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Influences of Mixed Traffic Flow and Time Pressure on Mistake-Prone Driving Behaviors among Bus Drivers

Vu Van-Huy*, Hisashi Kubota

Graduate School of Science & Engineering, Saitama University, Saitama, Japan
Email: *vanhuytbnuce@gmail.com

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Abstract

Bus safety is a matter of great importance in many developing countries, with driving behaviors among bus drivers identified as a primary factor contributing to accidents. This concern is particularly amplified in mixed traffic flow (MTF) environments with time pressure (TP). However, there is a lack of sufficient research exploring the relationships among these factors. This study consists of two papers that aim to investigate the impact of MTF environments with TP on the driving behaviors of bus drivers. While the first paper focuses on violated driving behaviors, this particular paper delves into mistake-prone driving behaviors (MDB). To collect data on MDB, as well as perceptions of MTF and TP, a questionnaire survey was implemented among bus drivers. Factor analyses were employed to create new measurements for validating MDB in MTF environments. The study utilized partial correlation and linear regression analyses with the Bayesian Model Averaging (BMA) method to explore the relationships between MDB and MTF/TP. The results revealed a modified scale for MDB. Two MTF factors and two TP factors were found to be significantly associated with MDB. A high presence of motorcycles and dangerous interactions among vehicles were not found to be associated with MDB among bus drivers. However, bus drivers who perceived motorcyclists as aggressive, considered road users' traffic habits as unsafe, and perceived bus routes' punctuality and organization as very strict were more likely to exhibit MDB. Moreover, the results from the three MDB predictive models demonstrated a positive impact of bus route organization on MDB among bus drivers. The study also examined various relationships between the socio-demographic characteristics of bus drivers and MDB. These findings are of practical significance in developing interventions aimed at reducing MDB among bus drivers operating in MTF environments with TP.

Keywords

Bus Safety, Mistake-Prone Driving Behavior, Mixed Traffic, Time Pressure, Factor Analyses, Bayesian Model Averaging

1. Introduction

Bus transport system plays a vital role in ensuring a sustainable transportation system [1]. Buses are particularly vital in many developing countries, where they serve as the primary mode of public transportation [2].

However, bus accidents have significant repercussions on society [3] [4] affecting both the frequency and severity of traffic accidents [3] [5]. The effects of bus accidents are often more severe in mixed traffic flow (MTF) environments, where motorcycles have a higher presence compared to traffic flows dominated by cars.

Various factors contribute to bus safety, such as weather, time, environmental factors and bus type [6], road conditions and bus drivers' socio-demographic characteristics [7]. However, the driving behaviour of bus drivers remains the primary cause of bus accidents [8]. Additionally, apart from driving violations, mistake-prone driving behaviors (MDB), which encompass errors and lapses, are significant predictors of bus accident involvement [9].

Numerous studies have been conducted to examine the factors that contribute to MDB. These factors include personality traits [10], altruism [11], burnout [12] and fatigue [13]. However, surprisingly, no study has directly evaluated the impact of MTF on the MDB of bus drivers. This knowledge gap assumes greater significance, particularly considering that bus drivers often experience time pressure (TP) in MTF environments [3].

The objective of this study is to fill the existing research gaps by being one of just two studies that investigate the impact of MTF features and TP on driving behaviors exhibited by bus drivers. The first study primarily examines how MTF features and TP influence violated driving behavior [14], whereas this second study specifically concentrates on the effects of MTF features and TP on MDB displayed by bus drivers.

The structure of this paper is organized as follows: Section 2 provides a review of previous studies, with a specific focus on related concepts, MTF and TP measurements in the first study, the impact of bus drivers' MDB on bus accidents, and the factors that influence the MDB of bus drivers. Section 3 describes the methodology employed for measuring the MDB of bus drivers, including details on data collection procedures and analysis techniques used. Section 4 presents a summary of the study's findings. Section 5 offers a detailed discussion of the results. Finally, Section 6 concludes the paper by summarizing the achievements and contributions of the study.

2. Literature Review

Similar to the first study [14], MTF is defined as a traffic scenario where different types of vehicles, including cars, buses, and particularly motorcycles, share the same lane. This traffic flow is characterized by the prominent presence of motorcycles, which are non-lane-based and small vehicles. The first study identified several distinct behaviors associated with MTF, such as overtaking, swerving, weaving, filtering, creeping, tailgating, and giving way. As a result, MTFs are considered complex systems due to the interplay of various behaviors and vehicle types within the traffic flow [15]. MTF has been the subject of research in various locations, including Ho Chi Minh City [16], Taipei [17], Hanoi [14], and India [18].

In this work, MDB is understood as all mistakes resulting from the failure of attention, concentration, judgment, and planned actions of bus drivers to achieve their intended consequences [19] [20]. To prevent any confusion, it is important to clarify that in this paper, the term MDB specifically pertains to the mistakes made by bus drivers. MDBs are classified into two distinct categories. Errors are described as failures in attention and planned actions that prevent bus drivers from achieving their intended outcomes. On the other hand, lapses are defined as failures in concentration and judgment, which can lead to embarrassing situations for bus drivers [19].

In addition to driving violations, MDB is one of the leading causes of bus traffic accidents. For instance, according to the research of Reason *et al.*, [20], driver errors and violations are of special interest due to their contribution to road accidents, and each type of driver error and violation carries distinct implications for comprehending road accidents. Driving errors and violations can be implicated differently in terms of accident liability, Accidents can often occur when an error is made while committing a violation, highlighting the potential significance of this combination as a cause of accidents [21]. For elderly drivers, elevated scores on both the error factor and lapse factor were indicative of active accident participation. Conversely, passive accident involvement was linked to higher scores specifically on the lapse factor [9].

Various studies have been conducted to investigate the factors influencing MDB. These studies have identified several underlying factors. Personality traits [10], altruism [11], burnout [12] and fatigue [13] have been found to have an impact on MDB. In addition, it has been observed that the national road safety culture is associated with aberrant driving behaviors exhibited by bus drivers [22]. According to a recent study by [23], it is important to consider that the results of bus interaction types can vary between societies with a motorcycle-based transportation system and those with a car-based transportation system. This distinction suggests that the scale of MDB may differ between traffic flows dominated by cars and MTF. Although MTF characteristics were found to have a negative impact on bus driver fatigue [13], another study indicated that burnout negatively influences MDB [12]. However, no research has yet examined the di-

rect influence of MTF characteristics on MDB, particularly in situations where bus drivers experience TP in MTF environments [3].

Similar to the initial study conducted by Liu *et al.*, [14] this research study defines TP as the various pressures experienced by bus drivers due to time constraints while operating a bus. Previous studies examining the impact of TP on driving behavior have primarily been conducted in laboratory settings using simulations, rather than in real-life situations. One simulation study consistently highlights TP as a significant factor that adversely affects driving behavior [24]. Additionally, traffic congestion in MTF has been recognized as a significant issue in developing countries [25]. Furthermore, studies have shown that drivers experience higher levels of stress in areas with high traffic congestion compared to those with low traffic [26]. The bus drivers also expressed that their driving mistakes can be attributed to TP [3]. These research findings suggest that due to TP and MTF environments, bus drivers may be more prone to engage in MDB compared to car-based flow traffic scenarios. Surprisingly, there is currently a lack of research studies that adequately investigate the specific effects of TP on MDB within the context of MTF environments.

3. Methodology

The first study established MTF and TP scales and investigated successfully bus drivers' perceptions of MTF and TP. In order to identify the effects of MTF environments and TP on the MDB of bus drivers, it was necessary to investigate the perceptions of bus drivers regarding their own MDB. The MDB questionnaires of bus drivers were also designed and distributed to bus drivers at the same time in the first study's survey.

The questionnaire survey was carried out in Hanoi city, which serves as a representative location for studying MTF environments. The city of Hanoi was chosen as the survey location due to several factors. Firstly, Hanoi has a high number of motorbikes compared to other vehicles [27]. Furthermore, motorcyclists in Hanoi have expressed strong criticism towards bus movements, perceiving buses as "street monsters". Moreover, bus drivers have justified their actions by citing the need to adhere to travel schedules set by their companies and the limited break time available between two rounds [3]. Therefore, Hanoi was deemed a suitable location for conducting the survey as it aligned with the objectives of this study.

3.1. Measurement

As mentioned above, the MTF and TP scales already were established in the first study. In this work, we focus on developing measurement of MDB of bus drivers.

3.1.1. Measures of MDB

As previously discussed, there was a significant association between aberrant

driving behaviors among bus drivers and traffic flow, external environmental factors, and road safety culture. Hence, the measurement of MDB may vary between car-based traffic flow and MTF environments as defined in this work. In this study, the measurement of MDB was conducted using the MDB scale derived from the driving behavior questionnaire [19]. This tool was established as a valid and reliable instrument for investigating the aberrant behaviors of bus drivers. The initial measurement of driver behaviour questionnaire comprised four subscales and 28 self-reported items [19].

However, for the purpose of this paper, the focus was specifically on mistake-prone behaviors, and thus the investigation narrowed down to 13 items and two subscales related to such behaviors, namely errors and lapses. Errors mentioned to the failure of attention and planned actions of bus drivers to achieve their intended consequences [19], included five items, such as "Distracted or preoccupied, realize belatedly that the vehicle ahead has slowed, and have to slam on the brakes to avoid a collision" and "Make a hard braking or sudden deceleration to avoid collision when a motorcycle is abruptly swerving right in front". Lapses referred to concentration and judgment failures, which can cause embarrassment to bus drivers [19], it comprised 8 items, such as "Fail to notice someone crossing illegally until it is nearly too late, and make a hard brake or lane change" and "Fail to notice someone going the wrong way until it is nearly too late, and make a hard brake or lane change".

The participants were interviewed to answer 13 items (items MP1-MP15 as shown in **Table 1**) on a 5-point Likert scale (from 1 "strongly disagree" to 5 "strongly agree"). Higher scores corresponded to a greater number of MDBs.

3.1.2. Measures of Socio-Demographic Variables

The study collected demographic information from the participants, including their gender, age, and education level. Additionally, other variables that could potentially influence MDB were taken into account. These variables encompassed marital status, smoking status, monthly income, daily driving hours, sleep hours per day, driving experience, number of accidents within the last 3 years, and penalties incurred in the past 3 years [28]. Previous studies have found significant associations between factors like being a migrant worker, insufficient income, and driving behavior [29]. Training activities have also been shown to improve driving behavior and help bus drivers cope with stressful work conditions [30].

3.2. Data Collection

From September to October 2022, a total of 260 bus drivers working for public transport operators in Hanoi took part in this study. To ensure confidentiality and minimize bias, participants were not required to provide their names on the questionnaires. Monetary compensation was provided to enhance the accuracy and validity of the collected data. Out of the initial sample, 232 responses were considered valid, yielding a response rate of 89.23%.

Table 1. Items of MDB of bus drivers.

ID number of items	Item content
MP1	Make a hard braking or sudden deceleration to avoid collision when a motorcycle is abruptly swerving right in front
MP2	Distracted or preoccupied, realize belatedly that the vehicle ahead has slowed, and have to slam on the brakes to avoid a collision.
MP3	Try to overtake without first checking your mirror, and then get hooted at by the vehicle behind which has already begun its overtaking maneuver.
MP4	Try to overtake without first checking your mirror, and then make the vehicles behind changing speed or lane, stopping, falling, or even making crashes
MP5	Misjudge speed of oncoming vehicle when overtaking
MP6	Fail to notice someone stepping out from behind a bus or parked vehicle until it is nearly too late, and make a hard brake or lane change
MP7	Fail to notice someone going the wrong way until it is nearly too late, and make a hard brake or lane change
MP8	Fail to notice vehicles parking illegally on the street or an obstacle up ahead on street until it is nearly too late, and make a hard brake or lane change
MP9	Fail to check your mirror before pulling out, changing lanes, turning
MP10	Fail to notice someone crossing illegally until it is nearly too late, and make a hard brake or lane change
MP11	Brake too quickly on a slippery road and/or steer the wrong way in a skid.
MP12	Fail to turn on blinkers when entering or leaving bus stops
MP13	Turn on wrong blinkers when entering (turning left blinker) and leaving (turning right blinkers) bus stops

3.3. Analysis Techniques

Similar to the first study, the data in this study were analyzed using R programming 4.0.2. The Shapiro-Wilk method was used to test the normal distribution of each questionnaire item, and none of the items were found to adhere to a normal distribution (see Table A1 in Appendix). To establish the structure of MDB measurements, a factor analysis was conducted. Kaiser-Meyer-Olkin (KMO)-parameters of principal component analysis, varimax rotation method, and Bartlett's test were employed to assess the scale's structure. The reliability of the questionnaire was evaluated using Cronbach's Alpha coefficient. Partial cor-

relation analysis was employed to investigate the relationships between MDB and MTF as well as TP, while controlling for socio-demographic characteristics. The linear regression analysis with the Bayesian Model Averaging (BMA) method was used to identify predictors of MDB for all bus drivers, as well as separate analyses for accident-experienced and accident-inexperienced bus driver groups. The effects of MTF and TP were taken into account in the analysis.

4. Results

4.1. Descriptive Statistics

Table 2 provides information on the background variables of the bus drivers surveyed. This table was also presented in the first study. The participants consisted entirely of male drivers (100%), as female bus drivers are uncommon in Vietnam. The age range of the bus drivers was between 25 and 57 years old, while their average years of driving experience varied from 1 to 25 years.

4.2. Factor Analysis

MTF and TP factor analyses were implemented in the first study. These results of MTF and TP factor analyses were shown in Table A2 (Appendix) and Table A3 (Appendix). MTF scale includes 4 factors and 16 items. TP scale consists of 2 factors and 6 items. In this study, factor analysis was conducted for only MDB.

Factor analysis was conducted to evaluate the reliability and validity of the 13 items included in the MDB scale (as presented in Table 3). Prior to conducting factor analysis, certain items were removed from the analysis due to their infrequent occurrence and low scores (item 4 = 1.45, item 12 = 1.44, item 13 = 1.42) [31]. After excluding three items.

Exploratory factor analysis (EFA) was performed to initially establish a two-dimensional MDB scale. Items with corrected item-total correlation (CITC) value below 0.4 were subsequently removed [28]. It was found that all items had CITC values greater than 0.4. However, as some items did not align well with the intended factors, they were removed. After multiple iterations of EFA, four items (5, 6, 9 and 10) were eliminated. As a result, a final two-dimensional MDB scale comprising six items was developed.

To determine the factor loading of the MDB scale, we utilized varimax rotation. Dimensions with factor loadings below 0.4 were eliminated from the analysis. The KMO test yielded a coefficient of 0.78 for the overall scale, whereas the Bartlett test resulted in a significant p-value of less than 0.0001, indicating the suitability of the data for factor analysis and demonstrating the validity of the scale. Table 3 displays the computed loading factors for the four dimensions of MDB, which were found to be satisfactory with a cumulative total of 65%. Additionally, we assessed the reliability and effectiveness of the six-item MDB scale and obtained a Cronbach's alpha coefficient of 0.83 (mean = 1.9, standard deviation (SD) = 0.59). These results indicate high internal consistency and reliability in measuring MDB among bus drivers.

Table 2. Sample characteristics.

Variables	Classification	Mean	Standard Deviation (SD)
Age	Continuous variable	40.44	6.57
Gender	Female = 1 (0%), Male = 2 (100%)	2	0
Education	Primary school = 1 (0%), Secondary school = 2 (16.81%), High school = 3 (33.19%), Diploma = 4 (37.5%), Associate = 5 (11.2%), Bachelor or higher = 6 (1.29%).	3.47	0.94
Marital status	Single = 1 (8.62%), Married = 2 (91.38%)	1.91	0.28
Migrant	Immigrant driver = 1 (53.01%), Indigenous driver = 2 (46.99%)	1.47	0.5
Smoking status	Smoker = 1 (33.62%), Non-smoker = 2 (66.38%)	1.66	0.47
Hours of sleep per day	1 - 4 hours = 1 (0%), 4 - 6 hours = 2 (23.71%), 6 - 8 hours = 3 (64.22%), 8 - 10 hours = 4 (12.07%)	2.88	0.59
Income	≤10 million Vietnamese Dong (VND) = 1 (56.46%), 10 - 20 = 2 (35.35%), 20 - 30 = 3 (4.74%), >30 = 4 (3.45%)	1.55	0.74
Daily driving hours	1 - 4 hours = 1 (12.5%), 8 - 10 hours = 2 (65.09%), >10 hours = 3 (22.41%)	2.10	0.58
Years of driving	Continuous variable	7.66	4.49
Perceived income	Sufficient = 1 (46.12%), Insufficient = 2 (53.88%)	1.54	0.5
Annual training	Attending = 1 (87.5%), Not attending = 2 (12.5%)	1.12	0.33
Days of rest per month	1 - 3 days = 1 (69.83%), 4 - 7 days = 2 (29.31%), 8 - 14 days = 3 (0.86%)	1.31	0.48
Accident-experience in last 3 years	Occurrence = 1 (29.74%), No occurrence (70.26%)	1.70	0.46
Fines and penalties in last 3 years	No = 1 (60.34%), 1 = 2 (25%), 2 = 3 (9.05%), 3 = 4 (3.5%), >3 = 5 (2.16%)	1.63	1.00

Table 3. The factor structure of seven-items MDB scale.

ID number of items	Item content	Mean (SD)	Factor loading
Factor 1	**Errors by bus drivers (α = 0.75, Aiic = 0.51, Ev = 30%)**	2.09 (0.69)	
MP1	Make a hard braking or sudden deceleration to avoid collision when a motorcycle is abruptly swerving right in front	2.55 (0.95)	0.48
MP2	Distracted or preoccupied, realize belatedly that the vehicle ahead has slowed, and have to slam on the brakes to avoid a collision	2.04 (0.82)	1.01
MP3	Try to overtake without first checking your mirror, and then get hooted at by the vehicle behind which has already begun its overtaking maneuver	1.69 (0.78)	0.6
Factor 2	**Lapses by bus drivers (α = 0.88, Aiic = 0.71, Ev = 35%)**	1.63 (0.67)	
MP7	Fail to notice someone going the wrong way until it is nearly too late, and make a hard brake or lane change	1.63 (0.77)	0.83
MP8	Fail to notice vehicles parking illegally on the street or an obstacle up ahead on street until it is nearly too late, and make a hard brake or lane change	1.63 (0.74)	0.81
MP10	Fail to notice someone crossing illegally until it is nearly too late, and make a hard brake or lane change	1.62 (0.72)	0.77
ID number of items	**Eliminated items**		**Reason for elimination**
MP4	Try to overtake without first checking your mirror, then make the vehicles behind changing speed or lane, stopping, falling, or even making crashes		Had low score
MP12	Fail to turn on blinkers when entering or leaving bus stops		Had low score
MP13	Turn on wrong blinkers when entering (turning left blinker) and leaving (turning right blinkers) bus stops		Had low score
MP5	Misjudge speed of oncoming vehicle when overtaking		Did not match target factor
MP6	Fail to notice someone stepping out from behind a bus or parked vehicle until it is nearly too late, and make a hard brake or lane change		Did not match target factor
MP9	Fail to check your mirror before pulling out, changing lanes, turning		Did not match target factor
MP11	Brake too quickly on a slippery road and/or steer the wrong way in a skid		Did not match target factor

Notes: Factor loading < 0.4 not reported; α = Cronbach Alpha; Aiic = Average corrected inter-item total correlation; Ev = Explained variance.

Factor 1: Errors by bus drivers: this factor accounted for 30% of the total explanatory variables, and the Cronbach's alpha coefficient was 0.75. "Errors by bus drivers" referred to the failure of attention and planned actions of bus drivers. It consisted of three items (for example, "Try to overtake without first checking your mirror, and then get hooted at by the vehicle behind which has already begun its overtaking maneuver").

Factor 2: Lapses by bus drivers: this dimension accounted for 35% of all the explanatory variables, and the Cronbach's alpha coefficient was 0.88. "Lapses by bus drivers" referred to concentration and judgment failures, which can cause embarrassment to bus drivers. It contained three items (for example, "Fail to notice someone going the wrong way until it is nearly too late, and make a hard brake or lane change").

4.3. Correlation Test

Similar to the first study, this study employed two-tailed partial correlations to examine the relationships between MDB, MTF, and TP. Control variables included age, hours of sleep per day, perception of income sufficiency, daily driving hours, years of driving experience, and accidents experienced in the last 3 years. Table 4 shows the results of correlation test. Contrary to expectations, no significant correlation was found between MDB and MTF characteristics. However, it is interesting to note that MDB was significantly and positively associated with the illegal traffic behaviour of road users. Therefore, as in the first study, the perceived diversity of motorcycles and the perceived interaction with dangerous vehicles were combined to form the MTF conditions. The perceived driving behaviors of motorcyclists and the perceived traffic habits of road users were grouped together as illegal traffic behaviors. As hypothesized, a significant and positive association was found between MDB and TP.

Table 4. Partial correlation between MDB and MTF/TP.

Variables	MDB of bus drivers	Errors	Lapses
1. MTF characteristics	−0.004	0.003	−0.01
1.1 Perceived diversity of motorcycles	−0.07	−0.08	0.38*
1.2 Perceived dangerous vehicles interaction	0.05	0.07	0.01
2. Illegal traffic behaviour of road users	0.22*	0.10	0.26*
2.1 Perceived motorcyclists' driving behaviours	0.14**	0.04	0.2*
2.2 Perceived road users' traffic habits	0.27*	0.16**	0.29*
3. TP	0.4*	0.38*	0.27*
3.1 Perceived bus route punctuality	0.27*	0.27*	0.17**
3.2 Perceived bus route organisation	0.42*	0.38*	0.3*

Notes: *$p < 0.01$; **$p < 0.05$.

4.4. MDB Predictive Model

The BMA method was adopted to determine the best MDB predictive model for all bus drivers. The independent variables comprised perceived diversity of motorcycles, perceived dangerous vehicles interaction, perceived motorcyclists' driving behaviors, perceived road users' traffic habits, perceived bus route punctuality, perceived bus route organization and background information about bus drivers (age, gender, monthly income, daily driving hours, frequency of getting penalties and so on). The statistically significant variables of the 24 best models were shown in Figure 1. Based on the results of the BMA method, we selected model number 1 as the best model with the minimum Bayesian Information Criterion (BIC) value. Next, we filtered out some variables that significantly affected MDB in the top five models. The final model included 4 independent variables, including sufficiency of perceived income, driving years, experiences of accidents over the last 3 years, and perceived bus route organization. In Figures 1-3, the variables highlighted in yellow did not show statistical significance, while those in red indicated positive significance and those in blue indicated negative significance. The linear regression model was employed to develop the MDB model of all bus drivers. This model had an R2 value of 0.447, BIC of −115.83 and a post probability of 0.199. The results are shown in Table 5.

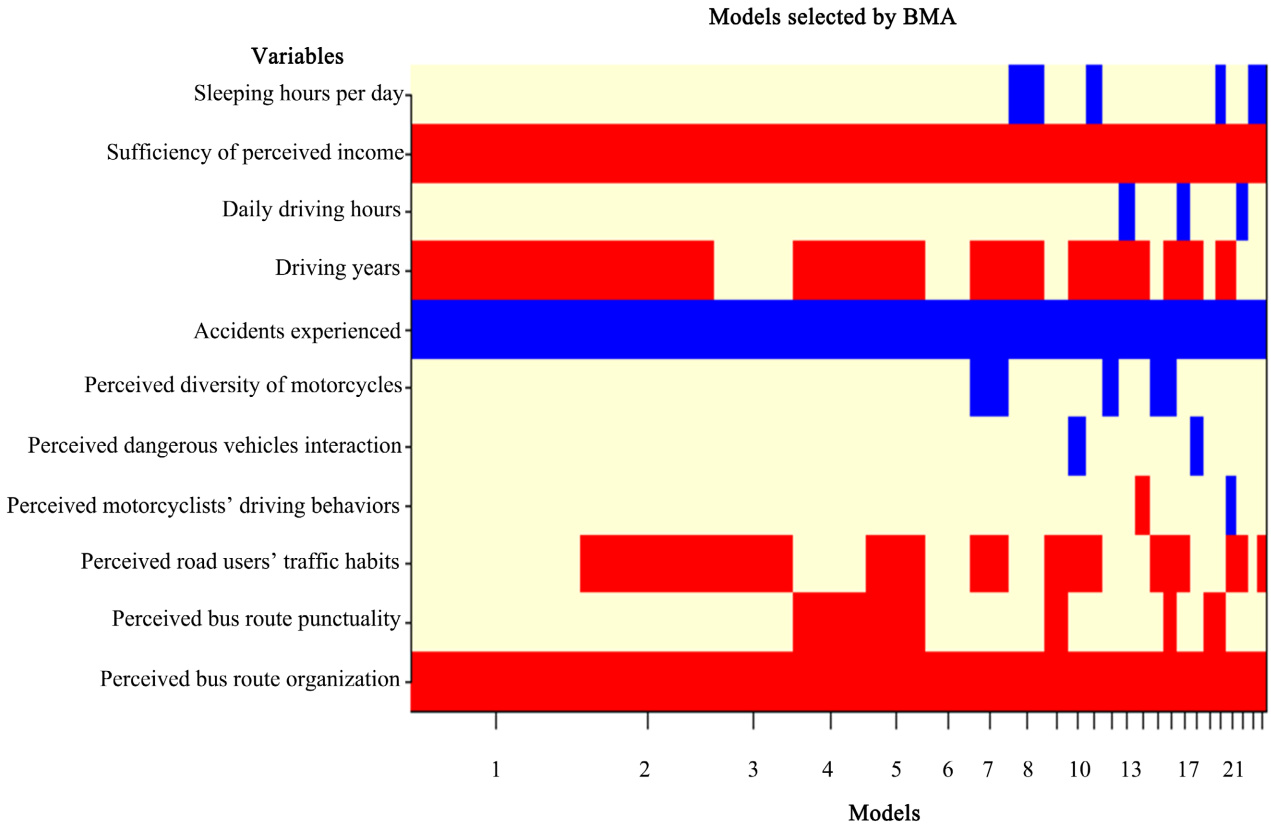

Figure 1. Selection of MDB predictive model using BMA method for all bus drivers.

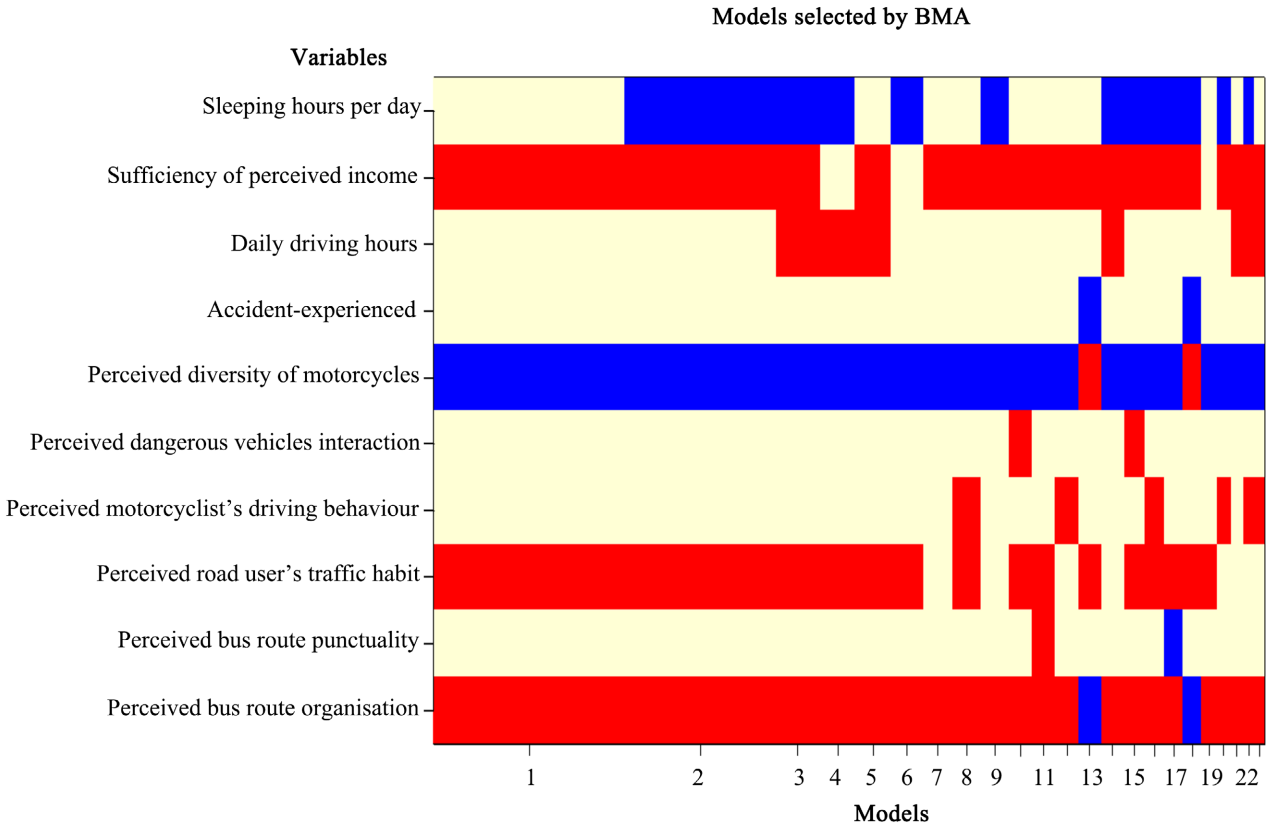

Figure 2. Selection of MDB predictive model by BMA method for accident-experienced group.

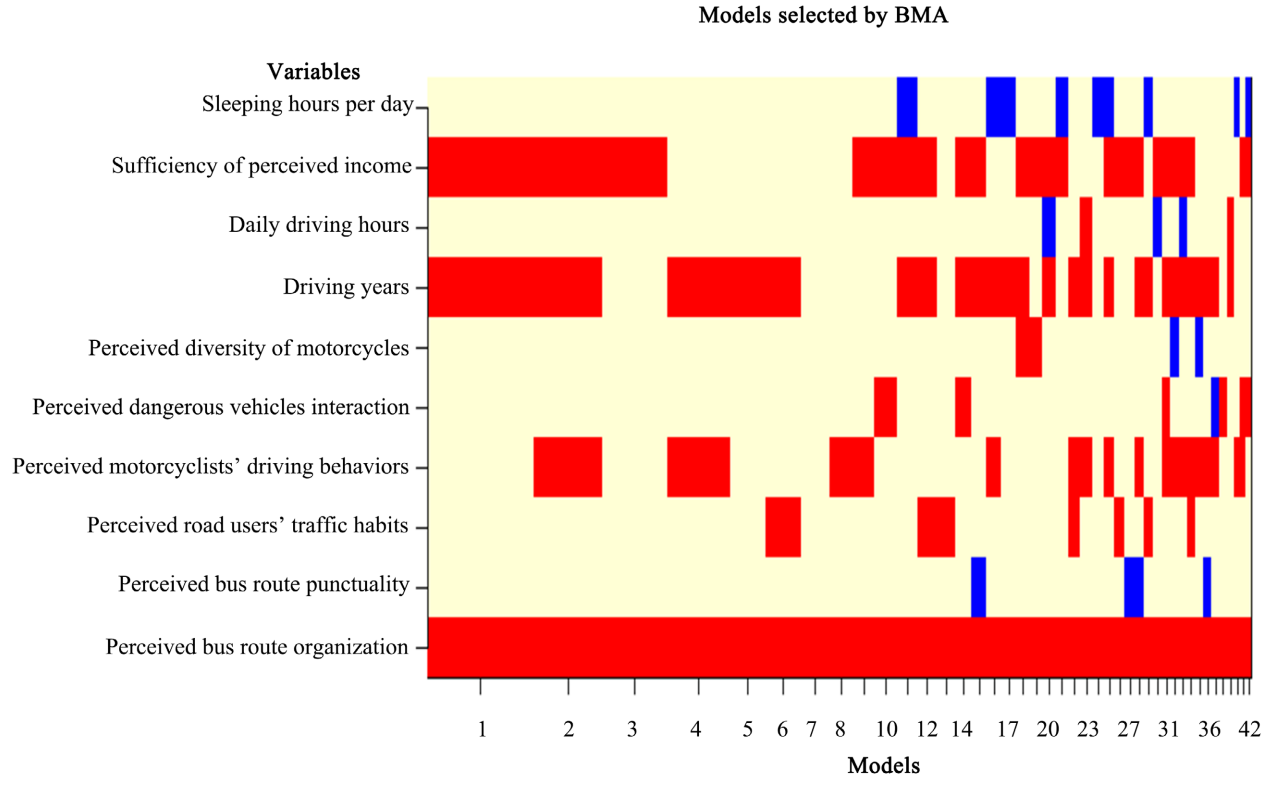

Figure 3. Selection of MDB predictive model by BMA method for accident-inexperienced group.

Table 5. The predictive model of MDB for all bus drivers, accident-experienced group of bus drivers and accident-inexperienced group of bus drivers in MTF.

No.	Variable	Coefficient and SD of all bus drivers	Coefficient and SD of accident-experienced group	Coefficient and SD of accident-inexperienced group
1	Intercept	1.08 ± 0.2***	0.28 ± 0.25	0.55 ± 0.16***
2	Sufficiency of perceived income	0.30 ± 0.06***	0.28 ± 0.11*	0.3 ± 0.07***
3	Driving years	0.02 ± 0.006**	0.03 ± 0.01*	0.02 ± 0.008***
4	Accident-experienced	−0.35 ± 0.07***	-	-
5	Perceived bus route organization	0.24 ± 0.03**	0.36 ± 0.05***	0.19 ± 0.04***

Notes: ***p < 0.001; **p < 0.01; *<0.05. Overall model: N = 232.

As presented in Table 5, only 4 variables significantly affected the MDB of all bus drivers. They were sufficiency of perceived income, driving years, accidents experienced in last 3 years, and perceived bus route organization. Among them, only accidents experienced in the last 3 years had negative significance in relation to the MDB. All the other affected variables had a positive influence on MDB. The most important variable affecting MDB was "accidents experienced in last 3 years". Furthermore, a significant 24% increase in the frequency of MDB incidents was observed when the perceived level of time restriction in bus route organization among all bus drivers increased by 1 unit. To compare the differences between bus drivers who had experienced accidents in the last 3 years and those who had not, two additional MDB predictive models were developed, one for each group. The BMA method was also ultilized to verify the best MDB predictive model for both groups. The independent variables included in the models were the same as those identified in the overall MDB predictive model for all bus drivers.

Figure 2 shows the results of the BMA method used to find the best MDB predictive model for the group of bus drivers who experienced accidents. The best MDB predictive model for the accident-experienced group of bus drivers, as determined by the BMA method, was selected based on model number 1, which had the minimum BIC value. Statistically significant variables were identified in the top five models, and non-significant variables were filtered out. The final linear regression model included three independent variables, resulting in an R2 value of 0.513, a BIC value of −36.89, and a post probability of 0.13. Table 5 presents the results of this model. Three variables, namely sufficiency of perceived income, driving years, and perceived bus route organization, had a significant positive impact on MDB in this group. Among these variables, the perceived bus route organization of the bus driver emerged as the most influential factor affecting MDB. When the perceived bus route organization among acci-

dent-experienced bus drivers as strict increased by 1 unit, the frequency of MDB increased by 36%.

Figure 3 displays the results of the BMA method applied to determine the best MDB predictive model for the accident-inexperienced group of bus drivers. Model number 1 was chosen as the best model based on the lowest BIC value. The analysis identified three statistically significant variables. The final model comprised three independent variables, resulting in an R2 value of 0.267, a BIC value of −35.43, and a post-probability of 0.121. These findings indicate that these three variables have a significant impact on the MDB of the accident-inexperienced group of bus drivers. After identifying the significant variables, a linear regression model was established to predict MDB for the accident-inexperienced group of bus drivers. The results of the linear regression model are shown in Table 5. All of these variables were found to have positive significance on the MDB of the accident-inexperienced group. The most important variable affecting MDB was the "sufficiency of perceived income of the bus driver". When the sufficiency of perceived income among accident-experienced bus drivers increased by 1 unit, the frequency of MDB increased by 30%. Moreover, when the perceived level of time restriction in bus route organization among bus drivers without prior accident experience increased by 1 unit, there was a 19% rise in the occurrence of MDB.

5. Discussion

This study successfully developed and validated the MDB scale in the MTF environment. Based on this scale, the study investigated how MTF and TP affect the MDB of bus drivers. In addition, the study successfully established three MDB predictive models for all bus drivers, the subgroups of accident- experienced, and accident-inexperienced bus drivers, by considering both MTF and TP.

Among the four factors on the MTF scale, the perceived diversity of motorcycles and the perceived interaction with dangerous vehicles were not associated with MDB among bus drivers. This result contributes to the findings of a previous study [3] where it was highlighted that bus drivers must focus on their tasks in an MTF environment.

The perceived motorcyclists' driving behaviours were positively related to MDB and were in line with the study of La *et al.*, [3]. It is recommended that policymakers focus not only on training policies related to the driving behaviors of bus drivers but also on those concerning motorcyclists. This approach aims to reduce MDB among bus drivers. In particular, implementing several sanctions to address dangerous motorcycle driving behaviors such as overtaking, swerving, weaving, filtering, tailgating, and slow driving can enhance overall bus traffic safety.

The perceived road users' traffic habits factor was also positively correlated with MDB. This result suggests that in order to decrease MDB among bus drivers, policymakers should prioritize the implementation of education and train-

ing policies that address unsafe traffic culture. It is crucial for this approach to be adopted across various sectors, emphasizing the importance of promoting a safer driving environment for all road users.

In addition, two factors of the TP scale, namely perceived bus route punctuality and perceived bus route organization, showed a positive correlation with MDB, aligning with previous studies [13] and [32]. Based on these results, policymakers and bus operators should prioritize the organization of a proper bus travel schedule to reduce MDB among bus drivers. This includes elements such as establishing a well-planned travel schedule, designing suitable working shifts, optimizing bus route lengths, and implementing incentives or penalties for bus drivers who adhere to or deviate from the designated time frame.

Additionally, a MDB scale with two factors and 6 items was retrieved from the 28 self-reported items driver behaviour questionnaire scale. Among the two MDB factors, the most influential factor was lapses by bus drivers (Ev = 35%). This factor comprised three items. The average score was low (1.63) and it was in agreement with previous studies [12] [19]. The second influential factor was errors by bus drivers (Ev = 30%), which contained three items with an average score of 2.09. The highest score (2.55) was for "make a hard braking or sudden deceleration to avoid collision when a motorcycle is abruptly swerving right in front". These results could be interpreted as a consequence of the prevalence of numerous illegal driving behaviors among road users in MTF environments, particularly motorcycles [3] [13]. This finding directly informs the development of training policies that specifically target the reduction of MDB among bus drivers.

Besides, the current study presented a MDB predictive model for all bus drivers. In addition to bus route organisation, it was found that MDB was correlated with "sufficiency of perceived income", "driving years" and "accidents experienced in the last 3 years".

Furthermore, this research study revealed that bus drivers who perceived their income as sufficient were found to engage in MDB less frequently, which aligned with previous studies [29]. It is possible that drivers experiencing MDB felt that their salary was inadequate considering the effort and time they invested. Consequently, while driving, they may have been preoccupied with thoughts about their side jobs in order to earn additional income. This finding highlights the importance for bus operators to implement suitable policies that guarantee satisfactory income for bus drivers, aiming to mitigate MDB among them.

In addition, the study revealed a positive relationship between the driving experience of bus drivers and MDB. It is logical to infer that as bus drivers accumulate more experience, they develop better skills to prevent errors or mistakes.

Moreover, there was a direct correlation observed between the frequency of accidents within the past 3 years and the level of engagement in MDB among drivers. This finding was consistent with the findings of a prior study [28]. The outcome of this study solidifies the impact of MDB on the likelihood of bus drivers being involved in accidents. In essence, the more bus drivers partake in

MDB, the higher the probability of them being engaged in an accident.

Based on the findings of the predictive models analyzing MDB among bus drivers who had experienced accidents and those who had not in the past 3 years, a decrease of 1 unit in bus drivers' perception of bus route organization led to a reduction of 36% and 19% in the frequency of MDB for the respective groups. Notably, bus drivers who had been involved in accidents within the past 3 years recognized the significant impact of their accidents on the MDB phenomenon. Consequently, they exhibited lower levels of MDB compared to their counterparts. Consequently, policymakers and bus operators are advised to arrange training seminars for bus drivers, enabling them to share their experiences and perceptions as a means to address the issue.

In addition to the significant contributions made by this study, it is crucial to acknowledge its limitations. Firstly, the samples were exclusively collected from Hanoi, Vietnam, limiting the generalizability of the findings to MTF cities worldwide. Secondly, the traffic behaviors of road users may vary in different countries or regions, potentially influencing the study's results. Thirdly, the study exclusively focused on male respondents due to the rarity of female bus drivers in Hanoi. It is plausible that female drivers may exhibit different responses to MTF compared to their male counterparts. Lastly, the study solely considered the perspectives of bus drivers, thus expanding the research scope to include other road users such as car drivers, motorcyclists, and pedestrians would provide valuable insights into how MTF impacts MDB.

6. Conclusions

This study represents a pioneering effort in investigating the influence of MTF environments and TP on the MDB of bus drivers. The notable accomplishments of this paper can be categorized into three primary contributions.

First, a modified scale of MDB was successfully established to measure MDB of bus drivers in MTF considering TP. This MDB scale comprised two factors with seven items.

Second, the effects of MTF characteristics and TP on the MDB were triumphantly figured out. The bus drivers' perceptions of motorcycle diversity and vehicle interaction danger did not have a significant impact on their MDB. However, the risky driving behaviors of motorcyclists, unsafe traffic habits of road users, and TP were identified as influential factors that encouraged the occurrence of mistakes by bus drivers.

Third, three MDB predictive models were successfully developed for all bus drivers, the accident-experienced group, and the accident-inexperienced group. These models accounted for the influence of MTF and TP on MDB. Increasing the Perceived bus route organization by one unit resulted in a 24%, 36%, and 12% decrease in the frequency of MDB of all bus drivers, the accident- experienced group, and the accident-inexperienced group, respectively.

The results of this research offer valuable perspectives and policy suggestions to decision-makers and bus companies, aiming to implement effective measures

that can help decrease MDB among bus drivers and enhance overall traffic safety in MTF environment. This study also highlights numerous avenues for future researchers to explore, including the following: examining the perceptions of other road users, such as car drivers, motorcyclists, and pedestrians, when faced with erratic driving behaviors exhibited by bus drivers in MTF scenarios; investigating how these users respond to such risky driving behaviors and exploring the impact of these reactions on other bus drivers and their likelihood of being involved in traffic accidents.

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Conflicts of Interest

The authors report there are no competing interests to declare.

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Appendix

Table A1. Normal distribution test of MDB.

ID number of items	Item content	Shapiro-Wilk coefficient	p value
MP1	Make a hard braking or sudden deceleration to avoid collision when a motorcycle is abruptly swerving right in front	0.88	$1.35e^{-12}$
MP2	Distracted or preoccupied, realize belatedly that the vehicle ahead has slowed, and have to slam on the brakes to avoid a collision.	0.84	$1.04e^{-14}$
MP3	Try to overtake without first checking your mirror, and then get hooted at by the vehicle behind which has already begun its overtaking maneuver.	0.77	$2.2e^{-16}$
MP4	Try to overtake without first checking your mirror, then make the vehicles behind changing speed or lane, stopping, falling, or even making crashes	0.67	$2.2e^{-16}$
MP5	Misjudge speed of oncoming vehicle when overtaking	0.78	$2.2e^{-16}$
MP6	Fail to notice someone stepping out from behind a bus or parked vehicle until it is nearly too late, and make a hard brake or lane change	0.78	$2.2e^{-16}$
MP7	Fail to notice someone going the wrong way until it is nearly too late, and make a hard brake or lane change	0.75	$2.2e^{-16}$
MP8	Fail to notice vehicles parking illegally on the street or an obstacle up ahead on street until it is nearly too late, and make a hard brake or lane change	0.75	$2.2e^{-16}$
MP9	Fail to check your mirror before pulling out, changing lanes, turning	0.79	$2.2e^{-16}$
MP10	Fail to notice someone crossing illegally until it is nearly too late, and make a hard brake or lane change	0.75	$2.2e^{-16}$
MP11	Brake too quickly on a slippery road and/or steer the wrong way in a skid.	0.72	$2.2e^{-16}$
MP12	Fail to turn on blinkers when entering or leaving bus stops	0.65	$2.2e^{-16}$
MP13	Turn on wrong blinkers when entering (turning left blinker) and leaving (turning right blinkers) bus stops	0.64	$2.2e^{-16}$
Factor 4	Mistake-prone by bus drivers	0.94	$1.05e^{-07}$
Factor 4.1	Lapses by bus drivers	0.83	$1.90e^{-15}$
Factor 4.2	Errors by bus drivers	0.94	$3.47e^{-08}$

Table A2. The factor structure of 16-items MTF scale.

ID number of items	Item content	Mean (SD)
Factor 1	**Perceived diversity of motorcycles (α = 0.87, Aiic = 0.69, Ev = 14.45%)**	3.56 (0.91)
M2	There are a lot of motorcycles on the road.	3.81 (1.07)
M3	There are several types of motorcycles on the road.	3.57 (0.96)
M5	There are several motorcycles around bus stops on the road.	3.31 (1.02)
Factor 2	**Perceived dangerous vehicles interaction (α = 0.82, Aiic = 0.54, Ev = 14.24%)**	3.13 (0.82)
M1	There is only one non-lane-based vehicle, that is, motorcycles.	3.20 (1.03)
M6	It is dangerous to drive on roads full of all kinds of vehicles.	3.31 (1.04)
M7	It is difficult to approach and stop at the bus stops.	3.05 (0.98)
M8	It is difficult to leave the bus stops.	2.96 (1.00)
Factor 3	**Perceived motorcyclists' driving behaviours (α = 0.96, Aiic = 0.84, Ev = 25.89%)**	3.46 (1.2)
M9	Motorcyclists engage in several overtaking manoeuvres on the road.	3.50 (1.18)
M10	Motorcyclists engage in several swerving manoeuvres on the road.	3.45 (1.33)
M11	Motorcyclists engage in several weaving manoeuvres on the road.	3.44 (1.37)
M12	Motorcyclists engage in several vehicle filtering manoeuvres on the road.	3.52 (1.29)
M13	Motorcyclists engage in several tailgating manoeuvres on the road.	3.41 (1.31)
Factor 4	**Perceived road users' traffic habits (α = 0.82, Aiic = 0.54, Ev = 17.65%)**	3.28 (0.82)
M15	Road users tend to ignore traffic signs	3.11 (1.37)
M16	Road users are only concerned about how to move quickly	3.14 (1.41)
M17	Road users comply tacitly with first-come-first-serve discipline and do not follow traffic rules.	3.04 (1.32)
M18	Everything about the traffic flow is unpredictable.	3.76 (0.93)

Table A3. The factor structure of six-items TP scale.

Id number of items	Item content	Mean (SD)
Factor 1	**Perceived bus route punctuality (α = 0.81, Aiic = 0.58, Ev = 31%)**	3.62 (0.86)
T1	The bus company lays down a strict travel schedule.	3.71 (1.00)
T2	Several fines would be imposed if each driving round is not completed on time.	3.51 (1.07)
T3	Several benefits would be earned if driving schedules are completed on time.	3.64 (0.97)
Factor 2	**Perceived bus route organization (α = 0.87, Aiic = 0.68, Ev = 34%)**	3.24 (0.94)
T5	Working shifts are too long.	3.25 (1.06)
T6	Working shifts are too late.	3.19 (1.07)
T7	The bus route is too long.	3.28 (1.04)