6	Shoulder Width	m	3.00	3.00	2.50	3.00	3.00	2.50	3.00	3.00	2.00	2.50	2.50	2.00	2.00	2.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50
	7	Shoulder Width >100m	m	1.00			1.00			1.00			0.50			0.50			0.50			0.50		
	8	Median Width (Min)	m	6.00	5.00	4.00	4.00	3.50	3.00	3.00	2.50	2.00	N/A			N/A			N/A			N/A		
	9	Median Width (Desireable)	m	18.00	12.50	8.00	12.00	9.00	6.00	9.00	6.50	4.00	N/A			N/A			N/A			N/A		
	10	Marginal Strip (width)	m	0.50			0.50			0.25			0.25			0.00			0.00			0.00		
	11	Minimum Reserve Width	m	60			60(50)b			40(30)b			20			20			12			12		
ELEMENTS OF DESIGN	12	Stopping Sight Distance	m	285	205	140	205	140	85	140	85	65	85	65	45	65	45	30	45	30	20	45	30	20
	13	Passing Sight Distance	m	N/A			700	550	450	550	450	350	450	350	300	350	300	250	300	250	200	300	250	200
	14	Minimum radius	m	570	375	230	375	230	125	230	125	85	125	85	50	85	50	30	50	30	15	50	30	15
	15	Min. Length of Spiral	m	133	121	104	88	70	59	70	59	55	59	55	43	55	43	39	N/A			N/A		
	16	Max. Superelevation	Ratio	0.1			0.1			0.1			0.1			0.1			0.1			0.1		
	17	Max.Grade (Desireable)	%	2	3	4	3	4	5	4	5	6	5	6	7	6	7	8	7	8	9	10		
	18	Maximum Grade		5	6	7	6	7	8	7	8	9	8	9	10	9	10	12	10	12	15	25		
	19	Crest vertical Curve (K)		120	60	30	60	30	15	30	15	10	15	10	10	10	10	5	10	5	5	10	5	5
	20	Sag Vertical Curve (K)		60	40	28	40	28	15	28	15	12	15	12	10	12	10	8	10	8	8	10	8	8