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DR. JOHNNIE BEN-EDIGBE
Associate Professor
Dept. of Geotechnics & Transportation
Universiti Teknologi Malaysia
81310 UTM Skudai, Johor

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Date	:	MAY 3rd, 2011

DR. JOHNNIE BEN-EDIGBE
Associate Professor
Dept. of Geotechnics & Transportation
Universiti Teknologi Malaysia
81310 UTM Skudai, Johor

EXTENT OF ROAD LIGHTING IMPACT ON HIGHWAY CAPACITY

NIMA JAHANDAR

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

Faculty of Civil Engineering
Universiti Teknologi Malaysia

May 2011

I declare that this thesis entitled "*Extent of Road Lighting Impact on Highway Capacity*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my beloved mother and father, Fariba and Mojtaba

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ABSTRACT

As roads are very scarce and costly to build, it is needed to use their maximum capacity at a reasonable serviceability. Clearly, to achieve this goal, roadways should be studied in different conditions in order to provide certain facilities. This study examines the impact of road lighting on roadway capacity during night-time under the road lightings and to compare to its original capacity when there is natural day light. Data for this study was collected from a two-lane urban highway "5" near Universiti Teknologi Malaysia in Johor state of Malaysia. A pneumatic loop detector was installed for 3 weeks to record volume and speed of the traffic 24 hour. The data was filtered to avoid adverse weather conditions and congestions. Data related to off-peak uncongested conditions during daylight and lighting were analysed to see the effect of road lighting. Capacity of study route estimated 2665 pc/h/ln during daylight. In addition, during lighting hours, maximum flow is estimated 2364 pc/h/ln which is approximately 11% reduction compare to daylight. Meanwhile free-flow speed and optimum speed computed during study and results show minor changes. Free-flow speed and optimum speed computed 85 km/h and 42 km/h, respectively, for both daylight and lighting hours.

ABSTRAK

Oleh kerana pembinaan jalan adalah sangat sukar dan mahal, ianya amat memerlukan penggunaan kapasiti yang maksimum pada satu nilai yang munasabah. Bagi mencapai sasaran yang diingini, laluan kenderaan haruslah dikaji mengikut keadaan yang berbeza bagi menyediakan kemudahan tertentu. Kajian ini dijalankan bagi memeriksa kesan pencahayaan jalan terhadap kapasiti laluan jalan ketika waktu malam di bawah pencahayaan lampu dan membandingkannya dengan kapasiti penggunaan ketika waktu siang. Data untuk kajian ini diperolehi daripada satu lebuh raya bandar dua lorong “5” berhampiran Universiti Teknologi Malaysia di negeri Johor. Satu Pengesan gelung pneumatik telah dipasang selama 3 minggu bagi merekodkan jumlah dan kelajuan trafik 24 jam. Data telah disaring untuk mengelak keadaan cuaca yang buruk dan juga kesesakan.Data berkaitan dengan kesesakan luar musim ketika waktu siang dan penggunaan lampu dianalisis bagi melihay kesan penggunaan lampu jalan. Keupayaan laluan kajian mengira 2665 pc/h/ln semasa siang. Sebagai tambahan, semasa menerangi jam, aliran maksimum ialah dianggarkan 2364 pc/h/ln yang mana dianggarkan kira-kira 11% pengurangan berbanding dengan waktu siang. Sementara itu kelajuan aliran bebas dan kelajuan optimum mengira semasa kajian dan keputusan menunjukkan perubahan kecil. Kelajuan aliran bebas dan kelajuan optimum yang diukur adalah 85 km/h dan 42 km/h, masing-masing, untuk waktu siang dan malam.

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LIST of SYMBOLS and ABBREVIATIONS

a	Deceleration Rate (m/sec^2)
AASHTO	American Association State Highway Transportation Officials
ADT	Average Daily Traffic (veh)
ATC	Automatic Traffic Count
B.S.	British Standards
cd	Candela
CI	Confidence Interval
d	Distance Travelled (km)
FFS	Free-Flow Speed (km/h)
ft	Foot
G	Longitudinal Grade of the Road
h	Height (m)
h	Hour
H	Time Headway (sec)
H_a	Alternative Hypothesis
HCM	Highway Capacity Manual
HGV	Heavy Goods Vehicle
H_o	Null Hypothesis
ITE	Institute of Transportation Engineers
JKR	Jabatan Kerja Raya
k	Density (veh/km)
k_{cr}	Critical Density (veh/km)
k_j	Jam Density (veh/h)
km	Kilometer
lm	Lumen

LOS	Level Of Service
lx	Lux
m	Meter
mi	Mile
M.S.	Malaysian Standards
n	Number of Observed Vehicles
ODOT	Ohio Department of Transportation
PCE	Passenger Car Equivalent
p.c.u.	Passenger Car Unit
PHF	Peak-Hour Factor
PI	Prediction Interval
q	Flow (veh/h)
q_i	Flow Related to Survey *i* (veh/h)
q_m	Maximum Flow (veh/h)
R^2	R-Squared
SE	Standard Error
SSD	Stopping Sight Distance (m)
SS_{error}	Error Sum of Squares
SS_{reg}	Regression Sum of Squares
SS_{total}	Total Sum of Squares
t_i	Time for Vehicle *i* to Traverse *d* (h)
t_{p-r}	Perception–Reaction Time (sec)
TRL, TRRL	Transport and Road Research Laboratory
u	Speed (km/h)
$\bar{u}$	Mean Speed (km/h)
u_f	Free-Flow Speed (km/h)
u_o	Optimum Speed (km/h)
$\overline{u_S}$	Space Mean Speed (km/h)
$\overline{u_T}$	Time Mean Speed (km/h)
UTM	Universiti Teknologi Malaysia
V_d	Design Speed (km/h)
veh	Vehicle
x	Length of Road (km)

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

One of the most essential issues for a safe and efficient traffic flow on highways is the ability to see for the drivers. However, in many cases, during night-time driving, human eyes' limitations prevent vehicle headlights alone from completely satisfying visual requirements. Therefore, help of fixed roadway lighting appears to be useful to supplement vehicle headlights. Fixed roadway lightings extend the visibility range both longitudinally and laterally, thus it helps the driver by providing earlier warning of hazards on or near the roadway [King, L., 1994], moreover, to illuminate adequately the road surface and objects on the road and its surrounding areas to be visible enough to ensure that the driving task is performed successfully [Aleksanteri. E. *et al*., 2008].

From the traffic engineer's viewpoint, the primary objective of road lighting is to improve the safety of roads at night by providing good visibility conditions for all road users. A second reason for installing road lighting is to promote better traffic flow at night, by providing improved delineation of road geometrics, safer overtaking opportunities, and easier observance of traffic management measures.

Quality and condition of traffic flow have a strong influence on capacity of the roadway. In Highway Capacity Manual (HCM), highway capacity is defined as "the maximum sustained 15 minutes flow rate, expressed in passenger cars per hour per lane, that can be accommodated by a uniform freeway segment under prevailing traffic and roadway conditions in one direction of flow". Observed 15-min flow rate, which is used to estimate highway capacity, may be vary depending on the traffic condition and roadway condition. The factors that affect highway capacity are road condition, traffic flow condition, traffic control condition and automobile technology. One of the most significant factors of road condition is the visibility for the road users. Road lighting plays in lieu of natural day light during night-time to increase visibility to desired level.

In addition, not always lighting helps, sometimes a bad design may be worst than no lighting at all [Mace *and* Porter, 2004]. Some authors have shown that risk compensation in lighted roads may lead to an increase in speed and a decrease of diffuse attention [Wilde, 1984], which may reduce road safety.

1.2. Problem Statement

As roads are very scarce and costly to build, it is needed to use their capacity at the highest level. Clearly, to achieve this goal, roadways' level of service in different conditions should be examined and certain facilities for road users should be provided. One of the issues to be studied is the extent of road lighting impact on drivers behavior thus roadway capacity. Some studies found no change in average speed when road lighting was introduced, while other showed the contrary [Anais M. *et al*., 2010].

There are too many researches that have been done regarding the effect of road lighting on road safety, rare studies aim for effects of road lighting on capacity. Roadway capacity should be considered while operating under the light of lighting facilities during night-time to compare to its original capacity when there is natural day light.

A slight difference in capacity is expected otherwise the roadway's lighting system and pattern should be revised to obtain the desired visibility and thus reduction in capacity loss of the roadway.

In a low traffic volume situation, driver's selections of speed is usually influenced by such factors as the road geometry, lighting and weather condition [Othman C.P., 2004], therefore, in a straight segment of road, lighting plays the most significant part in driver's behavior and their desirable speed. On the other hand, road lighting has minor effect to the flow and roadway capacity under the congestion condition. One reason is, in congestion condition, as the space headway decreased so does the speed of vehicles for drivers to retrieve safe time headway. In this situation drivers have enough time to decide what to do when they are seeing an obstacle or changing the lane, having same visibility they have in high speed, when they might been surprised and not have enough time to maneuver smoothly and shock the entire traffic flow.

1.3. Purpose and Objectives of the Study

The aim of this study is to determine the extent of road lighting impact on roadway capacity. To achieve this aim the study was carried out upon following objectives:

- To estimate flow and speed, hence compute density.
- To use flow and density relationship to determine capacity under day light and dry weather conditions.
- To use flow and density relationship to determine capacity under road lighting and dry weather conditions.
- To compare estimated capacities for the two scenarios and draw conclusions.

1.4. Significance of the Study

The results of this study will provide models of traffic pattern during daylight and lighting hours. Such models would be useful to verify whether road lighting has impact on the traffic characteristics and as a result the roadway capacity. Consideration of results of this study would help to improve assessments for local roads hence, more accurate and efficient planning and management of resources.

1.5. Scope and Limitations of the Study

In order to clarify the extent of road lighting impact on highway capacity, this study will be conducted to compare the capacity of diamond "5" highway namely "Lebuhraya Skudai-Pontian" under condition of existence of natural day light and lighting during night-time. The study will provide the traffic data including volume and speed of vehicles passing the road during 3 weeks, continuously.

Meanwhile, this study appears to suffer from a number of issues, such as changes in the driver populations between night and day, changes in trip motivations, in driver behaviors, etc. For instance, that people driving during darkness and daylight hours are not the same [Assum *et al*., 1999]. Thus, it is difficult to compare and generalize the findings, and to compensate for the methodological biases [Elvik, 2002].

On the other hand, collected data should present the base condition at which the standard capacity possibly could be estimated. Therefore, both congestion – peak hours, bottleneck, vehicle breakdowns, emerging ramps and intersections – and adverse weather conditions should be avoided during data collecting phase since previous research shows that adverse weather condition has the same effect on traffic flow as congestion [Alhassan *and* B. Edigbe, 2011].

The segment of the highway where the study will be carried out is situated to the south of Universiti Teknologi Malaysia. This portion of the road is 1.7 kilometer long and to avoid unwanted issues which discussed before is almost straight with no sharp bend. Study route starts from the grade separated interchange of Jalan Universiti and Skudai-Pontian highway and ends in Jalan Pontian Lama exit ramp. The site of the study is shown in figure (1.1).

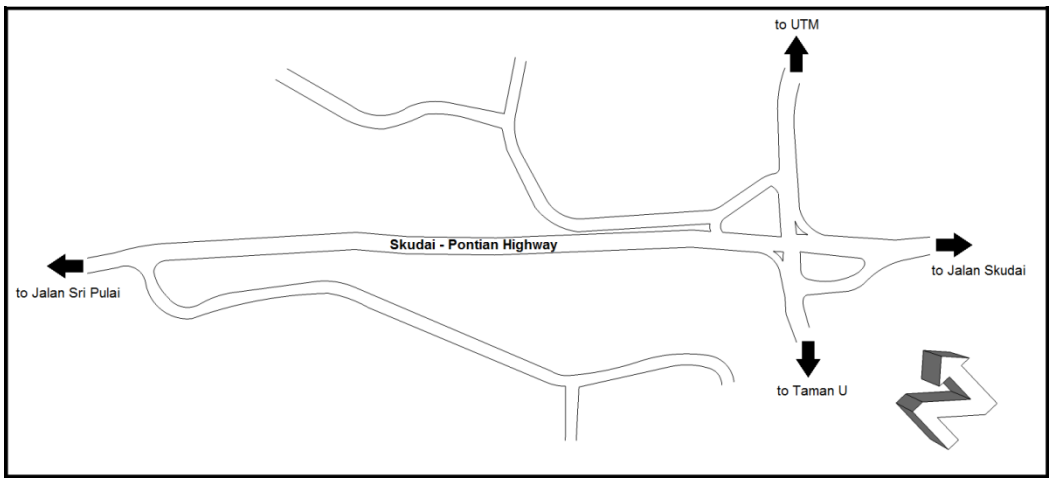

FIGURE 1.1 "Site Map"