A. Caroline Sutandi

Advanced Traffic Control Systems

Performance Evaluation in a Developing Country

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I dedicate this book to my family Eric, Irene Nadia, Renate Arlene
for their love and continuous encouragements
and to my colleague Dr Hussein Dia.

CONTENTS

LIST OF ABBREVIATIONS

AIMSUN: Advanced Interactive Microscopic Simulator for Urban and Non Urban Networks

ATMS : Advanced Traffic Management Systems

ATCS: Adaptive Traffic Control Systems

BLISS: Brisbane Linked Intersection Signal System

CBD: Central Business District

CCTV: closed circuit televisions

DMI: distance measuring instrument

GETRAM: The Generic Environment for Traffic Analysis and Modelling

TEDI: traffic editor

IHCM: Indonesian Highway Capacity Manual

ITS: Intelligent Transportation Systems

RLS: Recursive Least Squares technique

SCATS: Sydney Co-ordinated Adaptive Traffic System

SCOOT: Split Cycle Offset Optimisation Technique

STREAMS: Synergised Transport Resources Ensuring an Advance Management System

VADAS: Video Analysing Data Acquisition System

VDDAS: Vehicle Detector Data Acquisition System

PREFACE

Advanced Traffic Management Systems (ATMS) is one of the ITS technologies that have been used to ease transportation problems in many large cities in developing countries. ATMS will integrate the management of various roadway functions, by predicting traffic congestion, optimising traffic flow, and providing alternative routing instructions to vehicles in regional areas, so as to improve traffic safety and comfort and enhance the environment. One application of ATMS involves Adaptive Traffic Control Systems (ATCS), which are the focus of this book. ATCS deal with a wide variety of issues including traffic control devices, travel demand, traffic flow, the modeling, simulation, and management. Among a number of problems in transportation area, professionals have to deal with, for example traffic congestion, traffic managements, and safety, ATCS used to improve traffic performance.

This book is divided into ten chapters. Chapter 1 beginning with traffic conditions in large cities in developing countries. Moreover, the framework of Sydney Co-ordinated Adaptive Traffic System (SCATS) as one of ATCS tools, performance measures, and analysis of SCATS performance is provided. Chapter 2 discusses regarding microscopic traffic simulation models used as a tool to evaluate the systems, including developing the models, statistical methods used to analyse the result of the models, and applications. Chapter 3 involves the determination of road network, required field data regarding the road network, and examples in developing country as the real application. Chapter 4 discusses regarding the framework of microscopic traffic simulation models which used in developing calibrated and validated models presented in Chapter 5 and Chapter 6, respectively. Chapter 7 provides performance comparison between ATCS and Fixed Time Traffic Control Systems usually used in large cities in developing country with real application. Chapter 8 presents traffic performance measures and significant variables that are crucial to determine in order to improve traffic performance. A number of recommended improvement are also provided. Chapter 9 evaluates the recommended improvements to enhance the performance of ATCS implemented in developing country. Chapter 10 as the last chapter in this book provides conclusions, recommendations, and future research directions that can be done in the scope of ITS implementation.

Since there is a very limited academic and practical literature exist on providing solutions of the problems, the results and findings presented in this book are very beneficial for road authorities to determine traffic management policy, for traffic engineers to determine the best practices for the implementation of advanced traffic control systems in their cities, and also for researchers or anyone else who concern about how to reduce traffic congestion.

A. Caroline Sutandi

CHAPTER 1
ADVANCED TRAFFIC CONTROL SYSTEMS

1.1 TRAFFIC CONGESTION IN DEVELOPING COUNTRIES

Traffic congestion is increasingly becoming a severe problem in many large cities around the world. The problem arises from many causes such as rapid population growth, high rates of urbanisation (Morichi, 2005), high annual vehicle growth rates (World Bank, 2002), poor planning at early stages of development of the city, limited land area and diminishing financing for road infrastructure. The problem is more complex in developing countries, where cities are growing much faster than in developed countries. The average annual population growth in developing countries is estimated at around 5% compared to 0.7% in developed countries (Sinha, 2000). According to United Nations estimates, there will be about ninety-three cities with more than five million inhabitants each by the year 2050, and eighty of them are in Third World countries (Morichi, 2005, Kuntjoro Djakti, 1996).

Congestion causing poor traffic performance has negative impacts on economic productivity, environmental quality (Sutandi, 2007a, 2008) and safety, through higher fuel consumption, increased costs of goods and service, increased air pollution, and worsened safety conditions. Road authorities have now recognised that building additional road capacity alone does not help to solve traffic congestion. More emphasis is being placed recently on travel demand management techniques and the application of advanced technologies such as Intelligent Transportation Systems (ITS) to improve traffic operations. ITS involves the application of advanced technologies, including computers, information processing, communications and control systems, to improve the efficiency and capacity of existing road infrastructure, reduce traffic congestion, increase road safety and contribute to the ease and convenience of travel (Dia, 2005). These systems collect, store, process, and distribute information relating to the movement of people and goods (US DOT, 2005).

Advanced Traffic Management Systems (ATMS) is one of the ITS technologies that have been used to ease transportation problems in many large cities in developing countries. ATMS will integrate the management of various roadway functions, by predicting traffic congestion, optimising traffic flow, and providing alternative routing instructions to vehicles in regional areas, so as to improve traffic safety and comfort and enhance the environment (Sutandi, 2007a, 2008, Abdul Azeez, et al., 2005; Sussman, 1996). One application of ATMS involves Adaptive Traffic Control Systems (ATCS), which are the focus of this book.

There are a number of Adaptive Traffic Control Systems, for instance SCATS (Sydney Co-ordinated Adaptive Traffic System), SCOOT (Split Cycle Offset Optimisation Technique), BLISS (Brisbane Linked Intersection Signal System) and STREAMS (Synergised Transport Resources Ensuring an Advanced Management System). SCATS has gained popularity in Australia, Asia, and more recently in North America (PATH, ITS, 2005). While SCOOT is applied in England and BLISS and STREAM in Australia. Since the focus of this book is performance evaluation of SCATS in large cities in developing countries, therefore SCATS will be discussed in detail in the following sections and chapters.

SCATS is applied in many large cities in developing countries in Asia, including Singapore, Cebu and Manila in the Philippines, Sandakan and Serembam in Malaysia, Sha Tin, Hong Kong and Guangzhou in China, Bandung and Jakarta in Indonesia, Brunei Darussalam, and Suva in Fiji (AWA Plessey, 1996a and AWA Plessey, 1996b). In addition SCATS is installed in 36 cities worldwide and controls around 7,000 traffic lights (ITS Australia, 2005, Ogden and Taylor, 1999).

SCATS was developed by New South Wales Department of Main Roads Australia. SCATS is a dynamic control system that can accommodate changing conditions using real time input from a number of different sources, such as road detectors at stop lines, video cameras (CCTV), and pedestrian push buttons. This system updates intersection cycle length, stage split, and co-ordination with adjacent intersections within a road network to meet the variation in demand and improve traffic flow (US DOT, 2005, Ogden and Taylor, 1999).

SCATS application in developing countries is noteworthy, because cities in these countries face more severe transportation problems than those in developed countries (Sinha, 2000). These cities have low network densities, only 6 to 11% of the total city area, compared with 20 to 25% in large cities in developed countries, such as London, Paris and New York (Morichi, 2005). This limited road infrastructure has to serve city residents with a high population density and has also to serve vehicles with a high annual growth rate. Road authorities have realised that application of Intelligent Transportation is needed to improve the efficiency and capacity of existing road infrastructure.

In order to achieve a good traffic performance, application of SCATS should be based on the specific local conditions that commonly occur in large cities. There are many differences between conditions in developing countries and those in the developed countries where the advanced technology SCATS was developed. Some of these specific conditions include:

1. There is no prior experience with SCATS, so that preparation and planning has to be done well before implementation.
2. Large cities in developing countries have low road network densities with poor conditions, for instance: short distance between intersections, varying distances between intersections along the corridor, poor road hierarchy, and irregular patterns of road network, with many intersections.
3. These cities experience much higher congestion levels because of the intersection geometry, for examples: many types of intersection with poor road hierarchy and narrow lane widths.
4. Furthermore, traffic conditions are worse for various reasons, for instance:
   - many types of vehicle using the same lane (poor lane discipline);
   - parking activity near intersections;
   - road capacity is not fully utilised because of on-street parking and street vendor activity on sidewalks, forcing pedestrians to use the street;
   - poor land use regulation;
   - bus and other public transport vehicles frequently stop anywhere along the street.

Because of these conditions there are disparities between supply and demand, and there are many special features of roads and road networks in cities of developing countries. Therefore, it is crucial to investigate the factors that influence SCATS performance and what should be done to improve that performance. It is important to evaluate the traffic performance that exists after SCATS is implemented. Furthermore, it is more important not only to evaluate the traffic performance after SCATS is implemented, but also, based on the observations and evaluations made, to identify significant variables that influence SCATS performance. Moreover, it is vital to determine how to improve traffic performance, given the constraints of inadequate road networks and poor geometric conditions, poor lane discipline, and complex road user interactions. In order to provide recommended improvements, a simulation approach needs to develop to evaluate SCATS performance and to identify the significant variables that influence the performance.

1.2 THE FRAMEWORK OF SCATS

Advanced Traffic Control Systems have been recognised as one of the most direct methods for relieving urban traffic congestion. ATCS are effective tools in co-ordinating traffic signals to reduce delays, stops and fuel consumption (Ronghui, Liu, et al., 2005, Midenet, Sophie, et al., 2004, Taylor, James C., et al., 2004, Ogden and Taylor, 1999, Hendrickson, et al., 1998), to maximise traffic throughput in response to traffic demand via detectors (Giannakodakis, 1995) and to improve safety (PATH, ITS, 2005). The control system operates through the selection and implementation of three control elements i.e. cycle time, phase split and offset, for every signalised intersection in the network. The offset is the difference in the starting times of the green phases of adjacent intersections (Transportation Research Board, 2000, Ogden and Taylor, 1999).

In the SCATS system as one of ATCS tools, all signalised intersections are grouped into a number of regions, each consisting of up to 120 local controllers, all controlled by one regional computer, and connected to a central monitoring system. Each region is divided into smaller sub-areas, each containing from one to ten signalised intersections that share a common cycle time. The common cycle time is up-dated every cycle according to the degree of saturation of the sub-area. Four phases split plans and five internal offset plans are available at each intersection within a sub-area as a function of the current cycle time. There are also five external offset plans that are selected by an algorithm for the purpose of merging sub-areas. When two adjacent sub-areas are merged, the common cycle time for combined area is the larger cycle time of the two separate sub-areas before linkage (Ogden and Taylor, 1999). SCATS system operation is shown in Figure 1.1.

1.3 PERFORMANCE MEASURES

The usual measures used to evaluate the performance of SCATS systems are throughput, travel time, intersection delay, and queue length. When evaluating the performance of a SCATS system through simulation models, these measures would be collected as an independent data set. The first data set is used for developing the initial models and for model calibration while the second data will be used for model validation.

It is important here to define some of the basic parameters used in the evaluation of traffic systems. Traffic flow is the result of interactions between vehicles, driver behaviour, activities, road network, and the roadway system, including traffic signs, control devices, markings, etc. If an observer or recorder at a stop line counts the number of vehicles **N** passing the stop line in time **T**, then the throughput **q** is defined as:

$$q = \frac{N}{T} \qquad [1.1]$$

At a microscopic level, for a traffic analysis where individual vehicles are considered, the corresponding variables are time headways, individual vehicle speeds, and distance headways (Stamatiadis, 2000). Throughputs and time headways are related to each other. The total elapsed study time **T** is made up of the sum of the headways **h** recorded for each vehicle, defined as:

$$T = \sum_{i=1}^{N} h_i \qquad [1.2]$$

If the sum of the headways is substituted in equation 1.1 for the total time, **T**, then it can be seen that the throughput and the average headway, **h,** have a reciprocal relationship with each other.

$$q = \frac{N}{T} = \frac{N}{\sum_i h_i} = \frac{1}{\frac{1}{N}\sum_i h_i} = \frac{1}{\bar{h}} \qquad [1.3]$$

Measurement of the speed of an individual vehicle, $\mathbf{v_i}$, requires observation over both time and space. The instantaneous speed of an individual vehicle is defined as follows:

$$v_i = \frac{d_x}{d_t} = \lim_{t_2 \to t_1 \to 0} = \frac{x_2 - x_1}{t_2 - t_1} \qquad [1.4]$$

Traffic density, **k**, is defined as the number of vehicles, **M**, occupying one lane of a segment of roadway with length equal to one unit, **X**, for instance 1 km or 1 mile. Occupancy is the percent of time that a traffic detector, such as a loop detector, microwave or video detector, is occupied by vehicles.

$$k = \frac{M}{X} \qquad [1.5]$$

Obviously there is a relationship between density and vehicle spacing, where vehicle spacing is expressed as the distance headway, **d**. The total distance over which density is measured is the sum of the distance headways. Therefore, the density of the traffic stream is the reciprocal of the average distance headway.

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Traffic congestion is increasingly becoming a severe problem in ma large cities around the world. The problem is more complex developing countries where cities are growing at a much faster rate th those in the developed world. Advanced Traffic Control Systems (ATC are one of the Intelligent Transportation Systems (ITS) technologies th have been recommended and used as a tool to ease congestic problems in many large cities in the developing world. Analys regarding how specific local conditions commonly observed in the cities affect the performance of these systems, performance comparison between ATCS and Fixed Time Traffic Control Systems usually used in the large cities, and a number of recommended improvements to enhance the performance of ATCS are provided in this book. The results and findings presented in this book are very beneficial for road authorities to determine traffic management policy, for traffic engineers to determine the best practices for the implementation of advanced traffic control systems in their cities, and also for researchers or anyone else who concern about how to reduce traffic congestion.

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