# UNIVERSITI PUTRA MALAYSIA

***MOTORCYCLE - STOPPING SIGHT DISTANCE MODEL FOR GEOMETRIC DESIGN OF EXCLUSIVE MOTORCYCLE LANES***

**SEYED RASOUL DAVOODI**

# MOTORCYCLE - STOPPING SIGHT DISTANCE MODEL FOR GEOMETRIC DESIGN OF EXCLUSIVE MOTORCYCLE LANES

By

SEYED RASOUL DAVOODI



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

July 2011

# DEDICATION

## To my wife, Mahdieh and my daughter, Delara

## and

**All those working to enhance the safety of transportation system, and saving people's life.**

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

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**Seyed Rasoul Davoodi**

**July 2011**

**Chair: Hussain b. Hamid, PhD**

**Faculty: Engineering**

In developing ASEAN countries, motorcycle is a popular transport mode because it is cheap and provides flexible door-to-door mobility. But motorcyclists are also highly involved in road crashes. Separating motorcycles from other vehicles in traffic by providing motorcycle lanes is a good engineering measure to improve safety of motorcyclists. In designing the motorcycle lanes, designing of geometrical elements such as the horizontal and vertical curve lengths to provide of adequate stopping sight distance at every point along the roadway are essential. There are few studies on motorcycle characteristics, but none of them addressed the safe stopping sight distance in the geometric design of motorcycle lanes.

Stopping sight distance is calculated using basic principles of physics and relationships among the various design parameters. The majority parameters effects on stopping sight distance are: (i) vehicle characteristics, (ii) driver perception

response time, and (iii) driver deceleration rate. This research consists of four different field studies that were undertaken under controlled testing environments for the different aspects that make up the components of the motorcycle stopping sight distance. (i) Motorcycle characteristics, which in study 1 collected real world data to construct a cumulative distribution of rider eye, motorcycle headlight, taillight and motorcyclist head heights as determined by a current motorcycle fleet in Malaysia. Characteristics of the motorcycles observed along the existing exclusive motorcycle lanes in Selangor state of Malaysia were transcribed from a camcorder, using reference dimension. (ii) Motorcyclist Braking Performance, which consisted of three different field studies to obtain riders perception response time, riders deceleration ratio (braking distance). Study 2, tested a rider's simple perception response time. In this study participants sat on their motorcycles exactly the same way they do while riding and then they awaited activation of the taillight passenger car (parked) in front of them. Perception response times of the motorcyclists were transcribed from camcorder when the riders hit the brakes as quickly as possible following the activation of the car brake light. Study 3 and 4 evaluated rider braking performance including rider perception response time, braking performance and deceleration to an expected and unexpected object on the road. In this study 3, participants rode motorcycle and released the accelerator and applied brake as quickly as possible following activation of a light by the roadside. Study 4, measured rider braking performance when unalerted riders were confronted with the need to stop for an unexpected object that suddenly appeared in the roadway.

The motorcycle characteristic study found that all 525 motorcyclist eye heights are higher than the AASHTO 2004 design value of 1,080 mm. It is noted that the 5$^{th}$ percentile driver eye level height is 1,350 mm while the 10$^{th}$ percentile motorcyclist eye level is 1,367 mm. The 5$^{th}$ and 10$^{th}$ percentile motorcycle headlight heights are 800 mm and 880 mm respectively and the 5$^{th}$ and 10$^{th}$ percentile motorcycle taillight heights are 625 mm and 634 mm respectively.

The results of braking performance studies for rider simple perception response time show that the mean and the standard deviation of the motorcycle simple PRT are 0.44 sec and 0.11 sec respectively. The mean perception response time to expected and unexpected object scenario is 0.71 sec and 1.25 sec respectively. The 95$^{th}$ percentiles unexpected object perception response time was 2.12 sec. The findings from these studies indicated that most riders are capable of responding to an unexpected object in the roadway in 2.5 sec or less.

The results of braking performance studies for rider deceleration and braking distance show that the 90 percent of all riders chose deceleration of at least 3.3 m/s$^2$ on dry pavements. The study found that most riders chose decelerations that are greater than 2.75 m /s$^2$. These decelerations are within riders' capabilities to stay within their direction and maintain steering control during the braking maneuver on wet surfaces.

Overall, this research proposed a motorcycle stopping sight distance model based on motorcycle characteristics, motorcyclist capabilities and performance in response to an expected and unexpected object along the exclusive motorcycle lanes. Results of this research are not only useful for geometric design of exclusive motorcycle lanes but can be used for geometric design of roads in countries with high motorcycle volumes.

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

**MODEL JARAK PENGLIHATAN UNTUK MEMBERHENTIKAN MOTORSIKAL BAGI REKABENTUK GEOMETRI LALUAN MOTORSIKAL EKSKLUSIF**

Oleh

**SEYED RASOUL DAVOODI**

**Julai 2011**

**Pengerusi:** **Hussain b. Hamid, PhD**

**Fakulti:** **Kejuruteraan**

Di kalangan penduduk negara-negara ASEAN yang sedang membangun, motosikal merupakan pilihan pengangkutan yang amat popular kerana ianya murah dan menyediakan mobiliti yang amat fleksibel. Namun begitu, penunggang motosikal sering kali terlibat dengan kemalangan jalan raya pada kadar yang tinggi amat membimbangkan. Justeru itu, penyediaan lorong motosikal untuk mengasingkan motosikal daripada berkongsi trafik dengan kenderaan lain merupakan satu kaedah kejuruteraan yang baik untuk meningkatkan keselamatan penunggang motosikal. Unsur- unsur geometri seperti panjang lengkung mengufuk dan menegak adalah penting dan harus dititikberatkan semasa perancangan rekabentuk laluan motosikal. Ini dapat menyediakan jarak penglihatan yang mencukupi untuk berhenti pada setiap titik di sepanjang laluan motosikal tersebut. Walaupun terdapat beberapa kajian lepas mengenai ciri-ciri motosikal, kajian-kajian tersebut tidak

mengutamakan jarak penglihatan untuk berhenti yang selamat dalam rekabentuk geometrik lorong motosikal.

Jarak penglihatan untuk berhenti dikira dengan menggunakan prinsip asas fizik dan perhubungan antara pelbagai parameter rekabentuk. Kebanyakan parameter yang memberi kesan kepada jarak penglihatan untuk berhenti adalah: (i) ciri-ciri kenderaan, (ii) masa tindak balas tanggapan pemandu, (iii) kadar nyahpecutan pemandu. Kajian ini meliputi empat bidang penyelidikan yang berlainan dan semua ujian dilakukan di dalam persekitaran yang terkawal agar semua aspek berbeza yang membentuk komponen-komponen jarak penglihatan untuk memberhentikan motosikal dipenuhi. (i) Kajian pertama mengenai ciri-ciri motosikal, mengumpul data masa benar (real time) seperti ketinggian mata penunggang, ketinggian lampu depan motosikal, ketinggian lampu belakang dan ketinggian kepala penunggang motosikal untuk membina satu taburan terkumpul seperti yang ditetapkan oleh armada motosikal di Malaysia. Motosikal-motosikal di sepanjang lorong motosikal eksklusif yang wujud di negeri Selangor, Malaysia telah diperhatikan melalui kamkorder yang disalin menggunakan dimensi rujukan untuk mendapatkan ciri-ciri motosikal. (ii) Prestasi membrek penunggang motorsikal yang mengandungi tiga sub-kajian iaitu memperoleh masa tindakbalas tanggapan penunggang, nisbah nyahpecutan penunggang (jarak pembrekan). Kajian 2, menguji masa tindakbalas tanggapan mudah seorang penunggang. Di dalam kajian ini, para peserta duduk di atas motosikal mereka (diparkir) sepertimana mereka duduk semasa menunggang motosikal dan menunggu pengaktifan lampu brek kereta (diparkir) di depan mereka. Masa tindakbalas tanggapan penunggang motosikal kemudian disalin ke kamkorder apabila penunggang menekan brek dengan selepas pengaktifan lampu brek kereta. Kajian 3 dan 4 pula menilai prestasi penunggang membrek termasuk masa tindakbalas tanggapan penunggang, prestasi membrek dan nyahpecutan bagi objek yang boleh diduga dan tidak diduga di atsa jalan raya tersebut. Di dalam kajian 3, para peserta kajian menunggang motosikal dan melepaskan pemecutan dan menekan brek secepat yang mungkin berikutan pengaktifan cahaya di sisi jalan raya. Kajian 4 pula, prestasi pembrekan penunggang diukur melalui keperluan menghentikan motosikal apabila didatangi objek di dalam laluan penunggang secara tidak diduga.

Penemuan kajian ciri-ciri motosikal mendapati di kalangan 525 penunggang motosikal, kesemuanya memiliki ketinggian mata melebihi ketinggian daripada AASHTO 2004 dengan nilai rekabentuk, 1080 mm. Aras mata penunggang motosikal pada persentil kelima dicatatkan pada ketinggian 1350 mm manakala aras mata pada persentil ke-10 ialah 1367 mm. Lampu depan motosikal pada persentil kelima dan kesepuluh masing-masing mencatatkan ketinggian 800mm dan 880mm manakala persentil kelima dan kesepuluh ketinggian lampu belakang motosikal adalah masing-masing 625 mm dan 634 mm.

Keputusan yang diperolehi daripada kajian prestasi membrek untuk masa tindak balas tanggapan penunggang mudah menunjukkan min dan sisihan piawai untuk masa tindak balas tanggapan penunggang mudah ialah masing-masing 0.44 saat dan

0.11 saat. Min masa tindak balas tanggapan untuk objek dijangka dan tidak dijangka masing-masing ialah 0.71 saat dan 1.25 saat. Persentil ke-95 bagi masa tindak balas tanggapan objek tidak diduga ialah 2.72 saat. Penemuan dari kajian ini mendapati kebanyakan penunggang mampu bergerak balas kepada objek tidak diduga di atas laluan jalan dalam 2.5 saat atau kurang daripadanya.

Keputusan kajian prestasi membrek untuk nyahpecutan penunggang dan jarak pembrekan menunjukkan 90 peratus penunggang memilih nyahpecutan sekurang-kurangnya 3.3 m/s2 di atas jalan kering. Penemuan daripada kajian ini pula mendapati kebanyakan penunggang memilih nyahpecutan yang lebih besar daripada 2.75 m/s2. Nyahpecutan ini masih dalam keupayaan penunggang untuk memastikan halatuju mereka dan mengekalkan taktik kawalan penunggangan semasa membrek pada permukaan jalan yang basah.

Secara keseluruhannya, penyelidikan ini mencadangkan model jarak penglihatan untuk memberhentikan motosikal dengan selamat berdasarkan kepada ciri-ciri motosikal, keupayaan penunggang motosikal dan prestasi tindakbalas bagi objek dijangka dan tidak dijangka di sepanjang laluan motosikal eksklusif. Keputusan penyelidikan ini bukan sahaja berguna untuk rekabentuk geometrik lorong motosikal eksklusif tetapi ia juga boleh digunakan sebagai merekabentuk jalan-jalan secara geometrik di negara-negara yang mempunyai kepadatan penunggang motosikal yang tinggi.

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**APPROVAL**

I certify that an Examination Committee has met on date of viva to conduct the final examination of Seyed Rasoul Davoodi on his Doctor of Philosophy thesis entitled "MOTORCYCLE STOPPING SIGHT DISTANCE MODEL USE IN EXCLUSIVE MOTORCYCLE LANES GEOMETRIC DESIGN" 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:

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

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## DECLARATION

I hereby declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

**SEYED RASOUL DAVOODI**

Date: 26 July 2011

# TABLE OF CONTENTS