UNIVERSITI PUTRA MALAYSIA

ASSESSING INTERCITY BUS SAFETY PERFORMANCE IN MALAYSIA USING A COMPOSITE SAFETY PERFORMANCE INDEX

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By

MOHD SHAZWAN BIN DAUD

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

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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September 2016

Chairman: Assoc. Prof. Law Teik Hua, PhD
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In recent years in Malaysia, serious road traffic accidents involving intercity buses have been increasing. Intercity bus drivers are generally at a higher risk for crashes due to long hours of driving and exposure to different road conditions. Therefore, understanding and quantifying their risks and taking steps to manage them could improve intercity bus safety. However, testing intercity bus safety levels through a complete set of road crash risk indicators is difficult to quantify and interpret. In order to avoid this difficulty, it has been recommended that the analysis of intercity bus safety could be tackled by aggregating a multidimensional set of risk indicators into a composite safety performance index (SPI) by giving different weighted importance to different risk domains. However, the development of the composite SPI is sensitive to the choice of weighting method. Given this background, the present work has two objectives. First, to examine the suitability of different weighting methods to develop the composite SPI for intercity buses. Second, to apply SPI values obtained by appropriate weighting method to measure and compare intercity bus safety in terms of risk domains. The risk domains considered in this study are road environment conditions, bus driver driving behaviours and bus safety conditions. A two-stage sampling method was used to choose intercity bus samples. In the first stage, a simple random sampling technique was used to select 30 out of 50 active intercity bus companies in Malaysia. At the second stage of sampling, 30% of the total number of buses were randomly selected from each selected intercity bus company. A correlation analysis of each weighting method ranking and the road crash (RC) ranking was performed to determine which weighting method ranking appropriate for developing the SPI. The paired sample t-test was then applied to the best weighting method to determine which SPI were significantly different from each other. Of the three risk domains, road environment conditions have the highest average weight over the three weighting methods. This implies that an improvement in the road environment could increase the overall safety performance of intercity buses. The results of correlation analysis indicated that the FA method fits the best with the road crash (RC) ranking. The results of paired sample t-test indicated that road environment conditions have contributed more to intercity bus safety risks on the East coast than on the West coast

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of peninsular Malaysia. The evidence presented in this study reveals that different intercity bus companies showed mixed safety performance in different risk domains. Therefore, we suggest the development of targeted road safety programs for each intercity bus company to address intercity bus safety problems. In sum, the composite SPI can not only be used to identify possible risk management strategies to improve intercity bus safety but also to provide safety information for intercity bus passengers, making them fully aware of bus safety conditions. This, in turn, could place economic pressure on bus operators to improve their vehicles' safety performance.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

PENILAIAN PRESTASI KESELAMATAN BAS ANTARA BANDAR DI MALAYSIA MENGGUNAKAN KOMPOSIT INDEKS PRESTASI KESELAMATAN

Oleh

MOHD SHAZWAN BIN DAUD

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Dalam beberapa tahun kebelakangan ini di Malaysia, kemalangan jalan raya yang serius melibatkan bas antara bandar telah meningkat. Pemandu bas antara bandar secara umumnya mempunyai risiko yang lebih tinggi terlibat dalam kemalangan kerana waktu pemanduan yang panjang dan terdedah kepada keadaan jalan yang berbeza. Oleh itu, memahami dan mengukur risiko serta mengambil langkah-langkah untuk menguruskan risiko tersebut boleh meningkatkan keselamatan bas antara bandar. Walaubagaimanapun, pengujian tahap keselamatan bas antara bandar melalui satu set lengkap petunjuk risiko kemalangan jalan raya adalah menjadi sukar untuk diukur dan ditafsirkan. Bagi mengelakkan masalah ini, adalah dicadangkan bahawa analisis keselamatan bas antara bandar dapat ditangani dengan menjumlahkan satu set pelbagai dimensi penunjuk risiko ke dalam komposit indeks prestasi keselamatan (SPI) dengan memberi kepentingan pemberat yang berbeza untuk risiko domain yang berbeza. Walaubagaimanapun, pembangunan komposit SPI adalah sensitif kepada pilihan kaedah pemberat. Berdasarkan latar belakang ini, kajian semasa mempunyai dua objektif. Pertama, untuk mengkaji kesesuaian kaedah pemberat yang berbeza bagi membina komposit SPI untuk bas-bas antara bandar. Kedua, untuk mengaplikasikan nilai-nilai SPI yang diperoleh daripada kaedah pemberat yang sesuai untuk mengukur dan membandingkan keselamatan bas antara bandar dari segi domain risiko. Domain risiko dipertimbangkan dalam kajian ini adalah keadaan persekitaran jalan raya, tingkah laku pemanduan pemandu bas dan keadaan keselamatan bas. Kaedah persampelan dua peringkat telah digunakan untuk memilih sampel bas antara bandar. Di peringkat pertama, teknik persampelan rawak mudah telah digunakan untuk memilih 30 daripada 50 syarikat bas antara bandar yang aktif di Malaysia. Pada peringkat persampelan kedua, 30% daripada jumlah bilangan bas telah dipilih secara rawak daripada setiap syarikat bas antara bandar yang terpilih. Analisis korelasi setiap kedudukan kaedah pemberat dan kedudukan kemalangan jalan raya (RC) dilakukan untuk menentukan kaedah pemberat sesuai untuk membangunkan komposit SPI. Sampel berpasangan t-test kemudiannya diaplikasikan kepada kaedah pemberat yang terbaik untuk menentukan SPI yang jauh berbeza antara satu sama lain. Daripada tiga domain risiko,

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faktor persekitaran jalan raya mempunyai berat purata tertinggi berdasarkan tiga kaedah pemberat. Ini menunjukkan bahawa penambahbaikan dalam persekitaran jalanraya boleh meningkatkan prestasi keselamatan keseluruhan bas antara bandar. Keputusan analisis korelasi menunjukkan bahawa kaedah FA adalah yang terbaik dengan kedudukan RC. Keputusan sampel berpasangan t-test menunjukkan bahawa keadaan persekitaran jalanraya telah menyumbang lebih kepada risiko keselamatan bas antara bandar di Pantai timur daripada di Pantai barat Semenanjung Malaysia. Bukti yang dikemukakan dalam kajian ini menunjukkan bahawa syarikat-syarikat bas antara bandar yang berbeza menunjukkan prestasi keselamatan bercampur di domain risiko yang berbeza. Oleh itu, kami mencadangkan pembangunan pelbagai program keselamatan jalan raya yang disasarkan kepada setiap syarikat bas antara bandar untuk menangani masalah keselamatan bas antara bandar. Kesimpulannya, komposit SPI bukan sahaja boleh digunakan untuk mengenal pasti strategi pengurusan risiko bagi meningkatkan keselamatan bas antara bandar tetapi juga untuk menyediakan maklumat keselamatan untuk penumpang bas antara bandar, menjadikan mereka sedar akan keadaan keselamatan bas. Ini, seterusnya, boleh meletakkan tekanan ekonomi ke atas pengusaha bas untuk meningkatkan prestasi keselamatan kenderaan mereka.

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I certify that a Thesis Examination Committee has met on **26 September 2016** to conduct the final examination of Mohd Shazwan bin Daud on his thesis entitled "**Assessing Intercity Bus Safety Performance In Malaysia Using A Composite Safety Performance Index**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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

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LIST OF ABBREVIATIONS

ABS	Antilock Braking System
ARTSA	Australian Road Transport Suppliers Association
BA	Budget Allocation
BAC	Blood Alcohol Concentration
CI	Composite Index
DWI	Driving While Intoxicated
EC	European Commission
EFA	Exploratory Factor Analysis
EW	Equal Weighting
GPS	Global Positioning System
KMO	Kaiser-Meyer-Olkin
OECD	Organisation For Economic Co-Operative And Development
PDT	Peripheral Detection Task
RC	Road Crash
RLR	Red Light Running
RMP	Royal Malaysian Police
RSDI	Road Safety Development Index
RTA	Road Traffic Accidents
SPI	Safety Performance Index
SPSS	Statistical Package For The Social Sciences
TWI	Tread Wear Indicator
UN	United Nations

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CHAPTER 1

INTRODUCTION

The purpose of this chapter is to present the background of this study and its problem statement. It is also to set the scene for the research questions addressed in this thesis. This chapter identifies the rationale behind the decision to develop a composite SPI for intercity buses in Malaysia. The next section will outline the background of the research with an overview of the current intercity bus operation, followed by the its problems in Malaysia. In addition, the research questions related to this research will be briefly discussed and to be followed by, the objectives of the research together with an outline and summary of each chapter.

1.1 Background of the study

Public transport provides an efficient and equitable transport alternative for the community. An increase in public transport usage leads to a decrease in private vehicle ownership and hence a reduction in gas emissions (Dirgahayani, 2013; Steg, 2003). In Malaysia, an intercity bus service is a regular scheduled bus service provided for the public. It operates this service with limited stops over fixed routes connecting between two or more cities, towns, or other populated areas. It provides not only a more flexible but a cheaper alternative which can be considered to be a safer mode of transportation (European Commission, 2009; Govender and Pan, 2011; Augustin et. al., 2014). As a result, the demand for intercity bus service has increased significantly. These intercity buses are specifically designed for longer distance travel and typically operate at higher speeds when compared to other buses (Chang and Yeh, 2005; Rohani et. al., 2013; Horowitz, 2014). Moreover, for long distance trips, the intercity buses also operate during the early hours which consequently, could lead to higher number of road traffic accidents (RTA).

1.2 Problem Statement

In recent years in Malaysia, serious RTA involving buses have been increasing. According to Royal Malaysian Police (RMP), the crash rate for buses and the injury rate for bus occupants are relatively high compared to other transport modes. In 2012, the crash rate for buses was 140 for every thousand buses. This was higher than passenger cars and motorcycles crashes, which were 60 cases for every thousand passenger cars and 10 cases for every thousand motorcycles, respectively. As compared to other bus types, the fatality and injury rates for intercity buses were the highest, comprising 20 fatalities and 30 injuries per thousand intercity buses (RMP, 2013). This situation has attracted considerable attention in the media because intercity bus-related crashes resulted in higher number of killed or seriously injured. With increased public concerns about intercity bus safety, effectively managing travel risk has become critical for both intercity bus operators and road safety policy makers. Intercity bus drivers are generally at a higher risk for crashes due to long hours of driving and exposure to

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different road conditions. Therefore, understanding and quantifying their risks and taking steps to manage them could improve intercity bus safety. However, testing intercity bus safety levels through a complete set of road crash risk indicators is difficult to quantify and interpret. In order to avoid this difficulty, it has been recommended that the analysis of intercity bus safety could be tackled by aggregating a multidimensional set of indicators into a composite safety performance index (SPI) by giving different weighted importance to different indicators.

The composite SPI has been widely used in different research areas for the purpose of benchmarking, monitoring, policy evaluation, and communicating with public (Spangenberg et al., 2002; Hermans et. al., 2008; Papadimitriou and Yannis, 2013; Christoph et. al., 2013; Chen et. al., 2016). Specifically, in a road safety research, numerous composite SPI have been developed in order to assess safety performance in different topics. However, no studies have been conducted regarding the application of composite SPI to assess the intercity bus safety performance. Therefore, it is the aim of this study to fill the gap that existed in the literature. This is by developing and exploring a comprehensive composite SPI to improve the intercity bus performance in Malaysia. Although the composite SPI is viewed as a useful tool to improve safety performance of intercity buses, the development of the composite SPI is however sensitive to the choice of weighting method. Thus, in order to develop a valuable composite SPI, it is necessary to examine the suitability of different weighting methods.

1.3 Research Questions

The research questions addressed in this study are as below:

1) Which weighting method is appropriate in developing the composite SPI for intercity buses in Malaysia?
2) What are the risk domains that contributed to intercity bus safety risk using appropriate weighting method?

1.4 Objectives

This research work was carried out to develop the composite SPI for intercity buses in Malaysia. The specific objectives of this research are as follows:

1. To examine the suitability of different weighting methods to develop the composite SPI for intercity buses;
2. To apply SPI values obtained by appropriate weighting method to measure and compare intercity bus safety in terms of risk domains.

1.6 Outline of the Thesis

This study is focused on the development of composite SPI for intercity buses in Malaysia. For this thesis, there are five chapters namely, Chapter 1 where it introduces

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the study background and intercity bus safety problems in Malaysia. The research questions and objectives of the study have also been outlined in this chapter. Chapter 2 will discuss on the relevant literature from previous study, while Chapter 3 to focus on the methodology to be adopted in this study. Chapter 4 presents the results and discussions of the study and Chapter 5 on the summary, research contributions, limitations and recommendations for future research. The thesis is organized as follows:

Chapter 2: Literature Review
This chapter begins by reviewing the risk domains that affect the safety performance of motor vehicles, including driver's driving behaviours, vehicle safety conditions and road environment conditions. Several important risk indicators for each risk domain will be discussed together with an overview of the weighting methods as well as its application in previous studies. As for the SPI literatures they will be reviewed at the end of this chapter.

Chapter 3: Methodology
This chapter presents the methodology to be adopted in this study. First, in order to conduct a survey, the risk indicators are selected and the samples of intercity buses are identified. Second, by using the proposed weighting methods, the data would be analyzed. The correlation analysis between weighting ranking and the road crash ranking was performed to identify suitable method for the composite SPI development. The best weighting method is selected and the paired sample t-test was then applied to determine which SPI for risk domain were significantly different from each other.

Chapter 4: Result & Discussion
This chapter presents the applications of each weighting method as well as its impact on the intercity bus safety performance rankings. Additionally, the correlation analysis between each weighting method ranking and the RC ranking be demonstrated. A brief overview of descriptive statistics for all risk indicators related to intercity bus safety for intercity bus companies mainly operating on the West and east Coast of peninsular Malaysia would be provided. Finally, the results of paired sample t-test to be discussed in this chapter.

Chapter 5: Conclusions and recommendation for further research
The final chapter provides a conclusion whereby a summary of the main findings, research contributions, limitations of the study, as well as recommendation for future research.

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