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DETERMINIG ROADWAY CAPACITY USING DIRECT EMPIRICAL METHODS

AMINU SULEIMAN

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil – Transportation and Highway)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JULY 2011

I hereby declare that this project report entitled "*Determining Roadway Capacity Using Direct Empirical Methods*" is the result of my own study except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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“This Project is dedicated to my family and the Muslim Ummah”

“Also I owe special thanks to all my parents, wife lecturers, friends and well wishers, for their encouragement, motivation, support, and help. Thanks for being there on my side.”

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ABSTRACT

Estimation of a capacity of transportation systems and facilities is one of the major issues in traffic flow analysis. Capacity of transportation system or facility is a general term used to describe the maximum hourly rate at which persons or 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(TRB,2000). Capacity of a roadway can be estimated using direct empirical or indirect empirical methods. The focus of this project is the estimation of a roadway operational capacity using direct empirical methods. Direct empirical capacity estimation methods are used to estimate capacity values at a particular site using traffic data obtained from that site. The capacity values obtained using these methods reflect the actual site condition more than indirect empirical methods. Methods based on headway distributions (Generalized queuing model), observed volume (selected maxima), observed volume and speed (product limit selection), and observed volume, speed and density (fundamental diagram) were used for this purpose. Traffic observations (traffic volume, speed and headway) were collected using automatic traffic counter (MC5600 automatic counter) on an uninterrupted section on Skudai Pontian highway under dry weather and daylight condition, and the observations ware categorized into Monday, Friday and Sunday morning and afternoon peak periods. The data was processed and analyzed at 5minute, 10minutes and 15minutes intervals. The

results obtained, shows that the capacity values obtained with product-limit-selection method are closer to the observed maximum volumes for all the three days and three averaging intervals considered. The next method that has capacity values closer to observed maximum volumes is fundamental diagram method. Headway method was found to have higher and exaggerated capacity values compared to the observed maximum volumes. Since the data used for this study is largely free flow, it would be recommended that fundamental diagram method is the best method because it takes in to account the finite nature of the section considered by including critical density in the analysis. Product limit could have been the best if the data used was collected at a bottleneck where capacity of the road often observed downstream of the observation point, because of its sound theoretical background and consideration of the fact that capacity is stochastic in nature.

ABSTRAK

Anggaran kapasiti sistem dan kemudahan pengangkutan merupakan salah satu isu utama dalam analisis aliran lalu lintas. Kapasiti sistem atau kemudahan pengangkutan adalah istilah umum yang digunakan untuk menerangkan kadar maksimum setiap jam di mana pengguna atau kenderaan yang merentasi titik atau seksyen lorong atau jalan raya yang seragam sepanjang tempoh masa yang diberikan di bawah jalan raya semasa, trafik, dan syarat-syarat kawalan dapat dijangkakan (TRB, 2000). Kapasiti jalan raya boleh dianggarkan dengan menggunakan kaedah empirikal langsung atau empirikal tidak langsung. Fokus projek ini adalah untuk membuat anggaran kapasiti operasi jalan dengan menggunakan kaedah empirikal langsung. Kaedah anggaran kapasiti empirikal langsung digunakan untuk menganggarkan nilai kapasiti di tapak-tapak cerapan tertentu yang menggunakan data trafik yang diperolehi daripada tapak cerapan. Nilai-nilai kapasiti yang diperolehi dengan menggunakan kaedah ini menggambarkan keadaan sebenar tapak lebih daripada kaedah empirikal tidak langsung. Kaedah ini berdasarkan kepada pengagihan *headway* (model giliran umum), jumlah yang diperhatikan (dipilih maksima), isipadu dan kelajuan yang diperhatikan (pemilihan had produk), dan jumlah, kelajuan dan ketumpatan yang diperhatikan (gambarajah asas) telah digunakan untuk tujuan ini. Pemerhatian lalu lintas (jumlah lalu lintas, laju dan *headway*) telah dikumpulkan dengan menggunakan cerapan trafik automatik (MC5600 automatic counter) di seksyen tanpa gangguan di Lebuhraya Skudai Pontian di bawah keadaan cuaca yang kering dan siang hari, dan pemerhatian dikategorikan kepada Isnin, Jumaat dan Ahad, pada waktu puncak pagi dan petang. Data diproses dan dianalisis pada sela 5 minit, 10minit dan 15minit. Keputusan yang diperolehi menunjukkan bahawa kapasiti nilai yang diperolehi dengan kaedah product-limit-selection adalah menghampiri jumlah maksimum yang diperhatikan untuk ketiga-tiga hari dan purata sela. Kaedah yang

seterusnya yang mempunyai nilai-nilai kapasiti lebih hampir dengan isi padu maksimum yang diperhatikan adalah kaedah gambar rajah asas. Kaedah *headway* yang telah didapati mempunyai nilai-nilai kapasiti yang lebih tinggi berbanding dengan jumlah maksimum yang diperhatikan. Oleh kerana data yang digunakan untuk kajian ini adalah sebahagian besarnya aliran bebas, ia akan disyorkan bahawa kaedah gambar rajah asas adalah kaedah yang terbaik kerana ia mengambil kira sifat terhingga seksyen dipertimbangkan dengan kepadatan kritikal dalam analisis. Had Produk adalah yang terbaik jika data yang digunakan dikumpulkan di kawasan kesesakan di mana kapasiti jalan sering dapat dilihat di hilir titik pemerhatian, kerana latar belakang teori bunyi dan pertimbangan fakta bahawa keupayaan stokastik dalam keadaan semula jadi.

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CHAPTER 1

INTRODUCTION

1.0 Background of the study:

Estimation of the capacity of transportation systems and facilities is one of the major issues in traffic flow analysis. Capacity of transportation system or facility as defined in (TRB 2000) is a general term used to describe the maximum hourly rate at which persons or 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.

Capacity of a roadway is affected by changes in the prevailing condition. It is essential to note that capacity is expressed in terms of rate of persons or vehicles flow during a specified period. Capacity is assumed stochastic in nature because of the differences in individual driver behavior and changing road and weather conditions according to Minderhoud *et al*.,(Ref.1). The capacities of a road facility more importantly freeways are used in planning, design and operation of roadways. A traffic analyst is expected to predict with greater accuracy the places and times where congestion is likely to occur, the amount of delay associated with it and the expected traffic volumes at bottlenecks. Therefore, it is imperative that a traffic analyst can be able to clearly define and measure capacity that will be used in modeling and decision-making.

Minderhoud *et al*.,(Ref.1), examined different direct empirical methods of estimating capacity of a roadway in terms of the basic elements used in those methods such as; type of data used, measurement location, data selection, needed observation periods, required traffic state, lane or carriageway, the outcome (that is whether single value or distribution) etc. However**,** no direct comparison of the calculated values obtained using real life traffic data was carried out. This study addresses clear deficiency of previous studies by estimating and comparing roadway capacity empirical outcomes from each method. The capacity estimation methods covered include; headway method, observed volume method (selected maxima), observed volume and speed method (product limit) and observed volume, densities and speeds method (fundamental diagrams).

1.1 Problem statement

Attempts to determine the validity of existing roadway capacity estimation methods were disappointing because of the main ambiguities related to the derived capacity values and distributions. A reliable and meaningful estimation of capacity is not yet possible. Lack of a clear methodology that will yield accurate and consistent values or distribution of capacity is the main hindrance in understanding what exactly represents the estimated capacity value or distribution of a roadway. If this deficiency is corrected, it is possible to come up with promising methods for practical use in traffic engineering.

The principles of the different methods and mathematical derivation of roadway capacity estimation has been studied by Minderhoud et al. (1997). The basic elements used in these methods such as; type of data used, measurement location, data selection, needed observation periods, required traffic state, lane or carriageway, and the outcome (that is whether single value or distribution etc.), were analysed and compared. However, no direct comparison of the calculated values obtained using real life traffic data was carried out. If this is carried out it is possible to appreciate the viability or deficiency of each method considered. This study addresses this problem by estimating roadway capacities using direct empirical estimation methods and compares the values obtained with a particular reference to data fitness and method accuracy.

1.2 Research question

How accurate and consistent are various direct empirical methods for estimating roadway capacities? Are there disparities between the capacity values obtained using these methods for a particular section of a roadway?

1.3 Aims and objectives

1.3.1 Aim:

To determine roadway capacities using direct empirical methods and compare the values so derived.

1.3.2 Objectives

The study objectives are to estimate and compare outcomes of roadway capacity using headway, volume, flow and speed as well as fundamental relationship methods.

1.4 Scope and limitation

This project involves only the comparison of methods for capacity estimation of uninterrupted roadway sections. The methods covered are direct empirical methods, which include observed headway methods (Generalized queuing model), Observed volume method (Selected maxima), Observed volumes and speeds method (Product limit selection) and Observed volumes, speeds and densities method (Fundamental diagrams).

1.5 Importance of the study

The study could shed more light on the significance of using direct empirical methods when estimating roadway capacity and the degree of accuracy ascribed to each estimation approach.

1.6 General outline of research methodology

1.6.1 Data collection

Roadway geometric information, 24-hr traffic volume, speed and headway data were taken for four weeks on an uninterrupted roadway section under dry weather and day light conditions

1.6.2 Site description

The site was selected on Skudai Pontian highway. Skudai Pontian highway is a four-lane dual carriageway that traverse skudai town. A straight section was identified at place of about 400m away from Pulai Spring junction (Jalan Pontian Lama) as shown in figures 1.1 and 1.2 below. The data was collected on the two lanes leading to Pontian using automatic counter (metro count) as shown in the figure 1.2 below.

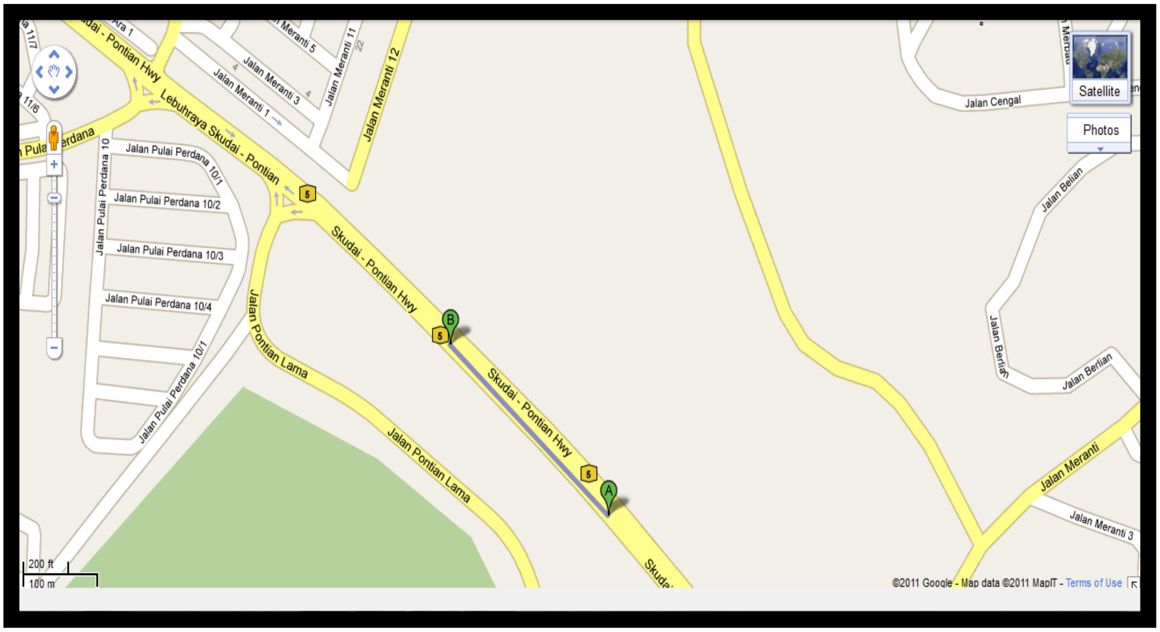

Figure 1.1Skudai Pontian Highway

Figure 1.2 Traffic Counters (MC5600 Automatic Counter)

1.6.3 Equipments

The data was taken using automatic counter (pneumatic road tubes counters). A counter was installed with two tubes separated by one-meter interval running across the road to the centerline (median). The data taken by the counter was retrieved using laptop equipped with the counter's software.

1.6.4 Data processing

The data collected, was graphically summarized on weekly bases. Daily and hourly summaries at 15minutes intervals were tabulated. These summaries allow accurate sampling from the data pool.

1.6.5 Data analysis

Data samples representing weekdays, Fridays, weekends were divided into 5minutes, 10minutes, and 15minutes drops. Capacity values were determined at each interval using headway, selected maxima, product limit selection and fundamental diagram methods

CHAPTER 2

LITERATURE REVIEW

2.1 Highway facilities

Highway facilities are classified into two categories of flow: Uninterrupted flow facilities and interrupted flow facilities.

2.1.1 Uninterrupted-flow facilities

Uninterrupted-flow facilities as described in (TRB 2000) have no fixed elements, such as traffic signals, that are external to the traffic stream and might interrupt the traffic flow. Traffic flow conditions result from the interactions among vehicles in the traffic stream and between vehicles and the geometric and environmental characteristics of the roadwa

2.1.2 Interrupted-flow facilities

Interrupted-flow facilities have controlled and uncontrolled access points that can interrupt the traffic flow. These access points include traffic signals, stop signs, yield signs, and other types of control that stop traffic periodically (or slow it significantly), irrespective of the amount of traffic.

Uninterrupted and interrupted flows describe the type of facility, not the quality of the traffic flow at any given time. A freeway experiencing extreme congestion, for example, is still an uninterrupted flow facility because the causes of congestion are internal. Freeways and their components operate under the purest form of uninterrupted flow. Not only are there no fixed interruptions to traffic flow, but access is controlled and limited to ramp locations. Multilane highways and two-lane highways can also operate under uninterrupted flow in long segments between points of fixed interruption. On multilane and two-lane highways, it is often necessary to examine points of fixed interruption as well as uninterrupted flow segments.

The analysis of interrupted-flow facilities must account for the impact of fixed interruptions. A traffic signal, for example, limits the time available to various movements in an intersection. Capacity is limited not only by the physical space but by the time available for movements. Transit, pedestrian, and bicycle flows generally are considered to be interrupted. Uninterrupted flow might be possible under certain circumstances, such as in a long busway without stops or along a pedestrian corridor. However, in most situations, capacity is limited by stops along the facility.

(TRB, 2000)

2.2 Capacity analysis

Capacity analysis is a set of procedures for estimating the traffic-carrying ability of facilities over a range of defined operational conditions. It provides tools to assess facilities and to plan and design improved facilities. A principal objective of capacity analysis is to estimate the maximum number of persons or vehicles that a facility can accommodate with reasonable safety during a specified time period. However, facilities generally operate poorly at or near capacity; they are rarely planned to operate in this range. Accordingly, capacity analysis also estimates the maximum amount of traffic that a facility can accommodate while maintaining its prescribed level of operation. Operational criteria are defined by introducing the concept of level of service. Ranges of operating conditions are defined for each type of facility and are related to the amount of traffic that can be accommodated at each service level.

The capacity of a facility is the maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions. Vehicle capacity is the maximum number of vehicles that can pass a given point during a specified period under prevailing roadway, traffic, and control conditions. This assumes that there is no influence from downstream traffic operation, such as the backing up of traffic into the analysis point.

Person capacity is the maximum number of persons that can pass a given point during a specified period under prevailing conditions. Person capacity is commonly used to evaluate public transit services, high-occupancy vehicle lanes, and pedestrian facilities. Prevailing roadway, traffic, and control conditions define capacity; these conditions should be reasonably uniform for any section of facility analyzed. Any change in the prevailing conditions changes the capacity of the facility. Capacity analysis examines segments or points (such as signalized intersections) of a facility under uniform traffic, roadway, and control conditions. These conditions determine capacity; therefore, segments with different prevailing conditions will have different capacities.