UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF CAPACITY AND LEVEL-OF-SERVICE FOR UNINTERRUPTED EXCLUSIVE MOTORCYCLE LANES IN MALAYSIA

HUSSAIN HAMID

DEVELOPMENT OF CAPACITY AND LEVEL-OF-SERVICE FOR UNINTERRUPTED EXCLUSIVE MOTORCYCLE LANES IN MALAYSIA

By

HUSSAIN HAMID

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

This work is lovingly dedicated to my late mother, Hajjah Rahimah binti Mohd. Ghouse and late father, Hamid bin Ahmad. May Allah bless their soul.

This work is also passionately dedicated to my beloved wife, Dr. Raja Zarina Raja Shahardin, my three little angels; Wan Nur Hasya Hussain, Wan Nur Hilman Hussain, Wan Nur Hadeeja Hussain, and my father-in-law; Lt. Col. (B) Raja Shahardin Raja Rome for their understanding, sacrifices and supports throughout the times that I have been working to accomplish this research.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

DEVELOPMENT OF CAPACITY AND LEVEL-OF-SERVICE FOR UNINTERRUPTED EXCLUSIVE MOTORCYCLE LANES IN MALAYSIA

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Chairman : Professor Ir. Radin Umar Radin Sohadi, PhD

Faculty : Engineering

In developing ASEAN countries, the key road accident problems arise from the high proportion of motorcycles in the mixed vehicle population. Considering that motorcycles are popular mode of personal travel and that they are highly numbered on the roads, the provision of exclusive motorcycle lanes is expected to reduce accidents and improve motorcycle safety. Studies have proven that segregation is the best engineering practice to save lives of motorcyclists. Acknowledging these benefits, the Malaysian government has adopted a policy to provide exclusive motorcycle facilities along its new highways and federal roads. The need to provide this special facility has brought to light the deficiencies in studies related on motorcycle traffic sciences, operations and facility design.

This research initially attempts to establish the characteristics of key components of a motorcycle-traffic system in Malaysia, i.e. the motorcycle-rider unit, motorcyclist space requirement and riding manner along motorcycle lane of various lane widths. Then, it seeks to establish the

fundamental motorcycle speed-flow-density relationships along uninterrupted motorcycle lanes in Malaysia. This would enable the maximum motorcycle flow, critical speed and critical density at capacity conditions to be estimated. Finally the level-of-service criteria for an exclusive motorcycle lane facility would be developed, thus allowing the motorcycle design charts and tables to be produced.

To understand the key components of a motorcycle-traffic system, digital recordings of motorcyclists along the existing motorcycle lanes in Malaysia were captured. Basic dimensions of a motorcycle/rider unit were directly measured. The separation distance between side-by-side motorcyclists was obtained by employing the digital recording technique. The motorcyclist operating space was then established. Three-stages of field and experimental studies was conducted to observe the motorcyclists riding manner along various lane widths from low to high volume conditions.

To establish the fundamental motorcycle speed-flow-density relationships and to develop the level-of-service criteria, the aggregated data from 8 sites ranging from the stable flow to unstable conditions were plotted. A simple linear regression analysis was conducted on the motorcycle speed on motorcycle density function to obtain the best linear regression equation that describes the relationship. Once the motorcycle speed-density relationship was established, the motorcycle speed-flow and motorcycle flow-density relationships were derived. The demarcation of the level-of-service boundaries for the uninterrupted exclusive motorcycle lanes was guided by the volume-capacity ratio (v/c) and service flow rates.

Results of the research revealed that the small- and medium-sized type motorcycles (150 c.c. and below) are the commonly used type in Malaysia. A single static motorcyclist spans about 0.8 m wide, but requires a mean width of 1.3 m to operate. In a lane width of 1.7 m or below, motorcycle flow applies the lane or headway concept. While in lanes of width between 1.7 m and 3.4 m, the motorcycle flow adopts the space concept. This highlights that 1.7 m is the optimum lane width where motorcyclists would travel in a single file, even during low speeds and high motorcycle flow conditions. There is not enough space for faster motorcyclists to pass the slower ones within the 1.7 m motorcycle lanes.

In the headway concept ($W \leq 1.7$ m), capacity is reached at a maximum motorcycle flow of 3306 mc/hr/lane, corresponding to a critical speed of 13 km/hr and critical density of 235 mc/km/lane. As for the space concept ($1.7 \text{ m} < W \leq 3.4$ m), capacity occurs at a maximum motorcycle flow of 2207 mc/hr/m. This corresponds to a critical motorcycle speed of 13 km/hr and critical motorcycle density of 0.166 mc/m^2 (or space of 6.0 m^2/mc). Based on the speed-flow-density relationships and the volume-capacity ratio, the level-of-service boundaries were demarcated. Subsequently, tables and charts of maximum motorcycle flow rates related to level-of-services for different motorcycle lane widths were developed.

The outcome provides useful input in developing design guidelines for motorcycle facilities in countries with high number of motorcycles in the effort to curb motorcycle safety problems. This study is seen as an initial effort to fill the missing link in basic research of motorcycle traffic sciences, operations and facility design that existed among various land transportation facilities, thus contributing new knowledge to the field of transportation engineering.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBENTUKAN KAPASITI DAN PARAS PERKHIDMATAN BAGI LALUAN KHAS MOTOSIKAL TIDAK TERHALANG DI MALAYSIA

Oleh

HUSSAIN HAMID

Ogos 2006

Pengerusi : Profesor Ir. Radin Umar Radin Sohadi, PhD

Fakulti : Kejuruteraan

Masalah keselamatan jalan raya yang utama di negara-negara ASEAN yang sedang membangun adalah berpunca daripada bilangan motosikal yang tinggi di dalam populasi kenderaannya yang pelbagai. Memandangkan motosikal merupakan mod perjalanan persendirian yang diminati dan juga menyumbang sebagai bilangan kenderaan yang sangat tinggi di jalan raya, maka penyediaan kemudahan laluan khas motosikal dijangka dapat mengurangkan kemalangan dan meningkatkan keselamatan pengguna motosikal. Kajian telah membuktikan bahawa pembinaan laluan khas motosikal merupakan salah satu amalan kejuruteraan yang terbaik bagi menyelamatkan nyawa pengguna motosikal. Berdasarkan kepada kebaikan-kebaikan ini, kerajaan Malaysia telah menetapkan suatu polisi untuk menyediakan kemudahan laluan khas motosikal di sepanjang lebuh raya baru dan jalan raya persekutuan. Keperluan di dalam menyediakan kemudahan khas untuk penunggang motosikal ini menunjukkan bahawa terdapat kekurangan penyelidikan

berkaitan bidang sains trafik, operasi dan rekabentuk kemudahan motosikal.

Kajian ini pada awalnya memberikan tumpuan kepada pemahaman ciri-ciri komponen utama sistem trafik motosikal di Malaysia seperti unit motosikal/penunggang, keperluan ruang bagi penunggang motosikal dan tabiat menunggang motosikal di sepanjang laluan khas motosikal pelbagai kelebaran. Seterusnya, kajian dijalankan untuk menghasilkan hubungan asas bagi kelajuan-aliran-ketumpatan motosikal di sepanjang laluan motosikal bagi segmen tanpa halangan di Malaysia. Ini membolehkan aliran maksimum motosikal, kelajuan kritikal dan ketumpatan kritikal motosikal dianggarkan. Akhirnya, paras-paras perkhidmatan bagi kemudahan laluan khas motosikal dapat dianggarkan. Seterusnya, carta-carta rekabentuk dan jadual bagi kemudahan laluan khas motosikal dapat dihasilkan.

Untuk memahami komponen-komponen utama sistem trafik motosikal, rakaman digital telah dijalankan ke atas penunggang motosikal di sepanjang laluan khas motosikal yang sedia ada di Malaysia. Dimensi asas bagi unit motosikal/penunggang diukur secara terus. Jarak di antara motosikal yang bersebelahan didapati dengan menggunakan teknik rakaman digital. Justeru itu, ruang untuk penunggang beroperasi dapat ditentukan. Tiga fasa kajian di tapak dan secara eksperimen di bawah keadaan aliran rendah sehingga aliran tinggi dijalankan bagi memerhati tabiat menunggang motosikal di sepanjang laluan motosikal yang berlainan kelebaran.

Bagi menghasilkan hubungan asas bagi kelajuan-aliran-ketumpatan dan juga untuk menentukan kriteria paras perkhidmatan, himpunan data dari 8 tapak kajian pada keadaan aliran stabil hingga aliran tidak stabil diplotkan. Analisis regressi linear mudah dijalankan ke atas data berkaitan kelajuan motosikal dan ketumpatan motosikal bagi menentukan persamaan regressi linear yang terbaik didalam menjelaskan perkaitan ini. Dengan tertubuhnya hubungan di antara kelajuan-ketumpatan motosikal ditubuhkan, hubungan antara kelajuan-aliran motosikal dan juga aliran-ketumpatan motosikal dapat diterbitkan. Sempadan-sempadan paras perkhidmatan bagi kemudahan laluan khas motosikal ditentukan dengan merujuk kepada nisbah isipadu-kapasiti dan aliran.

Hasil kajian menunjukkan bahawa motosikal bersaiz kecil dan sederhana (150 c.c. ke bawah) merupakan jenis motosikal yang paling banyak digunakan di Malaysia. Penunggang motosikal dalam keadaan statik mempunyai ukuran 0.8 m lebar, sementara penunggang motosikal pada puratanya memerlukan kelebaran minimum 1.3 m untuk beroperasi. Bagi laluan motosikal berkelebaran 1.7 m atau kurang, aliran motosikal adalah berdasarkan konsep lorong atau ‘headway’. Bagi laluan motosikal berkelebaran di antara 1.7 m dan 3.4 m, aliran motosikal adalah berdasarkan konsep ruang. Ini menunjukkan bahawa untuk 1.7 m merupakan kelebaran optimum laluan motosikal di mana penunggang motosikal akan menunggang mengikut satu barisan, walau pun di dalam keadaan di mana kelajuan motosikal adalah sangat rendah di dalam aliran motosikal yang tinggi. Ruang adalah tidak mencukupi bagi penunggang motosikal yang lebih laju untuk memotong penunggang motosikal yang bergerak perlahan di dalam laluan motosikal berkelebaran 1.7 m.

Hasil kajian juga menunjukkan bahawa di bawah konsep 'headway' ($W \leq 1.7$m), kapasiti dicapai pada aliran motosikal maksimum 3306 motosikal/jam/lorong yang bersamaan dengan kelajuan kritikal 13 km/jam dan ketumpatan kritikal 235 motosikal/km/lorong. Bagi konsep ruang pula (1.7 m $< W \leq 3.4$ m), kapasiti berlaku pada aliran motosikal maksimum 2207 motosikal/jam/m. Nilai ini adalah bersamaan dengan kelajuan kritikal 13 km/jam dan ketumpatan kritikal 0.166 motosikal/m^2 (atau ruang 6.0 m^2/motosikal). Berdasarkan kepada perkaitan kelajuan-aliran-ketumpatan dan juga lengkungan kelajuan-aliran-ruang di bawah konsep ruang, sempadan-sempadan paras perkhidmatan dapat ditentukan. Seterusnya, carta-carta aliran motosikal maksimum yang berkaitan dengan paras-paras perkhidmatan bagi laluan motosikal pelbagai kelebaran telah dihasilkan.

Hasil-hasil kajian adalah berguna di dalam menghasilkan panduan merekabentuk kemudahan laluan motosikal terutamanya bagi negara-negara yang mempunyai bilangan kenderaan motosikal yang tinggi. Kajian ini dianggap sebagai usaha awal di dalam mengisi ketiadaan maklumat di dalam penyelidikan sains trafik, operasi dan rekabentuk kemudahan motosikal yang telah lama wujud di antara pelbagai jenis kemudahan pengangkutan darat yang lain. Justeru itu, kajian ini menyumbangkan pengetahuan yang baru di dalam bidang kejuruteraan pengangkutan.

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I certify that an Examination Committee has met on 9 August 2006 to conduct the final examination of Hussain Hamid on his Doctor of Philosophy thesis entitled "Development of Capacity and Level-of-Service for Uninterrupted Exclusive Motorcycle Lanes in Malaysia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Wong Shaw Voon, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Ratnasamy Muniandy, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Kulanthayan K C Mani, PhD
Faculty of Medicine and Medical Sciences
Universiti Putra Malaysia
(Internal Examiner)

Ian Johnston, PhD
Professor
University of Monash
Australia
(External Examiner)

HASANAH MOHD GHAZALI, PhD
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

Radin Umar Radin Sohadi, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Ahmad Farhan Mohd. Sadullah, PhD
Associate Professor
School of Civil Engineering
Universiti Sains Malaysia
(Member)

Dadang Mohamad Ma'soem, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

AINI IDERIS, PhD
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 16 JANUARY 2007

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

HUSSAIN HAMID

Date: 18 DECEMBER 2006

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