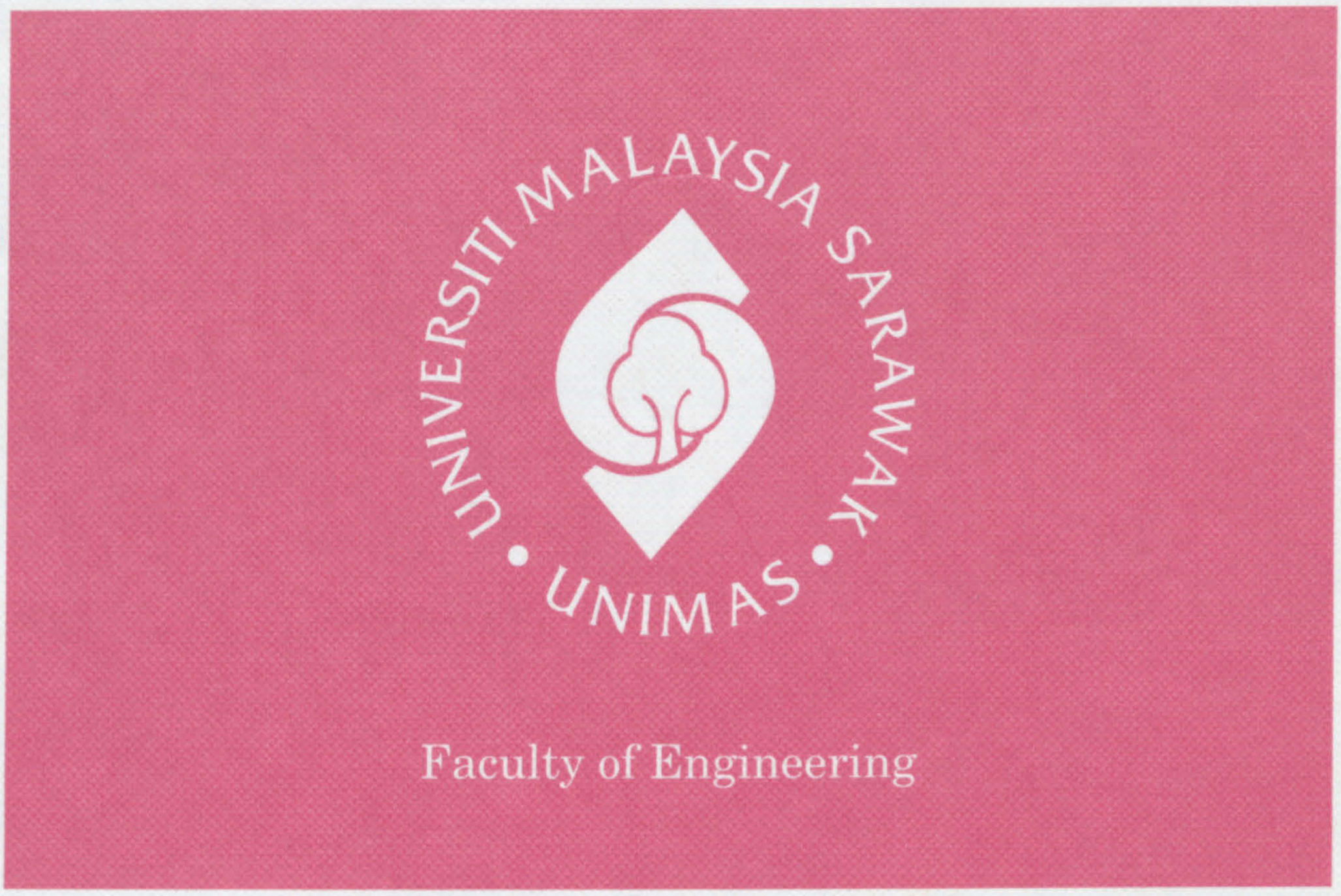


# FLOW PROCESSES OF BOTTLENECK FORMATION AT MODERN ROUNDABOUT INTERSECTION : A CASE STUDY AT KOTA SAMARAHAN

Lim Kok Ping



Bachelor of Engineering with Honours
(Civil Engineering)
2006

**Universiti Malaysia Sarawak**
**Kota Samarahan**

fk

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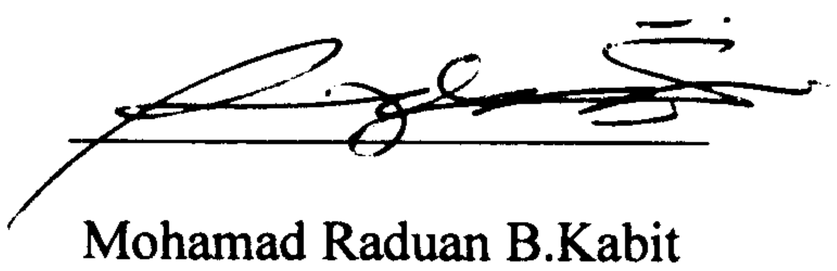

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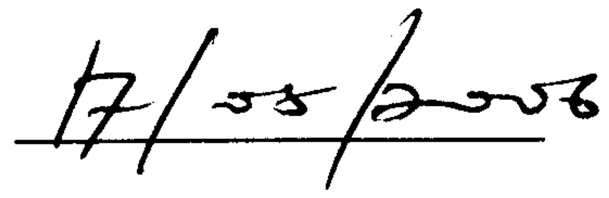

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Specially Dedicated To:
My beloved parents, brother and loved ones

# FLOW PROCESSES OF BOTTLENECK FORMATION AT MODERN ROUNDABOUT INTERSECTION: A CASE STUDY AT KOTA SAMARAHAN

LIM KOK PING

This project is submitted in partial fulfillment of

the requirements for the degree of Bachelor of Engineering with Honours

(Civil Engineering)

Faculty of Engineering

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2006

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# ABSTRACT

Increasing traffic congestion has brought with it environmental, social and economic implications. The bottleneck formation at roundabouts has been identified as one of the factors that contributed to traffic congestion. Primarily due its engineering design, exit arms at the roundabout tend to experience bottleneck formation which queues from upstream will cause formation at downstream. The aims of the project were to determine the flow processes of the bottleneck formation at modern roundabout intersection. Also, this study was aiming to find out clearly the patterns of the traffic that influence the bottleneck formation. Gyratory 4, was selected for the study site, which is located at Kota Samarahan. Traffic volume studies were carried out and the data obtained was analyzed at every 15 minutes for morning and afternoon peak hours to determine the rate of flows and density. At the meantime, the spot speed studies were also carried out to determine the average speed of vehicles at the bottleneck section. From the results obtained, the flow-density and speed-flow curves were plotted to show the pattern of bottleneck formation. It was found that the flow-density curves were less satisfactory and showed different curves when compared with theoretical ones. On the other hand, as the vehicles speed increases the bottleneck capacity decreases. Subsequently, some potential solutions, which are addressed in this report, could be adopted to alleviate the existing situations studied.

# ABSTRAK

Peningkatan dalam kesesakan lalu lintas telah membawa implikasi kepada alam sekitar, sosial dan ekonomi. Formasi "Bottleneck" yang berlaku di bulatan adalah antara factor yang menyebabkan kesesakan lalu lintas. Disebabkan oleh rekabentuknya, bulatan jalan keluar selalunya mengalami formasi "Bottleneck" di mana aturan berlaku di hulu akan menyebabkan formasi di hilir. Matlamat projek tahun ini adalah untuk menentukan process arus bagi formasi "Bottleneck" di persimpangan bulatan moden. Kajian berikut adalah bertujuan untuk mengetahui lebih jelas corak arus lalu lintaas yang menpengaruhi formasi "Bottleneck". Bulatan gyratori 4 dipilih untuk dijadikan kawasan kajian di mana terletak di Kota Samarahan. Kajian isipadu lalu lintas dilaksanakan dan data yang diperolehi dianalisis bagi 15 minutes untuk pagi dan petang masa puncak untuk menentukan arus dan ketumpatan. Kemudian, kajian kelajuan spontan dilakukan untuk menentukan kelajuan purata di kawasan "Bottleneck". Berdasarkan keputusan berikut, graf arus-ketumpatan dan kelajuan-arus dibuat untuk menunjukkan corak formasi "Bottleneck". Ia didapati bahawa graf arus-ketumpatan adalah tidak memuaskan dan menunjukkan perbezaaan dari graf sebenar teori. Di samping itu, apabila kelajuan kereta meningkat the keupayaan "Bottleneck" akan menurun. Kemudian, cadangan-cadangan akan dibuat untuk menyelesaikan masalah berkenaan di akhir laporan.

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| | | |
|---|---|---|
| PHF | - | Peak hour factor |
| $q$ | - | Volume (or Flow Rate) |
| $v$ | - | Speed (or velocity) |
| $k$ | - | Density |
| S | - | Standard deviation |
| vph | - | Vehicles per hour |
| E | - | Permitted error |
| N | - | Required sample size |
| Kph | - | Kilometer per hour |
| $V$ | - | Hourly volume, vehs |
| $V_{m15}$ | - | Maximum 15-minute volume within the hour, vehs |
| veh/15 | - | Vehicles per 15 minutes |
| $q_r$ | - | Passing rate |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Despite Sarawak's vast expanse, its major towns and cities are well connected by transportation routes. The road system within the State is being constantly upgraded and public transport system improved to cater to the increasing traffic volume. The Federal budget (for 2004) has allocated a sum of RM5.5 billion to widening the road networks connecting major towns in Sarawak (Sarawak.gov.my, 2004).

Trunk Road in Sarawak, totaling 4,600 km in services as of August 2003 (PPES News, 2004), are an indispensable infrastructure and have been playing a pivotal role in social and economic activities (Figure 1.1). Along the rural roadway, roundabouts are intersection systems which are introduced to manage the traffic flow from different direction. According to PPES News (2004), more than 100 roundabout systems have been introduce at Sarawak rural arterial road

since 1990 to secure a safe interchange of traffic for road user and also could accommodate the demand for the inhabitants in the state. However, with the economic growth and the variation of lifestyles, congestion is frequently caused mainly around major cities due to rapid increase of traffic demand and posing a serious social problem. Therefore, the Samarahan division is one of rural arterial network in Sarawak that has problem with heavy traffic flow and congestion.


**Figure1.1 Trunk road network in Sarawak (Sarawak.gov.my, 2004)**

Samarahan is situated some 40 kilometre from Kuching. Kota Samarahan is also the administration centre for the areas of Asajaya dan Muara Tuang. In the short time since its establishment, Kota Samarahan represents Sarawak´s research and development centre, with facilities and resources of International standards

(Sarawak Online, 2005). This is clearly demonstrated through the setting up of various institutions of higher learning in the area such as UNIMAS (Universiti Malaysia Sarawak), University Technology Mara (UITM), Tun Abdul Razak Teacher´s Training College, Industrial Training Institute Samarahan (ILP), Technology Park Sarawak, Sarawak International Medical Centre (SIMC), and the Dato´ Traoh International School and also the development of the Desa Ilmu residential areas due to high demand. There is also industrial area which known as Kota Samarahan Industrial Light (Mixed Light Industries).As such these have lead to the increment in the Kota Samarahan population. Consequently, the number of vehicles also increases in this region.

The scenario has become a phenomenon since the opening of Kota Samarahan expressway. In the Samarahan division, the population increase gradually in ten years times (1990-2000) which shown in the Table 1.1. The main attraction of traffic demand in Samarahan, especially in peak hour is higher institution learning and school. Traffic flow to Kota Samarahan has increased especially during peak hour periods. With the new expressway which has four roundabouts, whenever flows connected to this intersection and under high traffic flow, roundabout is unable to deal with such conditions. Excessive queues will occur as many vehicles are moving in circulating lanes.

**Table 1.1 Populations and average growth rate by division**
**(Source: spu.sarawak.gov.my, 2005)**

| Division | Population 1991 ('000) | Population 2000 ('000) | Average Annual Growth Rate (%) (1991-2000) |
|---|---|---|---|
| Kuching | 369.1 | 509.4 | 3.6 |
| Bau | 36.0 | 43.2 | 2.0 |
| Lundu | 24.5 | 28.1 | 1.5 |
| **KUCHING DIVISION** | **429.5** | **580.6** | **3.4** |
| Samarahan | 33.2 | 48.1 | 4.1 |
| Serian | 71.9 | 82.0 | 1.5 |
| Simunjan | 35.1 | 38.1 | 0.9 |
| Asajaya | 24.4 | 29.1 | 2.0 |
| **SAMARAHAN DIVISION** | **164.6** | **197.3** | **2.0** |

## 1.2 Statement of Problem

Congestion exist when the rate of flows are higher than any segments intersection capacity. At this junction the vehicles speed decreases considerably and so the travel time will increases. As such it affects the movement of people and goods. When there is accessibility, the economic activities and land use and also transport system will be increasing on that area. Therefore, the number vehicles will be increased and subsequently congestion occurs. Figure 1.2 shows the cycle of the land use and transport.

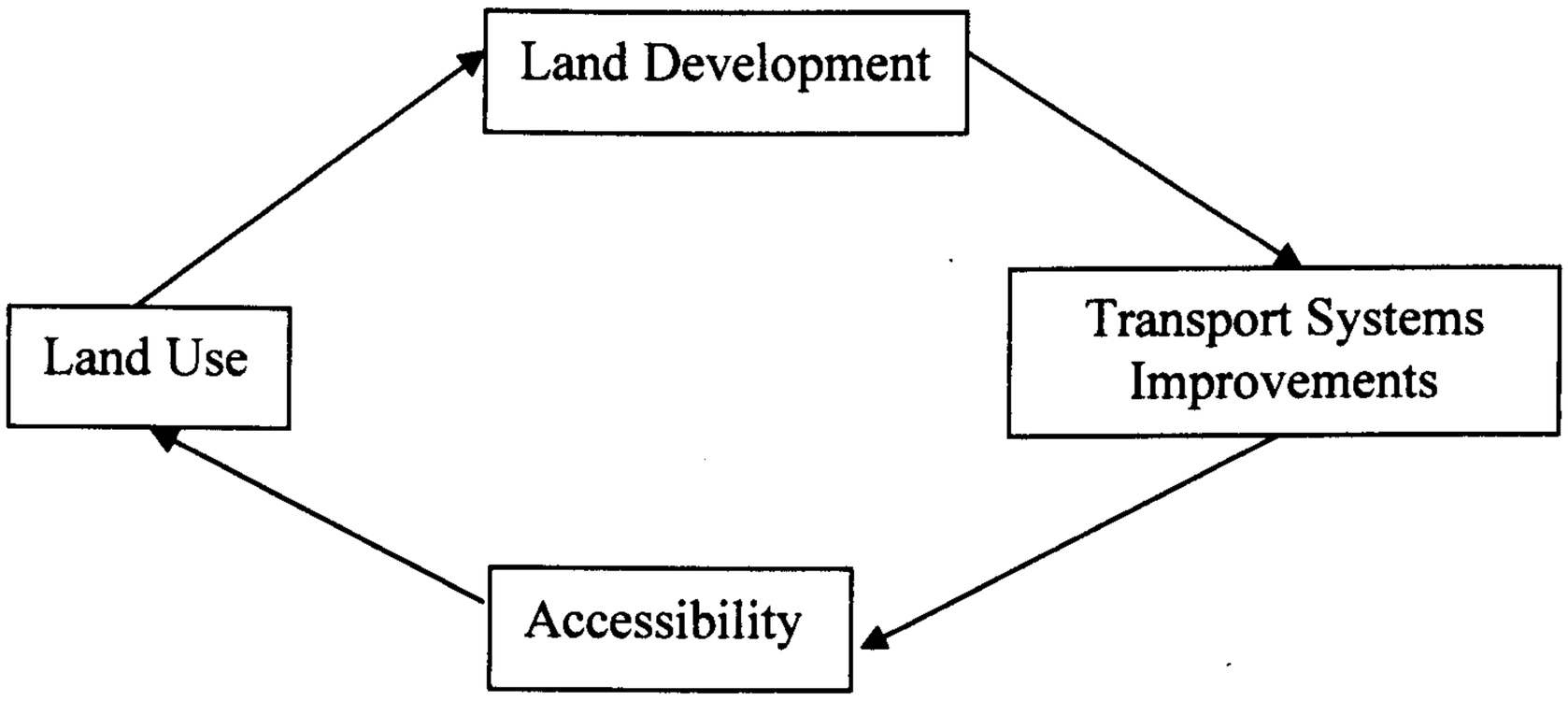


**Figure1.2 Land use and transport cycle (IHT, 1997, Transport in the Urban Environment. Chapter 8. Institute of Highways and Transportation, London.)**

Increasing traffic demand due to increased number of motor vehicle in Sarawak starting 1999-2003 (4 years) is to be some of the current impact on increasing of traffic congestion in Sarawak. Table 1.2 shows representative results of the congestion level and increased number of registered vehicles for Sarawak. With the increasing vehicles of external trips to and out of Kota Samarahan, obviously road congestion would be considerably high during the peak hours. At intersection system especially roundabout, congestion gives unique result, which are more influences by its geometric vehicles circulating flows. When dealing with unbalanced traffic flow, where one or more approach lane are dominant, others arms will experience a high delay (difficulty to enter) due to such condition. Blocking back at any exit arms start to activate when the capacity at the particular exit arm is lesser than the rate of flow.

The definition of traffic congestion on roundabout (bottleneck at roundabout) is a condition where the length of the queue of vehicle, which travel at low speed or repeat stop and go in circulation area, and the duration of such a state is more than 15 minutes. The bottleneck formation at the roundabout can illustrated as bottle that carry water. The bottle can carry only that much water, let say 500ml but we want to pour the water inside until 1000ml. Surely it will spill out and there is a lot of surplus water coming out from the bottle. This situation is much the same with the traffic at bottleneck locations. However, the situation for this traffic is even worse. In roundabout, we must see how many lanes are available to carrying the traffic. When the vehicles are increased in that area, for example from 2 lanes into 1 lane during peak hours, the traffic will become stop-and-go conditions. As the results, the capacity and traffic flow will reduce and fewer vehicles can get through the bottleneck area. Therefore, traffic congestion will take place and make that roundabout become poorly functioning to road user in term of comfort and convenience.

**Table 1.2 Statistic of the registered vehicles in Sarawak until 2003 (Source: Road Transport Department of Malaysia)**

| TYPES | 1999 | 2000 | 2001 | 2002 | 2003 | MEAN |
|---|---|---|---|---|---|---|
| **Car** | 231,234 | 244,991 | 263,752 | 286,696 | 311,682 | |
| **Growth Rate (%)** | | **13,757** | **18,671** | **286,696** | **311,682** | |
| | | **6%** | **8%** | **9%** | **9%** | **8%** |
| **Motorcycle** | 310,852 | 328,633 | 343,736 | 357,751 | 379,623 | |
| **Growth Rate (%)** | | **17,781** | **15,103** | **14,012** | **21,872** | |
| | | **6%** | **5%** | **4%** | **6%** | **5.3%** |
| **Taxi** | 3,881 | 4,133 | 4,383 | 4,575 | 4,891 | |
| **Growth Rate (%)** | | **6.5%** | **6%** | **4.5%** | **6.9** | **6%** |
| **Bus** | 2,225 | 2,259 | 2,281 | 2,347 | 2,390 | |
| **Growth Rate (%)** | | **1.5%** | **1%** | **2.9%** | **1.8%** | **1.8%** |
| **Truck** | 35,406 | 37,447 | 39,003 | 40,682 | 43,037 | |
| **Growth Rate (%)** | | **5.8%** | **4.2%** | **4.3%** | **5.8%** | **5%** |
| **Others** | 54,742 | 61,347 | 67,914 | 73,674 | 81,263 | |
| **Total** | **638,340** | **678,810** | **721,069** | **765,725** | **822,886** | |
| **Growth Rate (%)** | | **40,470** | **42,259** | **44,656** | **57,161** | |
| | | **6.3%** | **6.2%** | **6.2%** | **7.5%** | **6.6%** |

## 1.3 Objectives of the study

The primary aim for this study is to evaluate traffic flow of bottleneck at the roundabout in Kuching-Samarahan area. Below are the specific objectives, which include:

i) To analyze and evaluate the traffic flow characteristic at roundabout bottleneck area.

ii) To evaluate and model bottleneck formation at roundabout and determine the bottleneck capacities.

iii) To identify some potential alternatives solutions to mitigate the problem.

## 1.4. Scope of study

This study is focusing only on one of the roundabouts at Kuching-Kota Samarahan expressway which is Gyratory-4 (refer Appendix C). The study will involve analysis of traffic flow with strong stream of vehicles where the bottleneck formation occurs. The data of the traffic flow parameters can be collected using traffic volumes and spot speed studies. All the relationship of the traffic flow parameters such as density, speed and flow will be studied.

At later stage, the researcher will discuss some potential solution to alleviate the bottleneck formation problem.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Modern Roundabout

A roundabout is a form of circular intersection and control which accommodates traffic flow in one direction around a central island that resulting in lower operating speed, operates with yield control at all roundabout entry point, and gives priority to vehicles within the roundabout (circulating flow). Additionally, this roundabout is using the splitter island and flared lanes to smooth the progress of entry and exit conditions. Figure 2.1 shows the geometrical elements of the modern roundabout.