EFFECTIVENESS OF NOISE BARRIERS AT RESIDENTIAL AREAS IN KLANG VALLEY, MALAYSIA

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FPAS 2016 2

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By

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

February 2016

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

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February 2016

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The use of environmental noise barrier has increased as concerns of side effects of noise pollution in the environment grow. However, a lot of complaints from the residents occur after the installation of the noise barrier regarding its effectiveness. Thus, this study is carried out to determine the effectiveness of existing noise barriers such as vegetation, concrete hollow block, and panel concrete. This study is designed to evaluate the influence of source of noise (traffic composition) as well as meteorological condition towards level of noise at study sites with and without the presence of noise barrier. The results of the study reveals that L_{Aeq} in all study sites throughout all measurement periods recorded 61.9 dB(A) to 74.8 dB(A) during daytime (morning, afternoon, and evening) and 57.6 dB(A) to 73.2 dB(A) during night time. These results exceed the noise limit in Malaysia guidelines (daytime = 60 dB(A) and night time = 50 dB(A)). Results of PCA show the percentages of the total variance up to 95% by variables of traffic composition such as car, motorcycles, and light lorries. Apart from that, panel concrete noise barrier meet the minimum value of effective noise barrier insertion loss. The concrete hollow block partially meet the minimum value of effective noise barrier with computed insertion loss, while vegetation does not provide enough insertion loss of effective noise barrier. Therefore, the finding indicates that panel concrete provides consistent insertion loss followed by concrete hollow block and vegetation. The MLR model based on the traffic characteristics group exhibited optimal performance in term of coefficient of determination for with and without noise barrier location with values of 0.858 and 0.839, respectively.

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

KEBERKESANAN PENGHADANG BUNYI DI KAWASAN PERUMAHAN DALAM LEMBAH KLANG, MALAYSIA

Oleh

HERNI BINTI HALIM

Februari 2016

Pengerusi : Profesor Madya Ramdzani bin Abdullah, PhD
Fakulti : Pengajian Alam Sekitar

Penggunaan penghadang bunyi semakin meningkat berikutan kebimbangan kesan sampingan pencemaran bunyi kepada alam sekitar. Namun, banyak rungutan timbul berkaitan keberkesanannya mengurangkan bunyi bising jalanraya. Oleh itu, kajian ini dijalankan untuk mengkaji keberkesanan penghadang bunyi yang dibina daripada tumbuh-tumbuhan, blok berlubang konkrit, dan panel konkrit. Kajian ini direkabentuk untuk menilai pengaruh sumber bunyi (komposisi trafik) dan keadaan meteorologi kepada bunyi bising di kawasan kajian yang mempunyai dan tidak mempunyai penghadang bunyi. L_{Aeq} di semua kawasan kajian pada semua waktu pengukuran mencatatkan 61.9 dB(A) hingga 74.8 dB(A) pada siang hari (pagi, tengah hari, dan petang) dan 57.6 dB(A) hingga 73.2 dB(A) pada malam hari. Semua hasil kajian melebihi had bunyi Garis Panduan Malaysia. PCA menunjukkan peratus varians keseluruhan sehingga 95% oleh parameter komposisi trafik seperti kereta, motorsikal, dan lori kecil. Kehilangan sisipan penghadang bunyi konkrit panel adalah melebihi nilai minima penghadang bunyi yang berkesan. Blok konkrit berlubang pula mencatatkan sebahagian kecil kehilangan sisipan yang kurang daripada nilai minima penghadang bunyi yang berkesan manakala tumbuh-tumbuhan tidak menyediakan kehilangan sisipan yang mencukupi sebagai penghadang bunyi yang berkesan. Konkrit panel menyediakan kehilangan sisipan yang berkesan dan konsisten diikuti oleh blok konkrit berlubang dan tumbuh-tumbuhan. Model regresi linear kumpulan ciri-ciri trafik mempamerkan prestasi optimum pekali penentuan untuk lokasi yang mempunyai dan tanpa penghadang bunyi dengan nilai 0.858 dan 0.839 setiap satu.

ACKNOWLEDGEMENTS

"In the name of Allah, the most gracious, the most compassionate"

First and above all, I praise Allah, the almighty for providing me this opportunity and granting me the capability to proceed successfully in this study. This thesis appears in its current form due to the assistance and guidance of several people and organizations. I would therefore, like to offer my sincere thanks to all of them.

First and foremost, I offer my sincerest gratitude to my supervisor, Associate Professor Dr. Ramdzani bin Abdullah, who has supported me throughout my thesis with his patience and knowledge whilst allowing me the room to work in my own way. I attribute the level of my doctor of philosophy degree to his encouragement and effort and without him; this thesis too, would not have been completed or written. One simply could not wish for a better or friendlier supervisor.

I would like to offer special thanks to my co-supervisor, Profesor Dato' Abang Abdullah Abang Ali and Profesor Ir. Dr. Mohd Jailani Mohd Nor, who not only provided helpful suggestion but also for the careful review and valuable guidance throughout my study.

I would like to express my deepest gratitude to my family, Mohamad Firdaus bin Mahamad Yusob(my husband), Halim bin Din(my father), Shamsiah binti Kasim(my mother), Zaiton bin S. Abdul Hamid(my mother-in-law), Mahamad Yusob bin Osman(my father–in-law), Hafiza binti Halim(my second younger sister), and Hazren binti Halim(my youngest sister), who always there for me and also willing to take care of my little sons(Muhammad Ibrahim bin Mohamad Firdaus and Muhammad Nuh bin Mohamad Firdaus), while I continued my Ph.D study. You were the spark that rekindled my dream and led me to complete my Ph.D. I hope you know how grateful I am for you and how much I love you all.

I would like to express my deep appreciation to the many friends who provided so much support and encouragement throughout this process including Dr. Nurul Izma Mohammed, Dr. Badriyah Zakaria and Nurul Jannah Khairuddin, and Doreena Dominick. In particular, I would like to thank to my dearest friend, Dr. Nurul Hana binti Mokhtar Kamal for her constant support and always believe in me at all time to finish this study. Thank you for helping me with my thesis.

Finally, I wish to express my biggest acknowledgement to Universiti Putra Malaysia and Universiti Sains Malaysia for providing me financial support under Research University Grant Scheme(RUGS) and Academic Staff Training Scheme (ASTS), respectively. As a saying goes "Money isn't the most important thing in life, but it's reasonably close to oxygen, in a scale of 'got to have it", I really thanked to the both organizations for assisting me financially throughout my study.

This thesis was 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 were as follows:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

ANSI	American National Standards Institute
BESRAYA	Sungai Besi Expressway
BS	British Standards
dB(A)	A-Weighted Sound Level in Decibel
DOE	Department of Environment
DUKE	Duta-Kelang Expressway
ELITE	Central Link Expressway
GCE	Guthrie Corridor Expressway
IL	Insertion loss
ISO	International Standards Organisation
KESAS	Kuala Lumpur Shah Alam Expressway
km	kilometre
L_{10}	10^{th} Percentile Noise Level
L_{50}	50^{th} Percentile Noise Level
L_{90}	90^{th} Percentile Noise Level
LDP	Damansara Puchong Highway
LEKAS	Kajang- Seremban Expressway
LHH	League for the Hard of Hearing
L_{Aeq}	Equivalent Noise Level
L_{DEN}	Day-Evening-Night sound level
L_{max}	Maximum Noise Level
L_{min}	Minimum Noise Level
m	metre
mm	milimetre
m/s	metre per second
MEX	Kuala Lumpur- Putrajaya Expressway
MLR	Multiple Linear Regression
ND	Noise Descriptor
NKVE	New Klang Valley Expressway
NPE	New Pantai Expressway
PCA	Principal Component Analysis
SILK	Sistem Lingkaran Lebuhraya Kajang Sdn. Bhd.
SKVE	South Klang Valley Expressway
SLM	Sound Level Meter
SPL	Sound Pressure Level
SPRINT	Western KL Traffic Dispersial System
USDT	United States Department of Transportation
WCHB	With Concrete Hollow Block as Noise Barrier
WCP	With Concrete Panel as Noise Barrier
WHO	World Health Organization
WOCHB	Without Concrete Hollow Block as Noise Barrier
WOCP	Without Concrete Panel as Noise Barrier
WOV	Without Vegetation as Noise Barrier
WV	With Vegetation as Noise Barrier

CHAPTER 1

INTRODUCTION

1.1 Overview

Sound is created when an object moves. Vibration of molecules that caused by the movement and reach our ears is called sound. However, noise is categorized as unwanted sound. Noise pollution is by now recognized worldwide as a major problem for the quality of life in all urban areas either in developed or developing countries (Piccolo et al., 2004). Investigations in different countries in the past several decades have shown that noise affected different activities badly and caused sleep disturbances and a poorer life quality (Berglund et al., 1999; Onuu, 2000; Bavani et al., 2010). It will be a larger and serious social problem in the future if effective precautions are not taken accordingly. Noise effect includes various impacts on mental and physical health and disturbance of daily activities which may affect sleep, conversation, lead to perception of annoyance, cause hearing loss, cardiovascular problems as well as affect human judgment and performance (Langdon and Griffiths, 1982).

Out of varieties sources of noise generation, traffic is the main source of the unwanted sound. Furthermore, traffic noise is one of the most important environmental issues in recent years due to increasing number of road vehicles (Abdelazeez and Hammad, 1987; Al-Mutairi et al., 2009; Raza et al., 2011; Anirban et al., 2012). In many cities, it is not uncommon to have traffic-related noise reaching the level of 80 dB(A) and higher at the roadside (Dai et al., 2005; Ta et al., 2011; Anirban et al., 2012; Bijay et al., 2012). These studies reflected that traffic noise was the main problem for urban residential areas as their locations were very close to roads and highways due to inavailability of enough lands. Therefore, noise levels at the adjacent residential areas were very high.

Millions of lives are affected by traffic noise pollution across the globe. For instance, the United States of Environmental Protection Agency reported that over 100 million residents that are exposed to traffic noise. It has been estimated that 40% of the European population is exposed to traffic noise at levels above 55 dBA (WHO, 1999). There is increasing evidence that exposure to traffic noise may be associated with a wide range of psychological and physiological effects including annoyance, sleep disturbance, stress reactions, hypertension, cardiovascular events, and diabetes (Berglund et al., 1999; Onuu, 2000; Skanberg and Ohrstrom, 2002; Babisch, 2003; Dai et al., 2005; Sorensen et al., 2013). Therefore, there is an essential need to control the noise induced by transportation in urban areas.

Controlling traffic can sometimes reduce noise problems. By banning usage of horns, maximum noise reduction of 10dB occurred (Ali and Tamura, 2003). Other than that, bypasses of heavy vehicles should be created away from residential areas due to high level of noise produced by that type of vehicles (Ali and Tamura, 2003). Moreover, reducing speed limits on the highway could also work in reducing noise problems. A reduction of speed from 60km/h to 30 km/h was predicted to reduce 3 dB(A) (Mitchell, 2009).

Some noise reduction measures that are possible on existing roads including erect noise barriers and managing traffic. Noise barriers are solid obstruction built between the highway and residential areas. Noise barrier can be built out of wood, concrete, masonry, metal and transparent materials (FHWA, 2013). Noise barrier perform at its best if long enough and high enough to block the view of the road.

1.2 Problem Statement

Noise barriers prevent direct line-of-sight propagation between noise sources and receivers (Grubeša et al., 2011). Diffraction of sound over their horizontal edges is typically the dominant contribution to the sound field behind the barrier. A noise barrier is especially efficient at close distances, where a deep acoustic shadow zone is formed. With increasing receiver or source distance from the barrier, its shielding decreases as the difference between the length of the path sound has to travel from source to receiver over the barrier and the length of the direct sound path between source and receiver decreases. A noise barrier is also strongly influenced by the ground type. Typically, a barrier has a higher insertion loss when placed on a rigid surface relative to a porous ground. In the case of a flat terrain, the noise reduction due to fully covered barriers is predicted between 5 and 6 dB(A) for a low receiver zone. For a pedestrian receiver (or bicyclist), thought to be at 1 m from the noise wall (at a height of 1.5 m), the noise reduction is about 4 dB(A).

There are general traffic noise measurements carried out by many authorities in Malaysia. For instance, noise measurement and assessment carried out by Institute of Noise and Vibration, Malaysia at Taman Bukit Setiawangsa stated that 24 hours L_{Aeq} recorded was 65.3 dB(A), while night L_{Aeq} was measured to be 61.9 dB(A) (LLM, 2011). Apart from that, Department of Environment (DOE) has reported that there is a steady increase in complaints related to noise made by the general public. In order to solve the problem, some local authorities have required the highway developer and operator to build noise barriers in certain areas such that there are various types of barriers have been constructed very close to residential areas. However, there are concerns on the effectiveness of the noise barrier in Malaysia (Chan, 2008, Jayaraj, 2012) as traffic noise levels are considered high by residents even by the presence of noise barriers. In reality, there is no proper research carried out to determine the effectiveness of different types of noise barriers built in Malaysia. The only documentation that is closely related is the Guidelines of Noise Barriers at Highway-first edition (LLM, 2011). Inspired by the lack of studies, this study seeks to evaluate the effectiveness of noise barrier built at residential areas in Klang Valley, Malaysia. This research is conducted in anticipation to bridge the finer gap in the literature of this field as well as assist the local authority such as Lembaga Lebuhraya Malaysia (LLM) to build effective noise barriers in Malaysia.

1.3 Objectives

The aim of this study was to determine the effectiveness of the noise barrier in Malaysia. The research was carried out in order to acheive the following four main objectives:

(a) To investigate the level of traffic noise in residential areas with and without the presence of noise barriers
(b) To determine the significant variables contributing to traffic noise level in study sites
(c) To compare the effectiveness and suitability of the noise barriers in protecting residential areas from road traffic noise
(d) To determine the equivalent noise levels using multiple linear regression models for Malaysia noise level prediction model

This study is based on the environmental management point of view regarding to the effectiveness of the noise barrier. The results of this study will significantly assist various agencies such as highway agency which is known as Lembaga Lebuh Raya Malaysia (LLM) to build an effective noise barrier that suited the traffic characteristic on the highway. In the future, LLM will not only be able to enhance the effectiveness of noise barrier by focusing on the material, but also by looking at traffic characteristics factors that contributed to the high noise level which adversely affects the effectiveness of noise barrier in Malaysia.

1.4 Scope of the Study

The scope of the study covers the in-situ measurement of traffic noise at location with an without the presence of the noise barrier in order to evaluate the effectiveness of the noise barrier. An analysis of determining the contributing factors to the traffic noise is carried out. Comparison of traffic noise with the existing noise models is also performed to identify the accuracy of the models to predicts noise level in Malaysia with different traffic characteristics compared to other countries.This study is based on the environmental management point of view regarding the effectiveness of the noise barrier. Therefore, no erroneous noise (such as honking and sirens) is edited out as these noise are also categorized as traffic noise. No social study as well as laboratory study will be performed in this study. A prediction model of traffic noise is developed to satisfy Malaysia traffic conditions.

1.5 Structure of Thesis

Chapter 1 provides an overview of noise pollution and traffic noise worldwide and introduction of this thesis. It then, details the problem statements and objectives of the research. Chapter 2 reflects the literature review which discusses the details of traffic noise and its sources. Furthermore, related studies on noise barrier are also presented here. The information on noise and noise barrier guidelines that have been implemented to protect dwellings, especially the insertion loss is briefly discussed in this chapter. Chapter 3 explains all the materials and methods involved in this research. This chapter provides information on the study area, sampling strategies and data collection as well as the way the data has been analysed. Chapter 4 presents the results of this research. The temporal assessment of noise level were analysed in the form of descriptive statistics, principal component analysis, and multiple linear regression. In addition, two existing prediction models were presented to compare with the measured noise level. Next, the insertion loss of noise barriers in study sites was computed to determine the effectiveness of the noise barriers involved in this study. Chapter 5 concludes the research and lists the recommendation for further work. The following flowchart shows the framework of the research in this thesis (Figure 1.1).

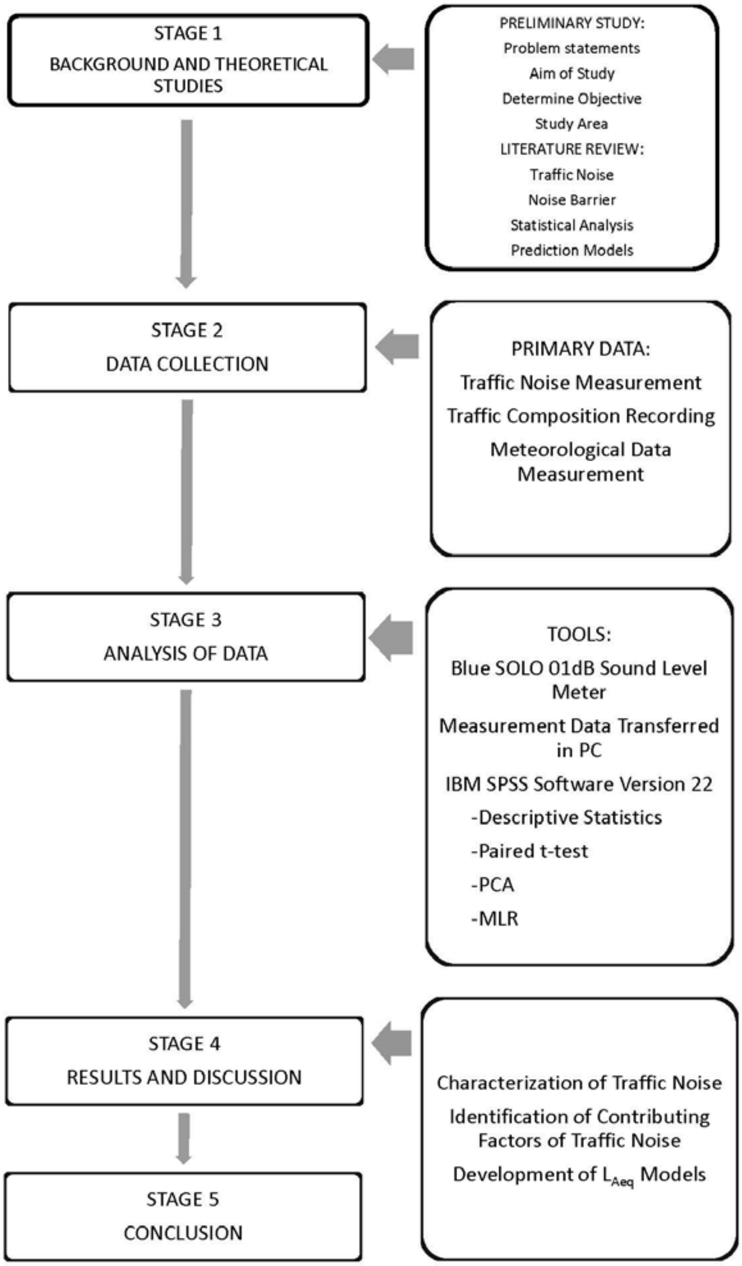

Figure 1.1: Flowchart of the Framework of Research Methodology

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APPENDICES

Appendix A: Other noise descriptors at location with barrier

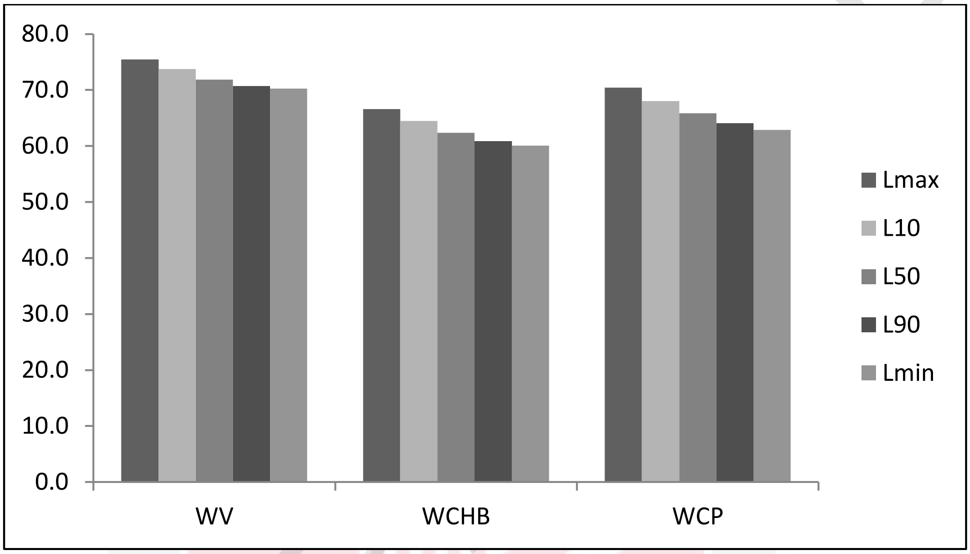

Figure A1: Average noise descriptors at with barrier locations in morning during weekdays

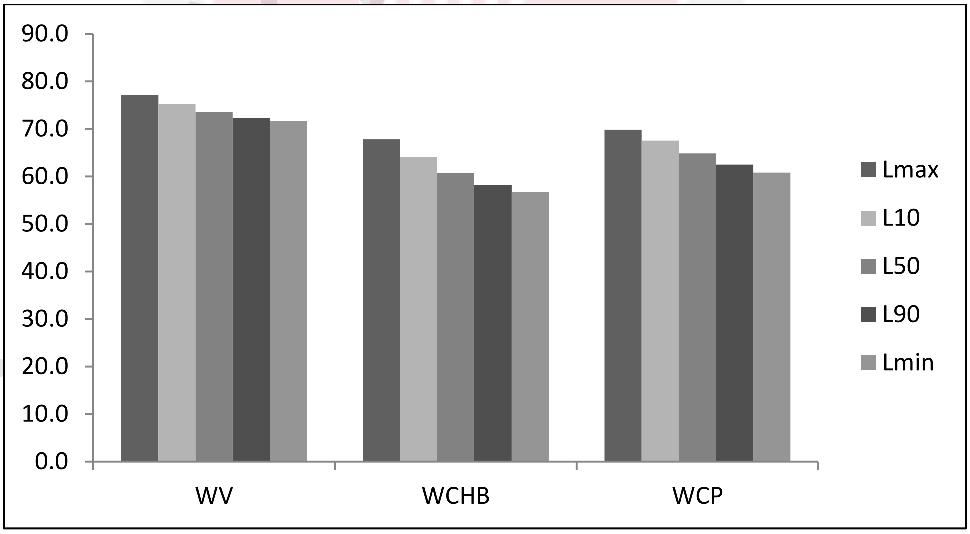

Figure A2: Average noise descriptors at with barrier locations in afternoon during weekdays

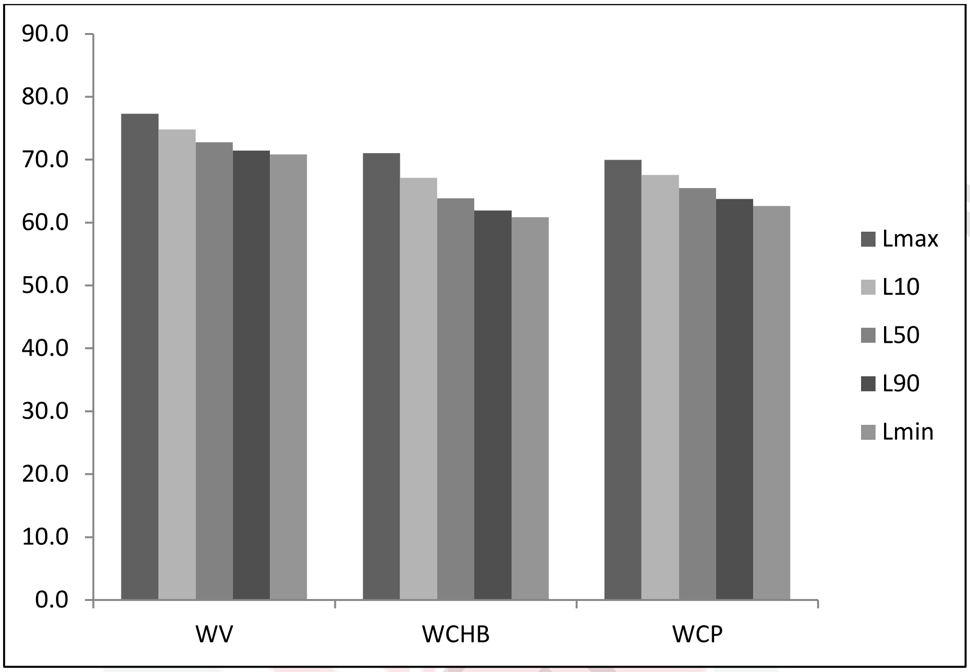

Figure A3: Average noise descriptors at with barrier locations in evening during weekdays

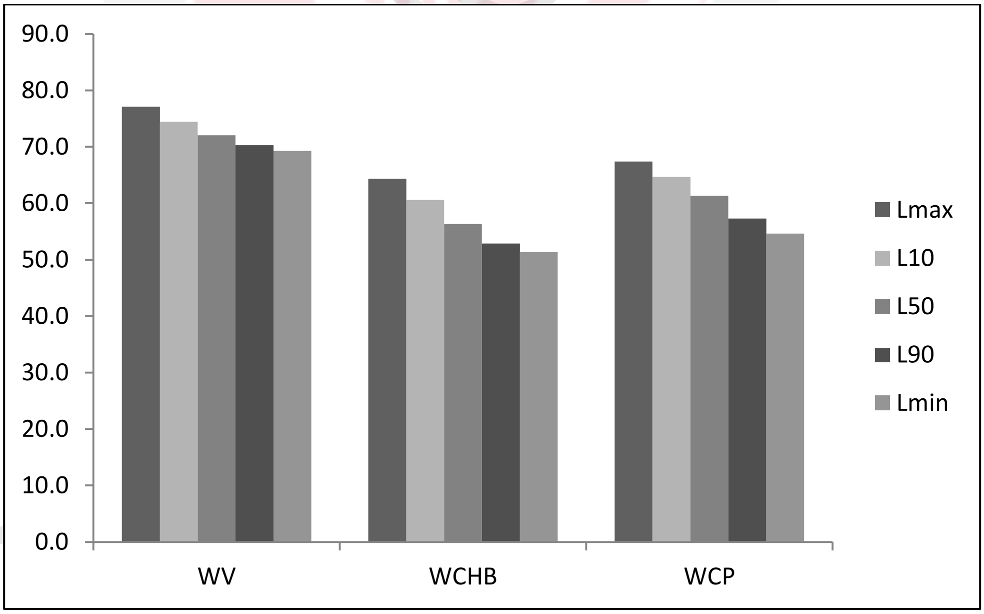

Figure A4: Average noise descriptors at without barrier locations in night during weekdays

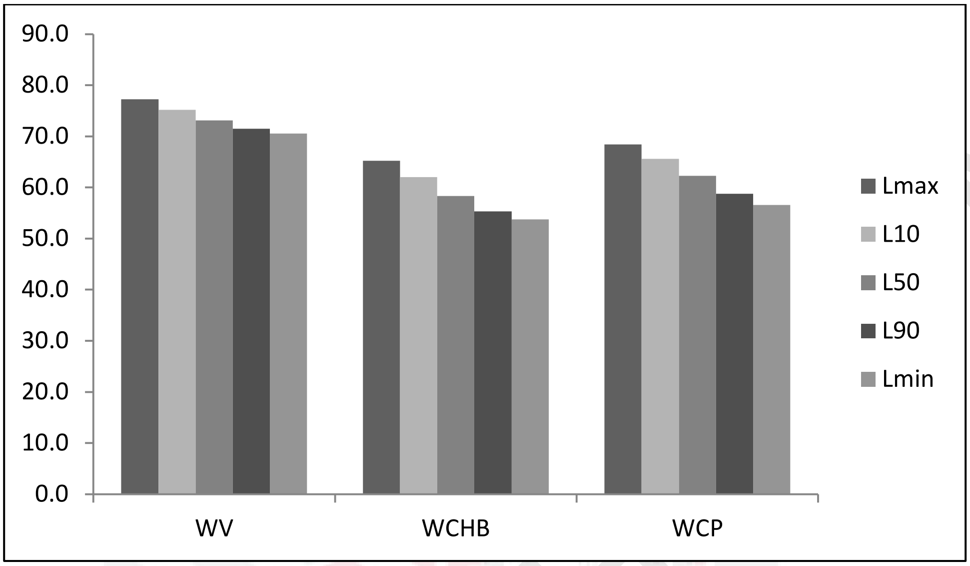

Figure A5: Average noise descriptors at with barrier locations in morning during weekends

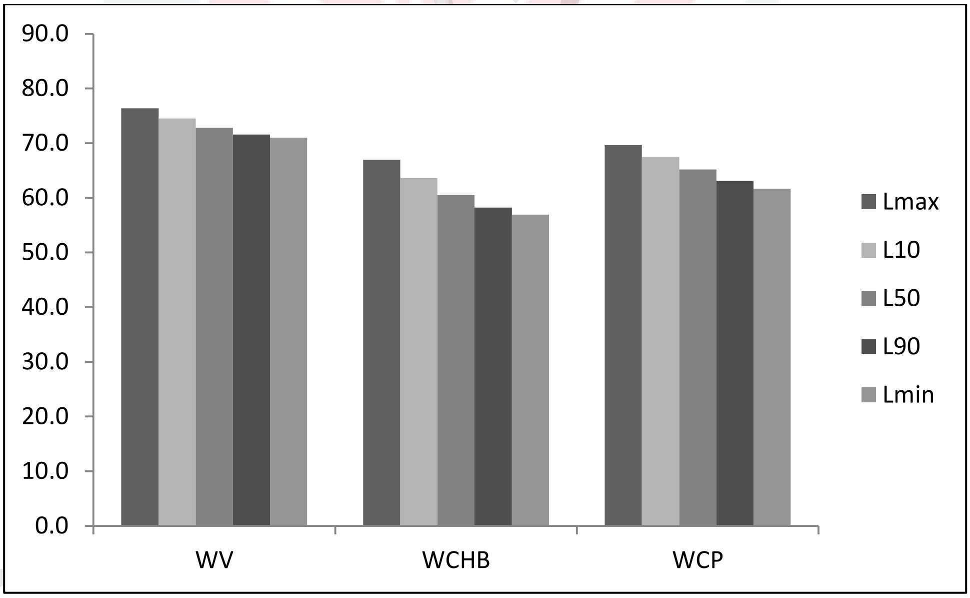

Figure A6: Average noise descriptors at with barrier locations in afternoon during weekends

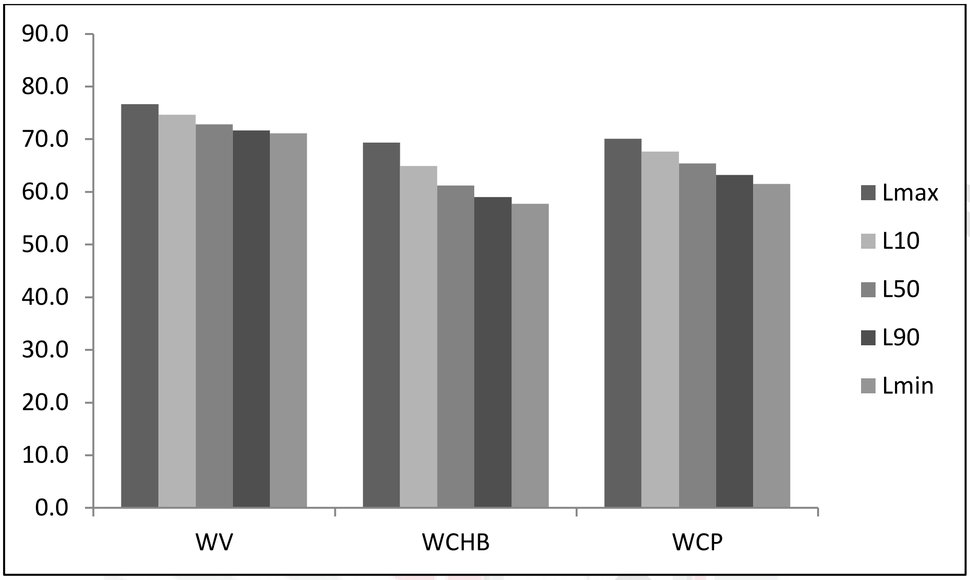

Figure A7: Average noise descriptors at without barrier locations in evening during weekends

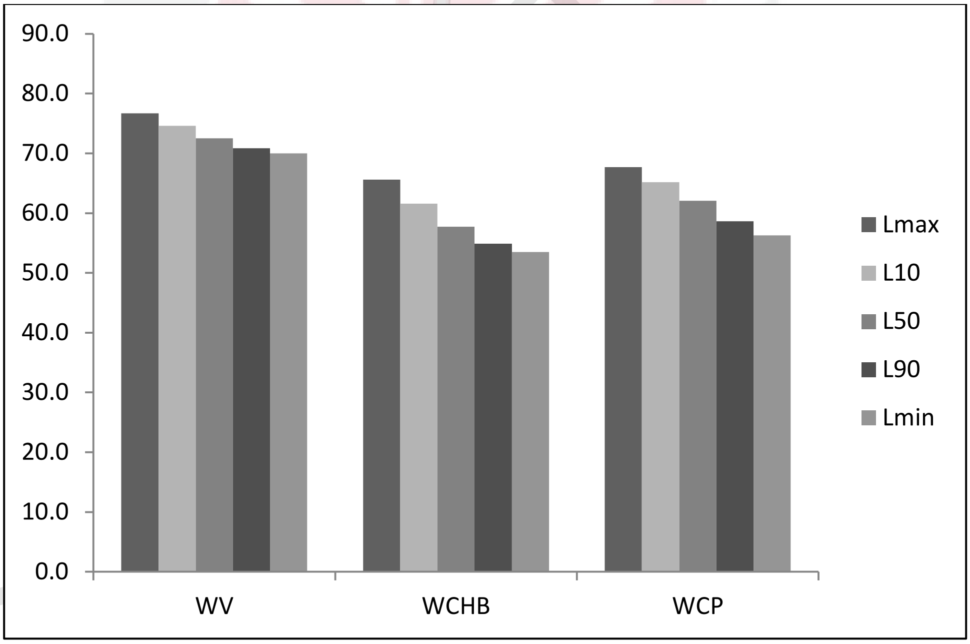

Figure A8: Average noise descriptors at without barrier locations in night during weekends

Appendix B: Number of different type of vehicles on Highway during measurement periods

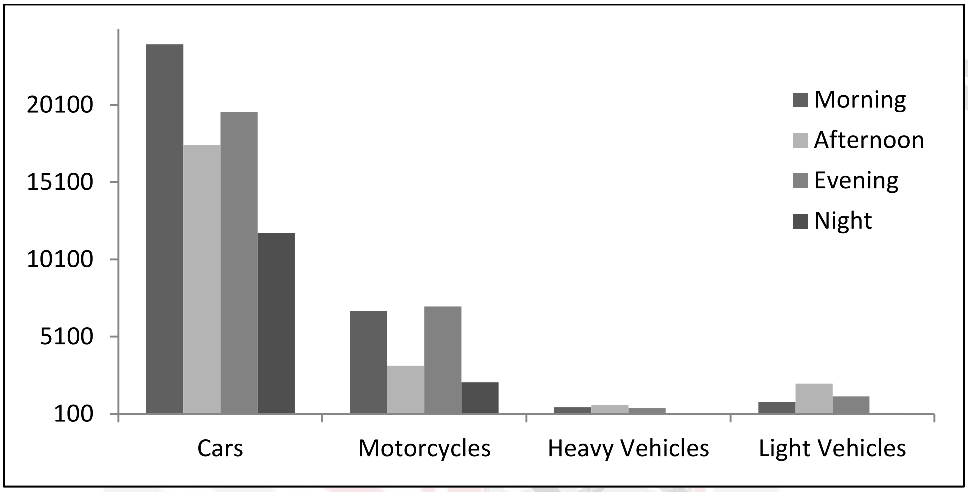

Figure A9: Number of different type of vehicles on weekdays on Sungai Besi Highway during measurement period

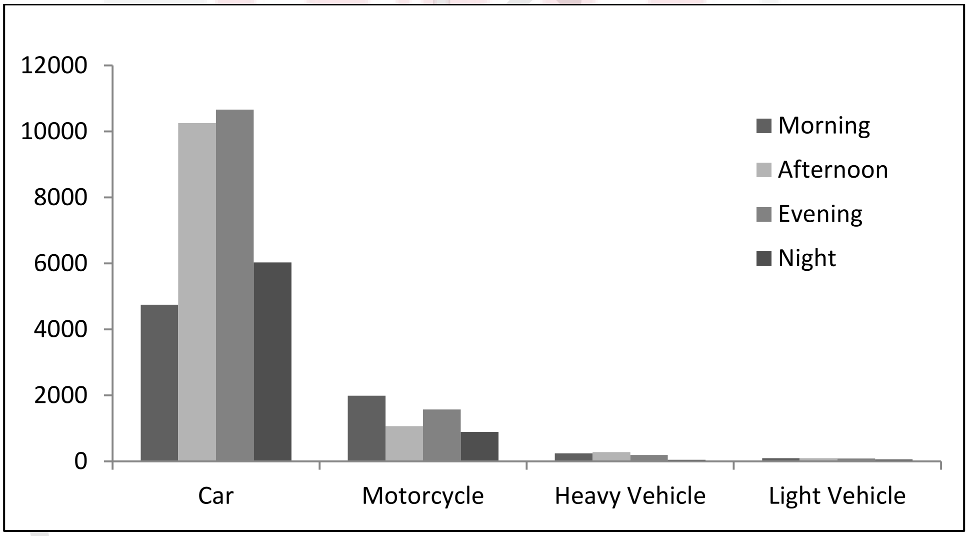

Figure A10: Number of different type of vehicles on weekends on Sungai Besi Highway during measurement period

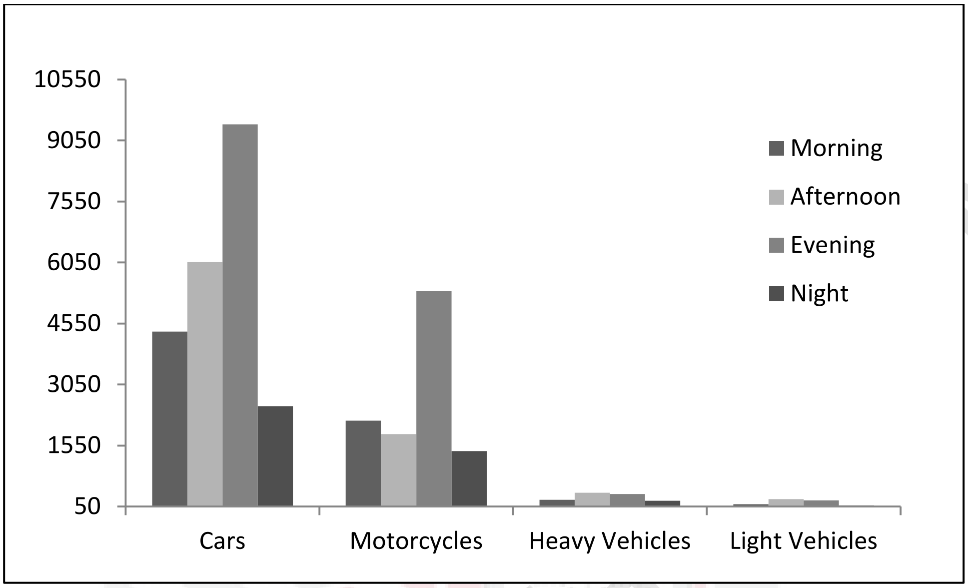

Figure A11: Number of different type of vehicles on weekdays on DUKE Highway during measurement period

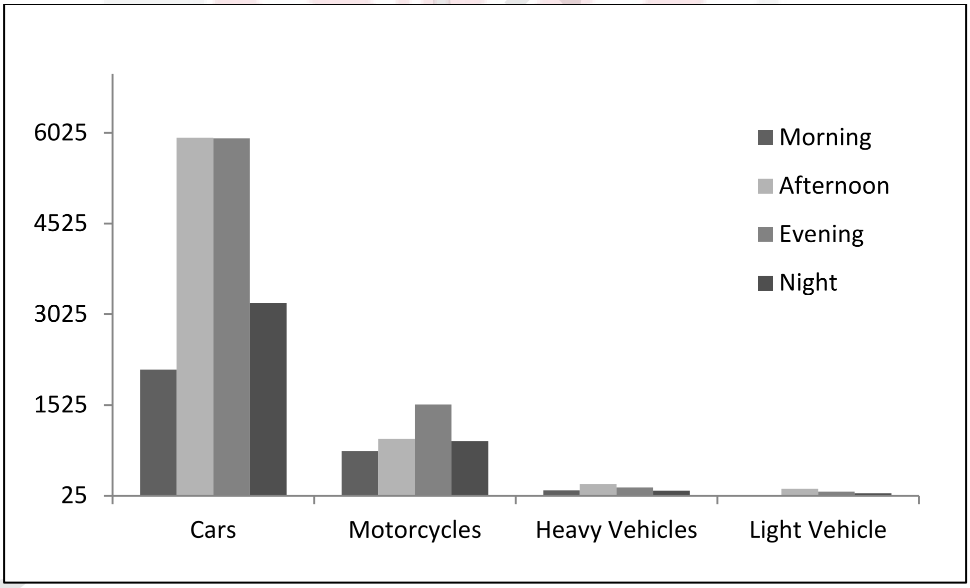

Figure A12: Number of different type of vehicles on weekends on DUKE Highway during measurement period

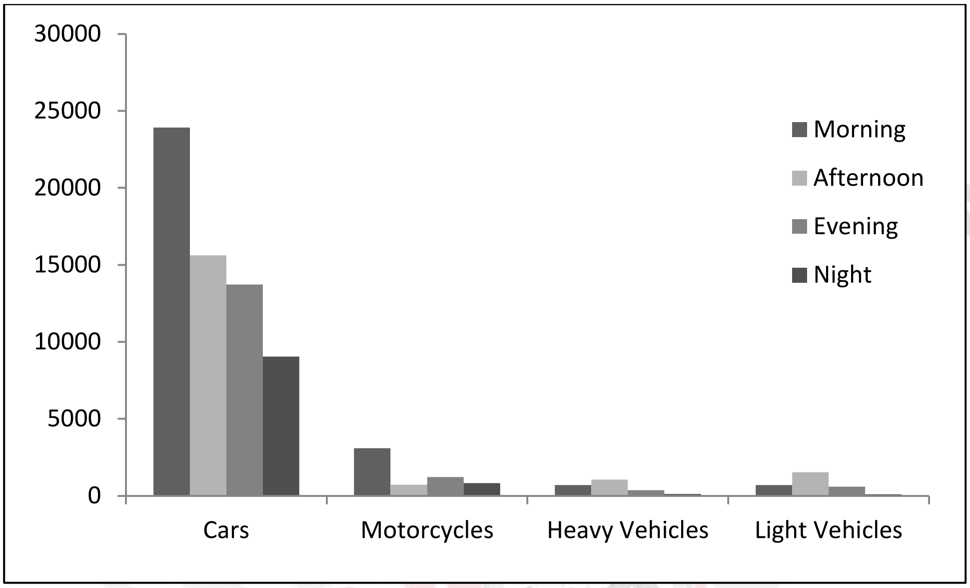

Figure A13: Number of different type of vehicles on weekdays on KESAS Highway during measurement period

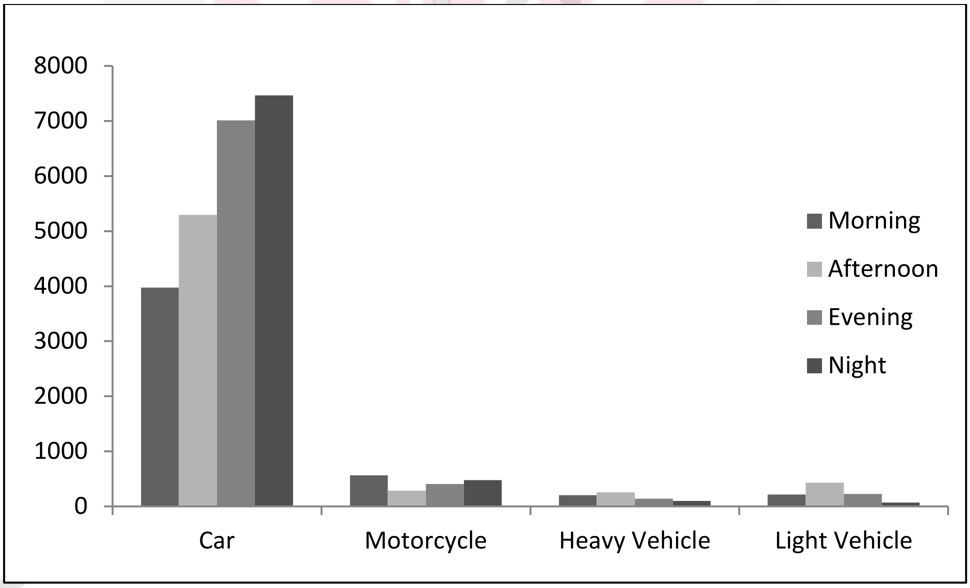

Figure A14: Number of different type of vehicles on weekends on KESAS Highway during measurement period

Appendix C: Percentage of different type of vehicles on Highways

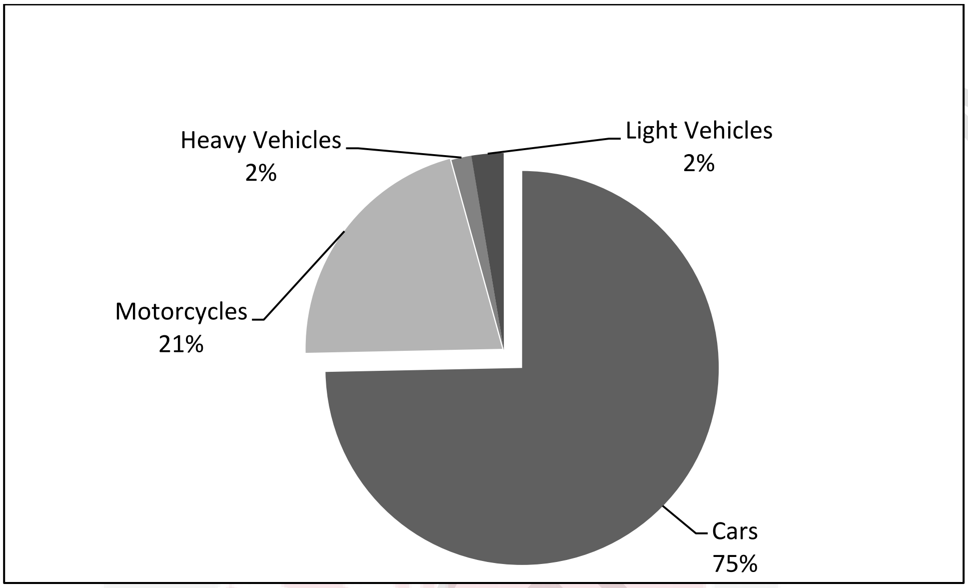

Figure A15: Percentage of different type of vehicles during weekdays on Sungai Besi Highway

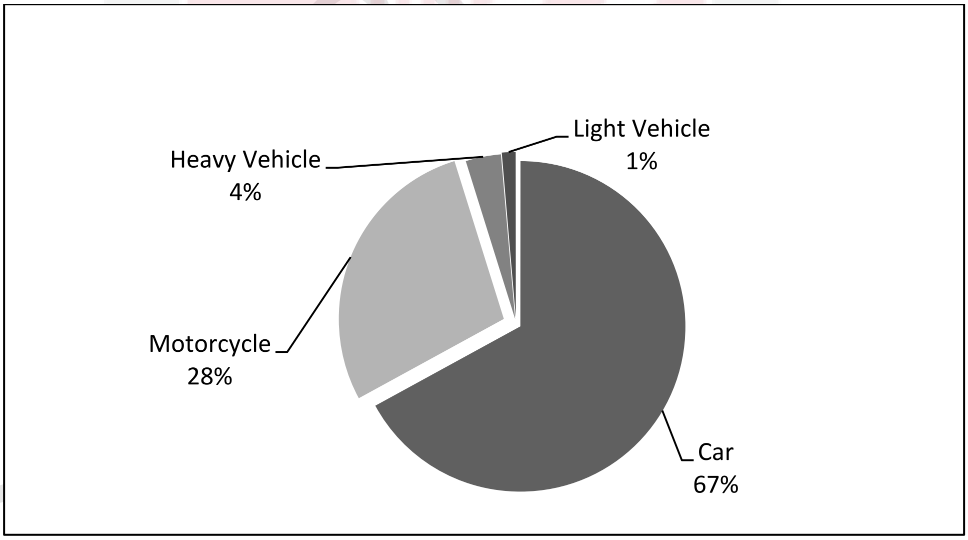

Figure A16: Percentage of different type of vehicles during weekends on Sungai Besi Highway

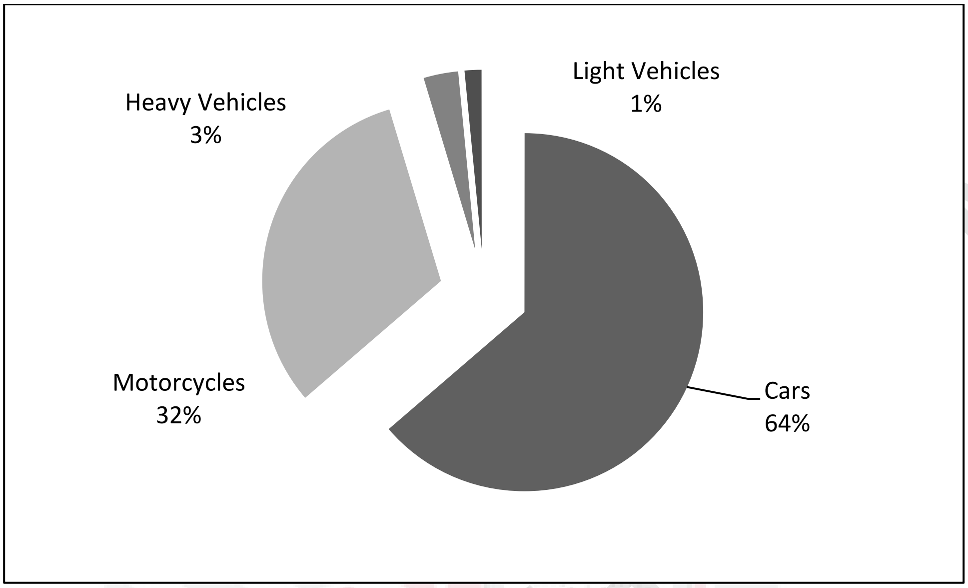

Figure A17: Percentage of different type of vehicles during weekdays on DUKE Highway

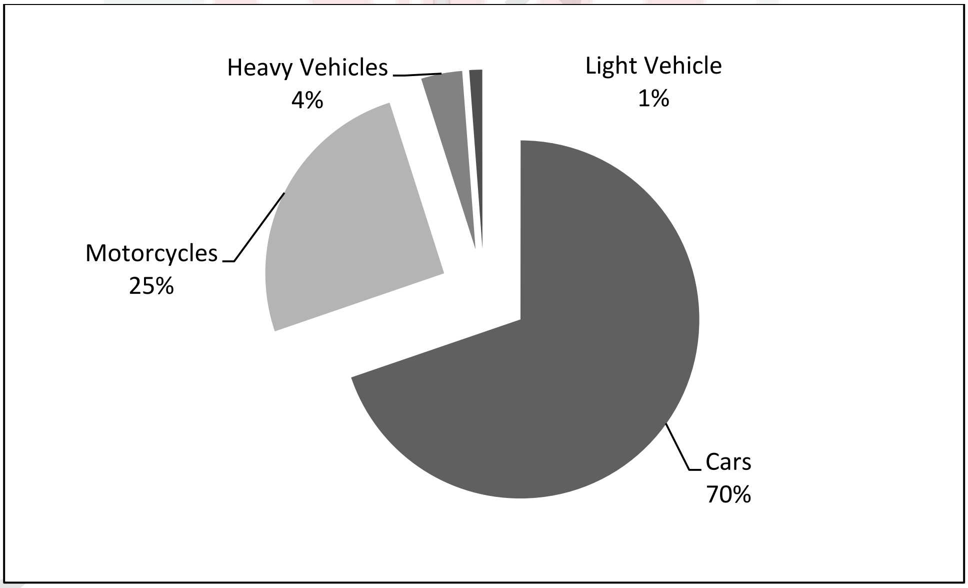

Figure A18: Percentage of different type of vehicles during weekends on DUKE Highway

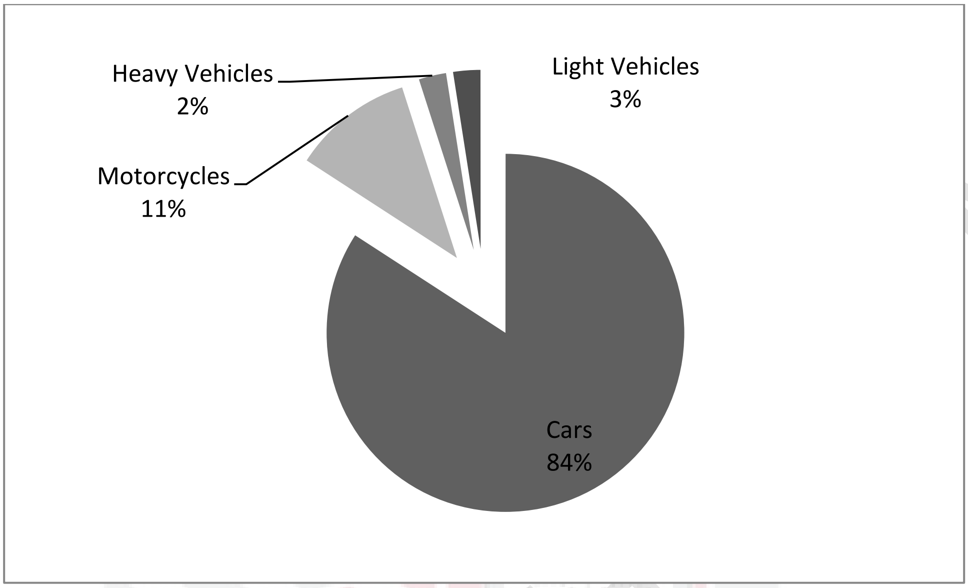

Figure A19: Percentage of different type of vehicles during weekdays on KESAS Highway

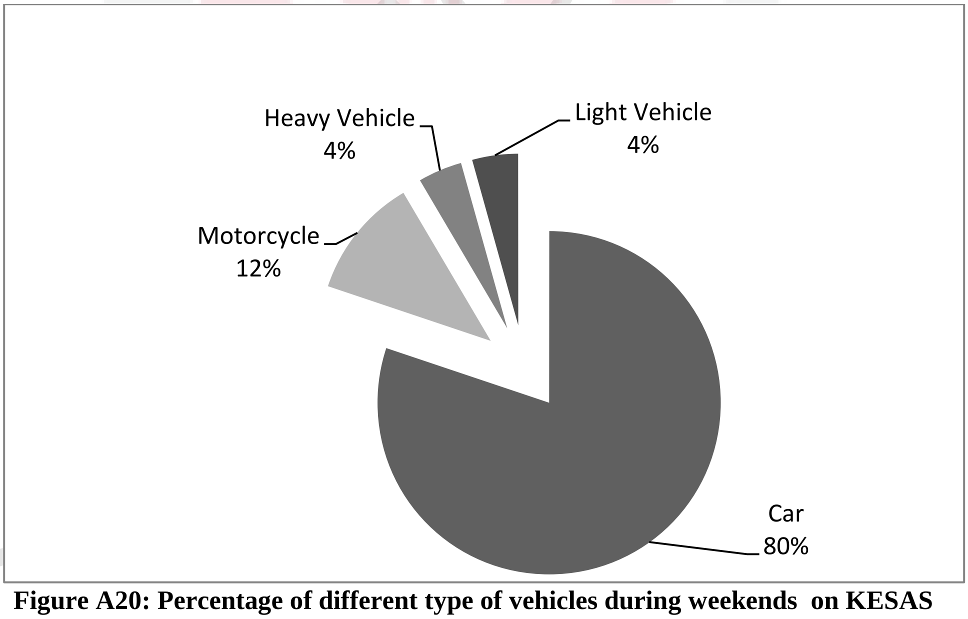

Figure A20: Percentage of different type of vehicles during weekends on KESAS Highway

Appendix D: Percentage of total number of vehicles during four measurement periods

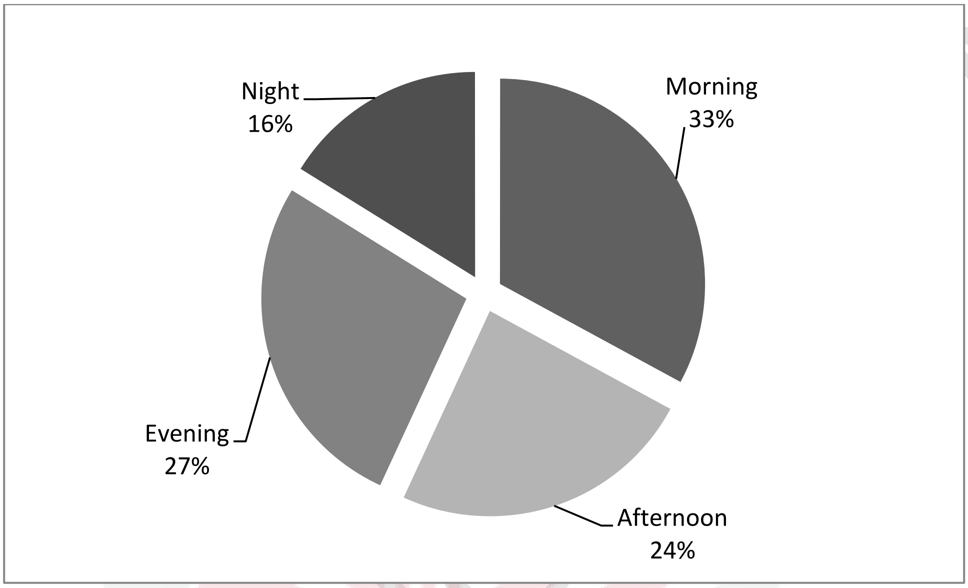

Figure A21: Percentage of total number of vehicles during four measurement periods at Sungai Besi Highway during weekdays.

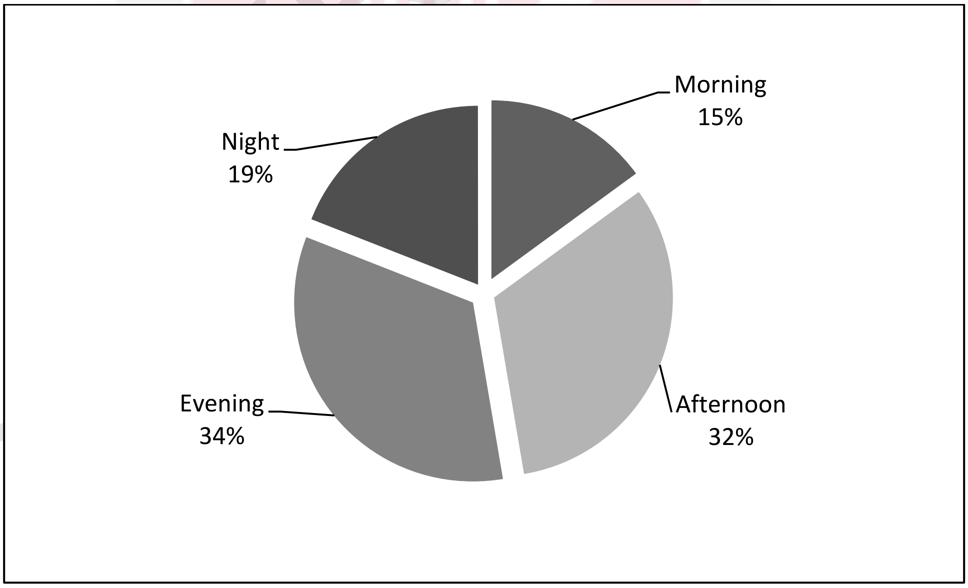

Figure A22: Percentage of different type of vehicles during four measurement periods at Sungai Besi Highway during weekends

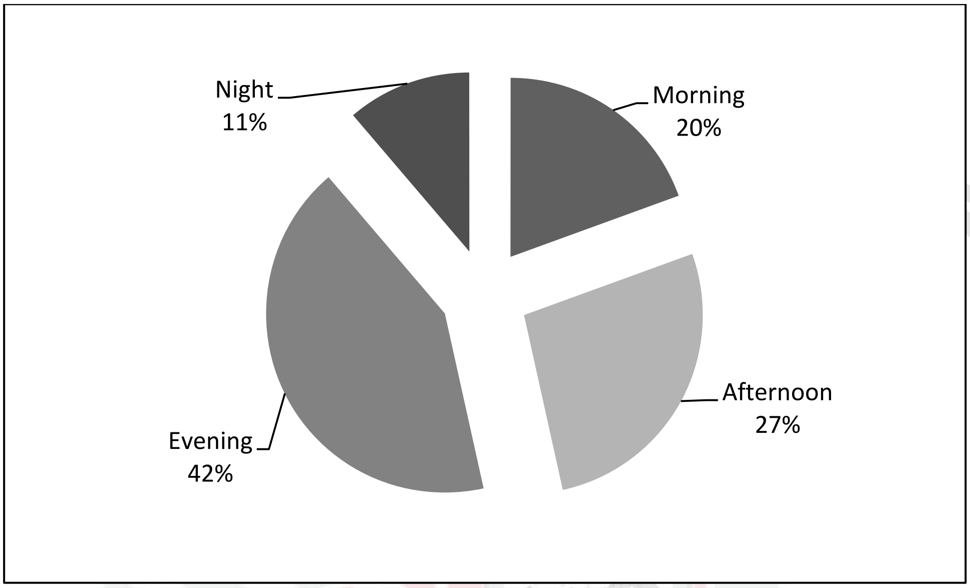

Figure A23: Percentage of total number of vehicles during four measurement periods at DUKE Highway during weekdays.

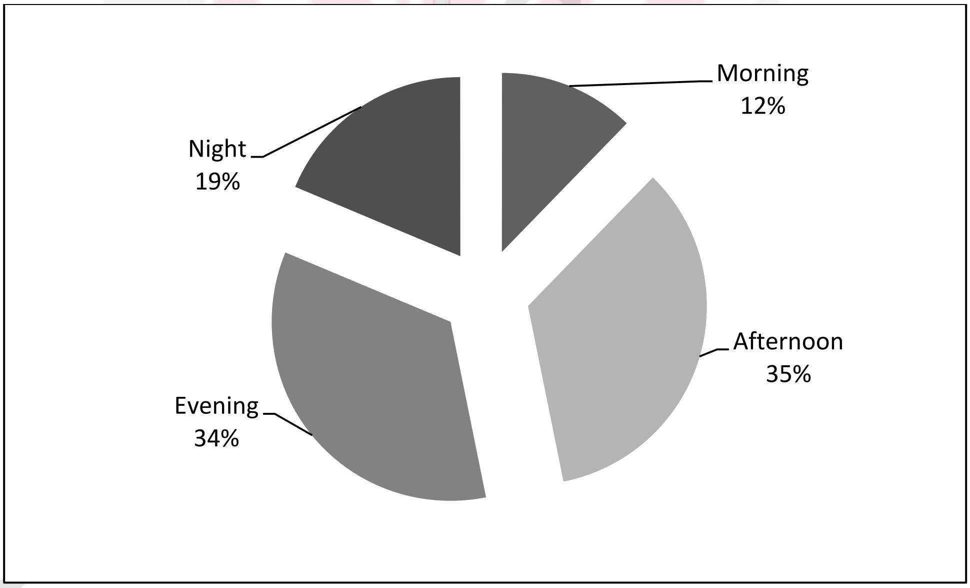

Figure A24: Percentage of total number of vehicles during four measurement periods at DUKE Highway during weekends

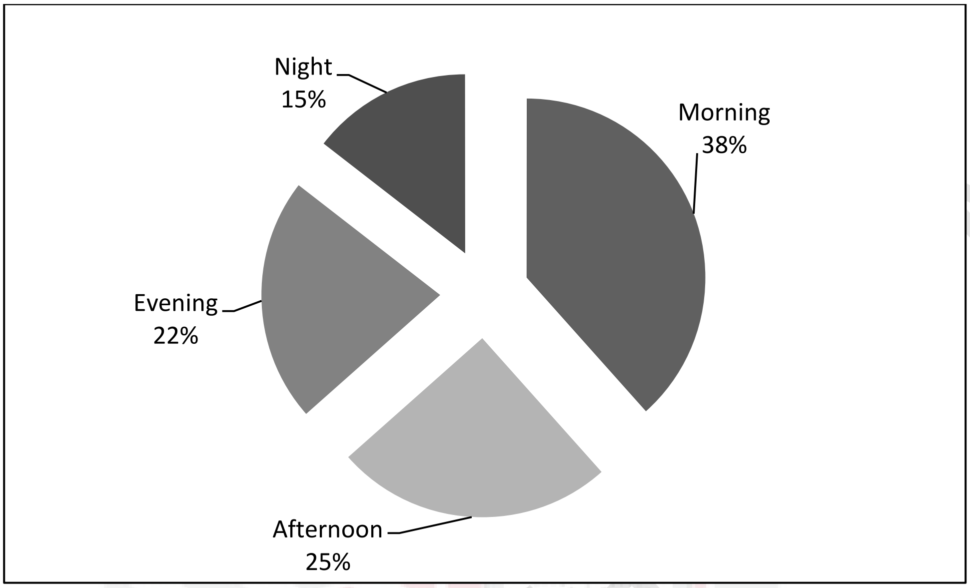

Figure A25: Percentage of total number of vehicles during four measurement periods at KESAS Highway during weekdays

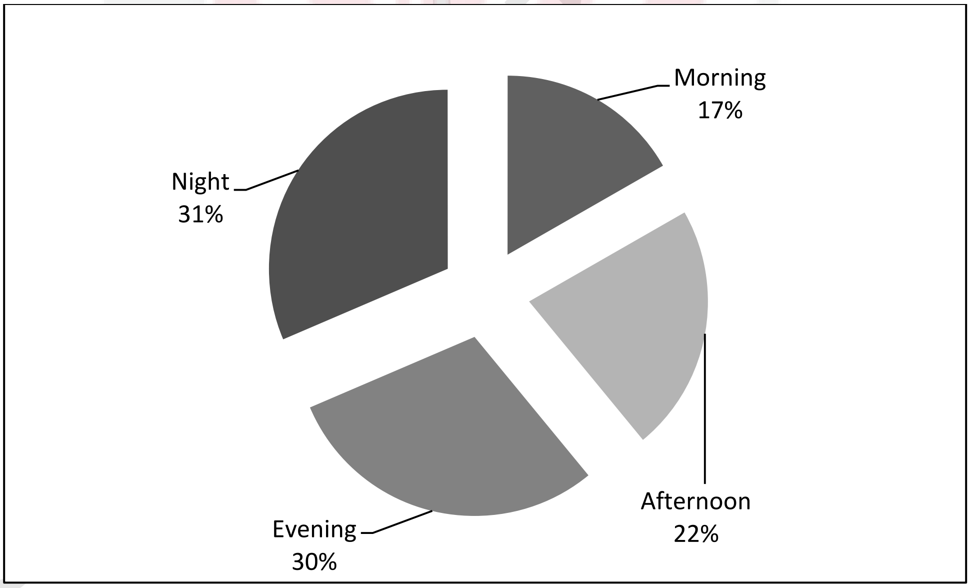

Figure A26: Percentage of different type of vehicles during four measurement periods at KESAS Highway during weekends

Appendix E

Table A1: Speed of Each Type of Vehicles during (a) Weekdays and (b) Weekends

Highways	Time	speed (km/ hr) cars	average	heavy vehicles	average	medium lorries	average	motorcycles	average
Sungai Besi Highway	0700-0900	3 to 34	19.52	3 to 34	20.64	11 to 38	21.67	13 to 41	28.95
	1200-1400	37 to 85	55.67	36 to 64	49.97	31 to 69	48.50	39 to 73	43.05
	1700-1900	34 to 75	51.11	27 to 70	44.63	20 to 59	40.50	42 to 95	53.05
	2300-0100	48 to 106	71.15	33 to 74	53.16	39 to 92	63.57	29 to 79	55.50
DUKE Highway	0700-0900	66 to 96	76.15	44 to 85	67.29	49 to 88	68.89	56 to 83	69.00
	1200-1400	59 to 124	78.46	44 to 79	65.53	45 to 77	61.30	57 to 92	73.65
	1700-1900	63 to 83	70.95	39 to 72	60.88	40 to 73	59.20	59 to 99	75.45
	2300-0100	60 to 149	80.85	38 to 86	60.50	42 to 106	67.75	55 to 100	70.47
KESAS Highway	0700-0900	75 to 102	86.05	37 to 84	63.10	48 to 83	69.35	53 to 80	65.45
	1200-1400	72 to 110	82.55	53 to 78	65.57	56 to 99	76.95	53 to 80	65.45
	1700-1900	66 to 110	83.31	48 to 83	68.81	50 to 78	68.75	55 to 88	68.85
	2300-0100	70 to 110	81.67	48 to 71	58.54	46 to 76	61.29	55 to 98	72.10

(a)

Highways	Time	speed (km/ hr) cars	average	heavy vehicles	average	Medium Lorries	average	motorcycles	average
Sungai Besi Highway	0700-0900	57 to 99	95.11	41 to 88	60.15	45 to 81	64.15	47 to 94	71.00
	1200-1400	36 to 89	63	29 to 62	47.60	40 to 81	50.55	35 to 74	55.30
	1700-1900	50 to 88	76.4	25 to 70	46.92	29 to 85	56.70	41 to 87	62.10
	2300-0100	56 to 106	85.83	37 to 72	60.08	22 to 90	57.30	44 to 106	64.30
DUKE Highway	0700-0900	60 to 95	76.45	52 to 99	67.20	47 to 93	71.75	46 to 89	63.55
	1200-1400	66 to 105	81.95	46 to 99	61.79	47 to 84	65.04	60 to 92	76.05
	1700-1900	72 to 106	79.95	46 to 73	62.31	43 to 85	64.33	59 to 91	72.16
	2300-0100	63 to 109	77.1	46 to 87	68.40	42 to 89	66.50	58 to 84	60.70
KESAS Highway	0700-0900	75 to 110	86.95	48 to 94	67.32	55 to 85	70.15	50 to 74	63.80
	1200-1400	82 to 116	89.76	52 to 82	69.32	49 to 92	72.75	60 to 99	52.55
	1700-1900	78 to 107	94.8	40 to 74	65.20	47 to 93	69.85	70 to 95	81.85
	2300-0100	75 to 114	88.95	58 to 81	69.40	55 to 85	65.95	60 to 92	74.85

(b)

LIST OF PUBLCATIONS

Herni H., Ramdzani, A., Abang Abdullah, A.A., and Mohd. Jailani, M.N. 2015. Effectiveness of Existing Noise Barriers: Comparison between Vegetation, Concrete Hollow Block, and Panel Concrete. International Conference of Environmental Forensics 2015(iENFORCE 2015).

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Herni, H. and Ramdzani, A. 2013. Equivalent Noise Level Response to Number of Vehicles: A Comparison between a High Traffic Flow and Low Traffic Flow in Malaysia. *Proceedings of the International Conference on Environmental Forensics* 2013. 149-152. Springer. Singapore

Herni H., Ramdzani A., Abang Abdullah, A.A. and Mohd Jailani M.N. (2013). Assessment on Road Traffic Noise Pollution Indices in Urban Residential Areas in Klang Valley, Malaysia. Submitted to Polish Journal of Environmental Studies (indexed in ISI with 0.6 impact Factor in 2013).

Ibrahim, Zulkiflee and Abdul Latiff, Abd. Aziz and Hashim, Noor Baharim and Halim, Herni and Mokhtar Kamal, Nurul Hana and Haron, Nuryazmeen Farhan (2009). Experimental Investigation on Behaviour of Cross-Flow Thermal Effluent Discharge in Free Surface Flow. *Malaysian Journal of Civil Engineering*, 21 (1). pp. 82-97. ISSN 1823-7843.

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