Transport Policy 58 (2017) 46–52

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

Development of safety performance index for intercity buses: An exploratory factor analysis approach

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ARTICLE INFO

Keywords:
Exploratory factor analysis
Intercity bus
Motor vehicle crashes
Safety performance index

ABSTRACT

In recent years in Malaysia, severe road crashes involving intercity buses have been increasing. 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 different road conditions. Therefore, understanding and quantifying their risks and taking steps to manage them could improve intercity bus safety. The aim of this study is to establish a safety performance index for each risk domain to measure and compare intercity bus safety in terms of risk factors. The risk domains considered in this study were road environment conditions, bus driver driving behaviors and bus safety conditions. The weighted indicators were aggregated into the safety performance index for each risk domain was done using the Exploratory Factor Analysis method. The paired sample t-test was then applied to determine which safety performance indices were significantly different from each other. The results indicate that road environment conditions have contributed more to intercity bus safety risks on the east coast than on the west coast of peninsular Malaysia. The evidence presented in this study shows 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.

1. Introduction

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). Moreover, public transport has been found to be a safe form of transportation as compared to other transport modes (Goh et al., 2014; Chimba et al., 2010). In European Union countries, such as the United Kingdom, road crashes involving buses and coaches accounted for only .43% of total road fatalities (Nicodeme et al., 2010). Similarly, in the United States, buses accounted for only .8% of total road fatalities (Cafiso et al., 2013). However, in Malaysia, 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 (PDRM, 2013). The fatality and injury rates for intercity buses were the highest compared to other bus types, comprising 20 fatalities and 30 injuries per thousand intercity buses.

Various risk factors contributed to motor vehicle crashes (MVC), including human, vehicle, and road environment factors. Human factors remain the major contributors to MVC. The two most common human-related risk factors significantly associated with MVC are speeding and mobile phone use while driving. Previous studies consistently indicate that the likelihood of MVC increases at higher speeds because drivers might have insufficient time to detect and respond to road hazards (Patterson et al., 2000; Aarts and Van Schagen, 2006). Consequently, this reduces vehicle maneuverability and increases the stopping distance. This is particularly acute for heavy vehicles, such as buses, because faster heavy vehicle speeds lead to a greater kinetics energy release in a road crash, thus increasing the likelihood of serious injury and fatality. Hand-held and hand-free mobile phone use while driving can seriously affect driving performance by distracting the driver's attention from the roadway (Fuse et al., 2001; RoSPA, 2002; Fitch et al., 2015). ARTSA (2015) reported that the risk of MVC increases fourfold for heavy vehicle drivers using mobile phones while driving.

Vehicle's stability and handling are important for ensuring road

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http://dx.doi.org/10.1016/j.tranpol.2017.05.003
Received 19 August 2016; Received in revised form 28 February 2017; Accepted 9 May 2017
Available online 13 May 2017
0967-070X/

safety, and good tire condition plays a significant role by optimizing vehicle control because tires filter road disturbances, supports vehicle weight, and apply forces during acceleration and braking (Gillespie and Karamihas, 1992; Kim et al., 2015). Thus, heavy vehicle tire blowouts[1] could lead to rollover crashes[2] (Wang et al., 2015; Noggle and Palmer, 2005; McKnight and Bahouth, 2009). Solah et al. (2013) reported that, in Malaysia, tire failure is one of the common factors identified in post-crash investigations. Wearing a seatbelt was found to be effective in reducing mortality by preventing motorcar occupants from being ejected through windows (Viano and Parenteau, 2010; Mátyás, 2013), hitting hard interior elements of the vehicle (Albertsson and Falkmer, 2005), and colliding with other occupants (King and Yang, 1995; Ichikawa et al., 2002). Similar effects were also observed for bus occupants (Chang et al., 2006; Belingardi et al., 2006). However, in Malaysia, it is only mandatory for buses registered after 2008 to be equipped with passenger seatbelts. This implies that many bus occupants are often insufficiently protected in MVC.

Several road environmental factors affect heavy vehicle safety, such as gradient, the number of lanes, road shoulders and travel time. It is expected that the road crash likelihood increases at at-grade sections that have a high number of heavy vehicles. Heavy vehicles may have braking deficiency on the descending gradients (Sétra, 2007), and they travel at lower speeds than lighter vehicles on the ascending gradients. Consequently, this would increase risky overtaking manoeuvers made by other vehicles (FHWA, 2014; Hosseinpour et al., 2014, Bar-Gera and Shinar, 2005). As sight distance decreases, drivers may not have sufficient reaction time to avoid a collision with an on-coming vehicle and thus causes a head-on crash (Hosseinpour et al., 2014). Similarly, head-on crashes also commonly occur on two-lane roads (Gårder, 2006; Farah, 2013). A wider roadway paved shoulder provides adequate space for a bus stopping in an emergency situation and also prevents buses from hitting roadside objects. This is consistent with the estimation that widening the road shoulder by 1 m in each direction decreases head-on crashes by .4% (Hosseinpour et al., 2014). Previous published studies consistently indicate that driving during nighttime is associated with a higher crash risk due to fatigue and visibility restriction (Massie and Campbell, 1993; Lin and Fearn, 2003; Keall et al., 2005; Tay et al., 2008). This is particularly acute for intercity bus drivers because they are involved in long hours of driving.

In recent years in Malaysia, severe road crashes involving intercity buses have been increasing. 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 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 in each risk domain into a safety performance index (SPI) for each risk domain by giving different weighted importance to different indicators. The risk factors considered in this study were road environment conditions, bus driver driving behaviors and bus safety conditions. Given this background, the aim of this study is to establish a SPI to measure and compare intercity bus safety in terms of risk factors. This index can be used as a safety benchmark for cross intercity bus company comparisons. Moreover, it can also be used to give various stakeholders, such as policy makers and intercity bus operators, a better understanding of how risk factors affect intercity bus safety and thus identifying potential countermeasures to improve intercity bus safety.

2. Research method

In this section, we present the methodology adopted in this study. First, the independent risk indicators were chosen in accordance with their analytical uniformity, measurability and relevance to the analyzed phenomenon. For each variable used to determine the risk indicator, the recognition of a related dataset, the imputation of missing data, the assessment of inherent errors and the normalization of the variable were needed. Normalization transforms the indicators into the same unit. After normalization, the weighted indicators were aggregated into the SPI for each risk domain was done using the Exploratory Factor Analysis (EFA) method. The paired sample t-test was then applied to determine which safety performance indices were significantly different from each other.

2.1. Sample

A two-stage sampling method was used to choose sample intercity buses. In the first stage, a simple random sampling technique was used to select 30 out of 86 intercity bus companies in Malaysia. The sample was weighted in terms of bus routes and travel time to match the profile of the overall target intercity bus companies. Out of 30 selected intercity bus companies, 4 intercity bus companies that mainly operating on the east coast of peninsular Malaysia where the road conditions are generally poor and not well developed were compared to bus companies driving on roads on the west coast. At the second stage of sampling, 30% of the total number of buses were randomly selected from each selected intercity bus company. There is no significant variance in the types of buses both within an intercity bus company and across companies.

2.2. Data collection

Three risk domains for intercity buses were identified in this study, which includes bus safety conditions, road environment conditions, and bus driver driving behaviors. The identification was based on the local context and understanding of intercity bus safety problems in Malaysia. The Malaysian Institute of Road Safety Research study indicated that intercity bus driver's inappropriate driving behavior is one of the main contributing factors to MVC (2016). These include using mobile phone while driving, driving under the influence of alcohol and drug, red-light running and speeding. Moreover, in Malaysia, there is no age limit for intercity buses and it is only mandatory for buses registered after 2008 to be equipped with passenger seatbelts. Therefore, the intercity bus safety conditions are not satisfactory. As indicated earlier, the road conditions in the east coast are generally poor and not well developed compared to road on the west coast of peninsular Malaysia. This indicates that road environment conditions have contributed more risk to intercity buses mainly operating on the east coast of peninsular Malaysia.

Enumerators travelled with buses to observe and collect intercity bus safety-related information. Data for bus driver driving behaviors were collected mainly through naturalistic observation. This approach not only provides an opportunity to gain an in-depth understanding of bus driver driving behaviors but also may avoid the possible biases of self-report measures (Eby, 2012). The mobile global positioning system tracker[3] was used to record bus running speed throughout the journey, and the maximum running speed[4] was chosen to indicate bus driver recklessness in driving. The average of maximum bus running speed

[1] Bareket et al. (2000) showed that tire blowout is the most common tire failure on heavy vehicles.

[2] The heavy vehicle has a higher gravity center, which can cause a rollover (Solmaz et al., 2008).

[3] The global positioning system equipment has a resolution of 10m and data was collected during daytime and nighttime.

[4] The maximum running speed was chosen because higher speed would increase the risk of crash and fatality.

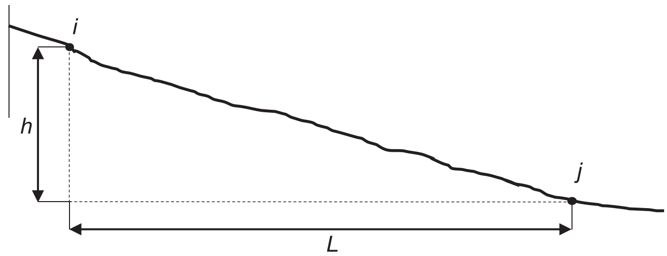

Fig. 1. The sketch map of profile parameters of a descending road section.

for all observed bus trips was calculated for each intercity company. Bus drivers using mobile phone while driving was used as another indicator of bus driver driving behavior. The percentage of bus drivers using mobile phone while driving was computed for each intercity bus company.

Three indicators were considered as proxies for the overall bus safety conditions: the percentage of buses with bald tires, the average of bus age, and the percentage of buses without passenger seatbelts. These data were computed for each intercity bus company. The tread wear indicator (TWI), which is located on the tire sidewall in the form of triangle sign, was used to indicate the quality of bus tires. The TWI of 1.6 mm represents the legal minimum tread depth and once it passed, the tire is considered bald and should be replaced. The bus age (to the nearest year) was calculated based on the bus registration number, while the availability of passenger seatbelt was observed in the bus.

Four indicators were used to evaluate the effect of road environment conditions on intercity bus safety: the percentage of road length with descending vertical gradient greater than or equal to 8%, the percentage of road length with narrow road shoulder, the percentage of two-lane roads and the percentage of nighttime trips. The descending vertical gradient was calculated as shown in Fig. 1; h denotes the altitude difference of point i and j, and L represents the section length. Altitude was obtained from the digital elevation model based on the geographic coordinates (GPS Visualizer); the section length is 2 km.[5] The vertical gradient (G) is the ratio between h and L ($G = h/L$). Fu et al. (2011) indicated that the road crash rates rise exponentially with average vertical gradient on continuous descending roads; therefore a higher percentage of descending vertical gradients (greater than or equal to 8%) were chosen in this study. Two-lane roads and narrow road shoulders[6] for each bus route were observed on the Google Street View images. The percentage of roads with the abovementioned characteristics were computed for all bus routes covered by each intercity bus company. The percentage of nighttime trips for each intercity bus company was calculated based on the bus timetable. Any trip after 7:00 PM was considered a nighttime trip.

2.3. Data analysis

2.3.1. Exploratory factor analysis

The Exploratory Factor analysis (EFA) is a statistical method used to examine the covariance relationship amongst a large number of observed items and to derive latent (unobserved) factors to account for these relationships (Mulaik, 2009; Field, 2009). Principal component factor extraction with a Varimax (orthogonal) rotation was used to identify meaningful components of intercity bus safety. The number of latent factors to be retained was determined using the Kaiser rule (eigenvalues greater than one) (Kaiser, 1960) and scree cut-off points (Cattell, 1966). The appropriateness of the factor model was examined prior to using the EFA in this study. The extraction communality of an item estimates the proportion of the variance in each variable accounted for by the factor solutions (Rietveld and van Hout, 1993). Large extraction communality values indicate that the items within each domain have a very high association among them. All extraction communalities were restricted to greater than .5 (Field, 2009; Stevens, 1992). The Barlett's test and the Kaiser-Meyer-Olkin (KMO) were used to examine whether the data were appropriate for the EFA. The Bartlett's test is based on the null hypothesis of no correlation between items, and a significant test result implies that sufficient correlation exists among the items (Bartlett, 1954). The KMO measures sampling adequacy for the execution of the EFA. Its value ranges from zero to one with a higher value indicates the stronger correlation between items and hence, the EFA would be appropriate (Kaiser, 1974; Norusis, 1993). The KMO value should be .60 or greater for a satisfactory EFA to proceed (Tabachnick and Fidell, 2007; Kaiser, 1974). Moreover, the internal consistency of a group of items was assessed by Cronbach's alpha (Cronbach, 1951). Guilford (1965) suggested that the Cronbach's alpha value of .9 or greater can be considered to have high consistency, the value between .35 and .7 is moderate reliability, and the value less than .35 is not acceptable. Bradley (1994) indicated that the lowest Cronbach's alpha value indicating adequate consistency increases with the number of items. For instance, for a three-item scale, a value of .5 is adequate, while for a ten-item scale, the value should greater than .7.

2.3.2. Indicators aggregation in each risk domain

Risk indicators are weighted and aggregated in each risk domain and a SPI for each risk domain is built. Factor loadings computed by Varimax rotation method was used to weight the risk indicators. A linear aggregation of the weighted risk indicator values in each risk domain is computed using

$$SPI_{ij} = \sum_{k=1}^{n} w_{kj} I_{ki} \tag{1}$$

where SPI is an index for risk domain j and the intercity bus company i, and w_{kj} denotes the weight of risk indicator k in the risk domain j and I_{ki} represents the normalized risk indicator k for intercity bus company i. The weights w_{kj} are computed from the Varimax rotation as follows:

$$w_{kj} = \frac{(factorloading)^2}{eigenvalue_j} \tag{2}$$

2.3.3. Comparison of the index values among the risk domain

The normality test of the data was assessed by using the Shapiro-Wilk test. All computed indices met the assumptions of normality, and therefore the paired sample t-test was used to determine which performance indices were significantly different from each other. The paired sample t-test was performed separately for intercity bus companies mainly operating on the east coast and west coast of peninsular Malaysia, respectively. Significance values less than 10% were considered statistically significant.

3. Results

3.1. Descriptive statistics

Tables 1, 2 report 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, respectively. As shown, the averages of all road environment indicators for intercity bus companies mainly operating on the west coast of peninsular Malaysia are lower than the averages for 4 intercity bus companies mainly operating on the east coast of peninsular Malaysia, suggesting that road environment conditions have contributed more to intercity bus safety risks on the east coast of peninsular Malaysia. As explained earlier, this is probably because the road conditions on the east coast are generally

[5] Fu et al. (2011) indicated that the average gradients over distances of 2km and 3km have the highest association with road crash rates.

[6] The bus width is 2.5m and, therefore, a shoulder width less than 2.5m is classified as a narrow shoulder.

Table 1
Descriptive statistics for all indicators related to intercity bus safety (26 intercity bus companies mainly operating on the west cost of peninsular Malaysia).

Domain	Indicator	Average	Std. dev.	Min	Max
Road environment	Nighttime trip (%)	35.85	11.46	7.72	55.67
	Descending vertical gradients (%)	3.52	2.74	.59	13.46
	Narrow road shoulder (%)	16.83	15.33	3.25	50.24
	Two-lane (%)	9.44	13.16	0	41.18
Driving behavior	Mobile phone use (%)	38.58	31.90	0	100
	Average max running speed (kmph)	117.54	10.89	101.45	152.47
Bus safety conditions	Passenger seatbelt (%)	63.51	40.69	0	100
	Bald tire (%)	16.69	28.30	0	100
	Bus age (years)	**4.12**	**2.14**	**.1**	**10**

Table 2
Descriptive statistics for all indicators related to intercity bus safety (4 intercity bus companies mainly operating on the east cost of peninsular Malaysia).

Domain	Indicator	Average	Std. dev.	Min	Max
Road environment	Nighttime trip (%)	75.61	17.52	58.29	100
	Descending vertical gradients (%)	7.24	.91	6.44	8.35
	Narrow road shoulder (%)	68.38	16.66	53.35	77.09
	Two-lane (%)	59.56	20.42	40.44	68.03
Driving behavior	Mobile phone use (%)	37.50	47.87	0	100
	Average max running speed (kmph)	108.91	5.20	103.64	115.99
Bus safety conditions	Passenger seatbelt (%)	75.00	50.00	0	100
	Bald tire (%)	0	0	0	0
	Bus age (years)	**2.71**	**1.06**	**1.5**	**4**

poor and not well developed compared to roads on the west coast of peninsular Malaysia. Table 3 presents the number of road crashes for years 2012 and 2013, the daily vehicle kilometer traveled, and the number of observed buses for each intercity bus company.

3.2. Exploratory factor analysis results

Preliminary analyses were performed to examine the suitability of the data for the EFA. The covariance relationship amongst the items was examined through correlation analysis and any items have lots of correlations below .3 should be removed. The correlation analysis results showed that no variables have more than three correlations below .3. With reference to Table 4, all extracted communalities were greater than .5; this indicates that the risk indicators fit well with the factor solution, and should be retained in the analysis. The KMO statistic is .612, while the p-value of Bartlett's Test is less than .001 (Chi-square =132.73, df =28, $p < .001$), suggesting that correlations between items are adequate for the EFA. The principal component analysis showed three components with eigenvalues of over 1.0, explaining 71.9% of the total variance. With reference to the scree plot in Fig. 2, the inflexion point occurs at the fourth data point and, thus, further supports the Kaiser's criterion in retaining three factors. The Cronbach's alpha coefficients range from .601 to .82, indicating adequate internal consistency and reliability. The percentage of buses without passenger seatbelts was not included in the analysis because its communality value is less than .5, the KMO value is less than .6.

The component loadings are shown in Table 4. All loadings greater

Table 3
The number of road crashes for years 2012 and 2013, the daily vehicle kilometer traveled, and the number of observed buses for each intercity bus company.

Intercity Bus Company	Road Crashes, 2012 and 2013	Daily Vehicle Kilometer Traveled (KM)	Observed Buses
A	24	16079.6	3
B	33	12842	7
C	8	3087.8	5
D	8	2582.1	3
E	14	2841.4	6
F	39	18323.2	5
G	19	20476.7	6
H	27	7914.3	3
I	4	1082	3
J	2	4384.8	3
K	103	23449.8	6
L	100	24642.9	5
M	21	4052.5	3
N	47	13117.9	5
O	102	25098.8	6
P	47	13541.9	3
Q	3	2176	3
R	26	12056	5
S	1	8452.2	3
T	81	37470.6	7
U	69	19646.5	5
V	35	9637.4	9
W	36	17214.8	6
X	6	8366.6	3
Y	31	17297.2	5
Z	32	14033.3	5
AA	32	10157.4	5
AB	8	1464.9	3
AC	5	5076.4	3
AD	**14**	**5088.6**	**3**

than .60 are in bold font. As suggested by Tabachnick and Fidell (2007), an item was judged to be a good indicator of the underlying domain if it exhibited higher component loading and weak cross loadings with other domain. A positive sign of the component loading indicates that the risk indicator is positively correlated with the intercity bus safety. The first domain, which was labeled road environment conditions, explains most of the variance (37% of the total). The second domain, which accounts for 18.5% of the total variance, was labeled as bus driver driving behaviors, while the third domain was labeled bus safety conditions and accounts for 16.4% of the total variance.

3.3. Pair sample t-test results

Table 5 presents the results of paired sample t-test for comparing the mean of SPI values for each risk domain for 26 intercity bus companies mainly operating on the west coast of peninsular Malaysia. As shown in Table 5, the average value for the road environment risk domain was significantly lower than the mean value for the other two risk domains. However, there was no significant difference between the driving behavior risk domain and the bus safety condition risk domain. On the other hand, for the analysis of 4 intercity bus companies mainly operating on the east coast of peninsular Malaysia, the average value for the road environment risk domain was significantly higher than the other two risk domains (see Table 6). The results also indicate that the mean value for the driving behavior and bus safety condition risk domains did not differ from each other significantly.

Table 7 presents the results of t-test for comparing the mean SPI values for each risk domain between bus companies mainly operating on the east coast and west coast of peninsular Malaysia. The results indicated that the average value for the road environment risk domain for intercity bus companies mainly operating on the east coast was significantly higher than intercity bus companies mainly operating on

Table 4
Results of the EFA.

Item	Road environment Conditions	Driving Behavior	Bus Conditions	Communality
Two-lane	**.931**	−.109	.121	.894
Narrow road shoulder	**.905**	−.150	.185	.876
Nighttime trip	**.815**	.431	−.601	.669
Descending vertical gradients	**.622**	−.242	−.245	.505
Mobile phone use	.03	**.873**	.910	.771
Average max running speed	−.312	**.745**	−.230	.653
Bus age	−.205	−.110	**.865**	.802
Bald tire	−.293	−.239	**.663**	.583
Cronbach's alpha	8.50	6.01	6.41	
Variance explained (%)	37.0	18.5	16.4	
Eigenvalue	**2.96**	**1.48**	**1.31**	

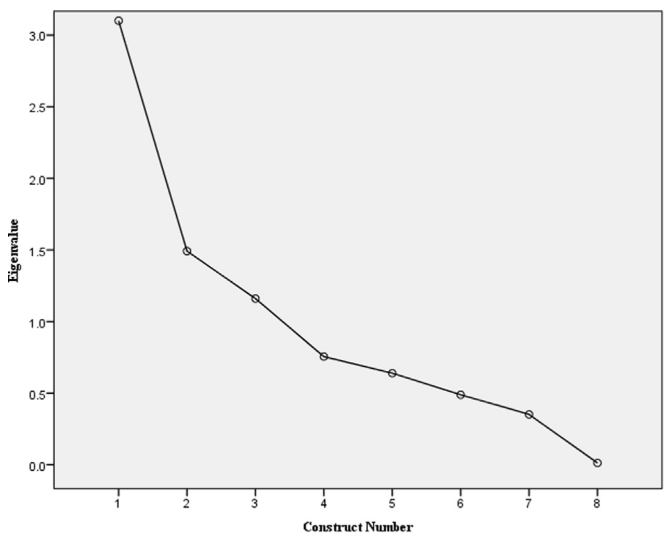

Fig. 2. Scree plot.

Table 5
Paired sample t-test results for 26 intercity bus companies mainly operating on the west coast of peninsular Malaysia.

Risk domain	Mean	SD	df	t-stat	p-value
Road environment vs Driving Behavior	−.3295	1.144	25	−1.468	.077
Road environment vs Bus Safety Conditions	−.3449	1.148	25	−1.531	.069
Driving Behavior vs Bus Safety Conditions	**−.0154**	**1.482**	**25**	**−.0532**	**.478**

Table 6
Paired sample t-test results for 4 intercity bus companies mainly operating on the east coast of peninsular Malaysia.

Risk domain	Mean	SD	df	t-stat	p-value
Road environment vs Driving Behavior	2.141	1.172	3	3.653	.017
Road environment vs Bus Safety Conditions	2.242	.776	3	5.775	.005
Driving Behavior vs Bus Safety Conditions	**.101**	**.997**	**3**	**.201**	**.426**

the west coast. Meanwhile, there was no significant difference between two groups for the average value for the driving behavior and bus safety condition risk domains.

Figs. 3 and 4 present the scatter plots for the correlations between the SPI values for each risk domain. As shown in these figures, the SPI values for different risk domains varied among the intercity bus companies. For example, the index values for all risk domains for

Table 7
T-test results for comparing the mean SPI values for each domain between bus companies mainly operating on the east coast and west coast of peninsular Malaysia.

Risk domain	West coast		East coast		df	t-stat	p-value
	Mean	SD	Mean	SD			
Road environment	−.325	.268	2.12	.518	3	6.545	.004
Bus Safety Conditions	.003	1.033	−.023	1.062	4	−.047	.482
Driving Behavior	**.019**	**1.152**	**−.123**	**.046**	**25**	**−.598**	**.277**

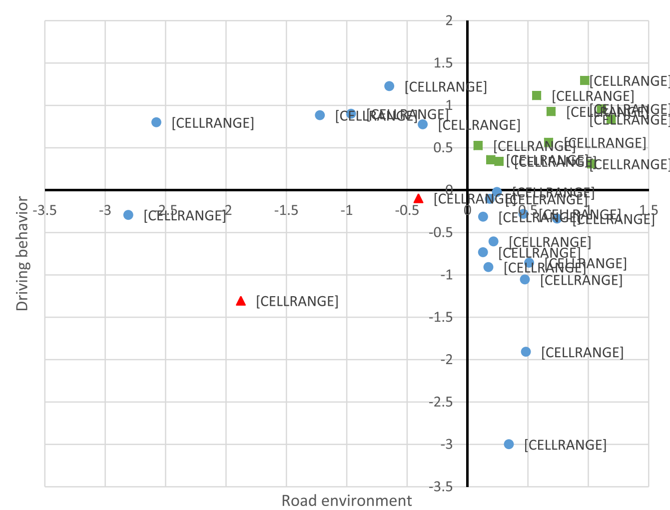

Fig. 3. Scatter plot of road environment conditions domain vs. bus driver driving behaviors domain.

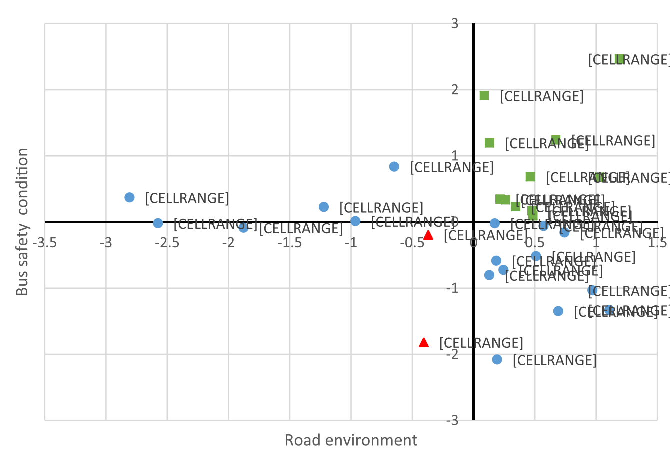

Fig. 4. Scatter plot of road environment conditions domain vs. bus safety conditions domain.

intercity companies *A, C, G, N* and *V* are consistently positive, while the intercity bus company *X* is the only company where all index values are consistently negative. On the other hand, other companies show a mixed safety performance with a combination of positive and negative SPI values.

4. Discussions

The results indicate that road environment conditions have contributed more to intercity bus safety risks on the east coast than on the west coast of peninsular Malaysia. This is due to the expansion of the expressway network on the east coast over the last two decades, which can safely accommodate intercity bus use. Expressways are generally safer than arterials because they are designed for high-speed traffic with partial or fully controlled access, the opposing lanes are divided by barriers, and there are usually two or more lanes in each direction. Kweon and Kockelman (2005) indicated that the expressways meeting interstate standards are accompanied by a reduction of 14.7% and a 46.1% in injury and fatal crash rates, respectively, compared to other limited-access principal arterials. However, this development mainly took place on the west coast of peninsular Malaysia. Therefore, building more expressways and upgrading the existing roads specifically on the east coast of peninsular Malaysia is required in order to safely accommodate intercity buses.

An examination of data in Tables 1, 2 indicates that there is a high percentage of intercity bus drivers using mobile phones while driving[7] and driving above the speed limit.[8] In view of this, interventions, such as driving training programs for bus drivers, installation of a telematics device in an intercity bus and increasing the enforcement of traffic law, are recommended to improve intercity bus driver driving behaviors. On the other hand, a glance at the data in Tables 1, 2 also show that a significant number of intercity bus tires are not good; therefore, it is suggested that more frequent periodic roadworthiness inspection would improve intercity bus safety. It is important to note that, even though the percentage of buses without passenger seatbelts was not included in the analysis, our data reveals that approximately 65% of intercity buses are not equipped with passenger seatbelts. This is mainly because, in Malaysia, it is only mandatory for buses registered after 2008 to be equipped with a seatbelt. There is no law requiring intercity bus passengers to wear seatbelts, which decreases the wearing of seatbelts, thereby, worsening intercity bus passenger safety. In view of this, it is essential to enact seatbelt laws for bus passengers and require all buses to install seatbelts.

Even though it has been shown that road environment conditions have contributed less risk to intercity buses traveling on the west coast of peninsular Malaysia, improvements in road environment conditions would help to further enhance intercity bus safety. Several viable ways are identified for this purpose. One way is the provision of passing facilities and safe overtaking zones to reduce risky overtaking manoeuvers. Another way is by widening the paved shoulder along bus routes. With regard to the risk of driving at night, there are two possible countermeasures. The first countermeasure is to enhance roadway and vehicle visibility at night. This can be achieved by improving street lighting, illuminating road markings and traffic signage, and equipping buses with conspicuity treatments. The second countermeasure is to implement a policy for intercity buses to have a co-driver to prevent fatigue-related crashes.

As shown in the second and fourth quadrants of Figs. 3 and 4, each bus company faces different risk problems. For instance, the bus safety conditions index value and road environment conditions index value for the intercity bus company *J* are positive, but the driver driving behaviors index value is large and negative. On the other hand, for intercity bus company *Q*, the road environment conditions index value and bus driver driving behaviors index value are positive, but the bus safety conditions index value is large and negative. These results indicate that an intercity bus safety problem could not be solved by a single road safety intervention. Therefore, developing targeted road safety programs for each intercity bus company is crucial in order to improve their buses' safety.

[7] According to the traffic law in Malaysia, all drivers are prohibited from using handheld devices while driving.

[8] The maximum speed limit for buses on Malaysia roads is 90km/h.

5. Conclusions

The results indicate that intercity bus safety can be explained by three risk factors: road environment conditions, bus driver driving behaviors and bus safety conditions. The evidence presented in this study shows 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.

Two limitations of the current study should be noted. First, due to the naturalistic nature of this study, several important risk indicators were not included into the analysis. These indicators include bus drivers driving under influence, driving experience, and bus roadworthiness. Second, the SPI for each risk domain was computed using the EFA only. Therefore, we would suggest using different weighting methods, such as analytic hierarchy process, budget allocation, data envelopment analysis and equal weighting, to facilitate the selection of an acceptable and justifiable weighting method.

In sum, the findings of this paper indicate that the development of a SPI for each risk domain is a useful tool for evaluating intercity bus safety. The 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. Policies to reduce private vehicle ownership, such as motorcycles and motorcars, and increase the use of public transport will never be realized if the intercity bus safety is not improved.

Acknowledgment

This research was funded by Ministry of Education Malaysia (Grant no. ERGS/1–2013/5527146). The funding source played absolutely no role in the study design nor any collection, analysis, or interpretation of the data.

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