Safety of Public Transportation Occupational Drivers

Risk Perception, Attitudes, and Driving Behavior

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Public transportation plays a key role in providing transport services for the public in most cities of China. Safety is a top priority for improving the level of services of public transportation. This study aims to identify crash risk factors associated with demographic characteristics, driving-related experiences, and aberrant driving behaviors of the drivers of public transportation vehicles as well as to establish the influence of risk perception, risk-taking attitudes, and risky driving behaviors. The data used for analyses were obtained from a self-reported questionnaire survey carried out among 248 taxi and bus drivers in Wuhan, China. The results showed that drivers who both reported more tendencies toward aggressive violations and ordinary violations and had previously been involved in crashes were at high risk of crash involvement. Moreover, through the use of a structural equation model, it was found that drivers' attitudes toward rule violations and speeding significantly affect risky driving behaviors. Two risk perception scales, likelihood of crash and concern, have indirect effects on risky driving behaviors through their influence on drivers' attitudes toward rule violations and speeding. The significant risk factors and influential paths identified in this study are expected to result in better planning of road safety campaigns aimed at the occupational drivers in public transportation.

Public transportation is very important in most cities of China because of low rates of private car ownership. For example, as the biggest city in central south China, Wuhan City had a population of about 9 million in 2008, but had only 300,000 privately registered vehicles (*1*). The ratio of vehicles to population was only 3.3%. The vast majority of residents have to travel regularly by public transportation vehicles. Taxis and buses, as two main modes of public transportation, play a key role in providing transport services for the public. In 2008, Wuhan City had a total of 12,137 taxies and 6,104 buses in service, which accounted for about 2.5% of the total registered vehicles (*1*). Due to the passenger-transporting nature of public transportation, safety is a top priority for improving the level of services.

The operational characteristics of public transportation vehicles (that is, taxis and buses) and their occupational drivers are somewhat special. In most cities of China, according to administrative provisions for public transportation vehicles, only specialized transportation firms can obtain permission for operating taxi and bus transport services, and these firms are run by specialized government agencies (*2, 3*). Individuals contract with the authorized firms to operate taxis and buses, pay these firms a management fee, and usually take full responsibility for their own profits and losses in daily operation. To maximize the profit, vehicles generally run continuously, and drivers operate the vehicles in shifts. As a result of enforced regular vehicle inspections, few crashes are caused solely by vehicle mechanical malfunction. Rather, most crashes are attributed to driver-related factors such as fatigue and distraction (*4*). Generally, one public transportation vehicle is operated by two or at most three drivers in shifts daily, and each driver usually operates for more than 6 h continuously. Moreover, many drivers usually drive over the speed limit to enhance operation efficiency, and even race with each other to compete for the passengers waiting on the roadside (*4*). Such characteristics related to public transportation drivers undoubtedly increase the crash risk for themselves and the passengers.

Considerable research efforts have been made to investigate the safety issues related to taxi and bus services in various aspects. For instance, Chin and Huang (*5*) and Clarke et al. (*6*) conducted general analyses in Singapore and the United Kingdom, respectively, to identify risk factors affecting taxi and bus crash occurrence from driver demographics and vehicle and environmental factors. More specifically, several safety problems related to the work characteristics of public transportation drivers have been investigated. Dalziel and Job (*7*) and Gander et al. (*8*) investigated the fatigue problem of occupational drivers in Sydney, Australia, and in New Zealand, respectively. Af Wåhlberg (*9*) analyzed the influence of temperature on bus crashes in Sweden. Several other studies have focused on drivers' obedience to specific traffic rules and laws, such as safety belt use (*10*) and red light violations (*11*).

Since the overwhelming majority of road crashes may be related to human error (*12*) in which driver behavior is a primary determinant (*13*), correcting drivers' risky behavior is normally regarded as an efficient way to improve safety. For this purpose, driving behavior has been established as being associated with driver personalities, risk-taking attitudes, and risk perception factors by several studies (*14–18*). Particularly focusing on the drivers in public transportation, Mirza et al. (*19*) investigated risky driving behavior of bus drivers in Pakistan. Moreover, several studies have also been conducted to relate driver personalities, attitudes, risk perception, risky driving behavior, and crash involvement (*20–22*).

However, in China little has been done to comprehensively analyze the relationships among psychological factors (that is, attitudes

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and risk perception), driving behavior, and crash involvement of taxi and bus drivers. Most important, there is a dearth of understanding about which specific attitudes and risk perception factors correlate with drivers' risky driving behavior. Hence, this study aims to develop a comprehensive analysis for occupational drivers of public transportation vehicles (that is, taxis and buses) with two main objectives:

1. To identify which categories of aberrant driving behavior tend to result in crashes and
2. To explore the influential paths from specific risk-taking attitudes and risk perception to risky driving behaviors.

PRIOR RESEARCH ON ABERRANT DRIVING BEHAVIOR, RISK-TAKING ATTITUDES, AND RISK PERCEPTION

To measure the dimensions of aberrant driving behavior, Reason et al. (*23*) developed an instrument, namely, a driver behavior questionnaire (DBQ). The initial 50-item DBQ classifies aberrant driving behavior into errors (failures of planned actions to achieve intended consequences), lapses (unwitting deviation of action from intention), and violations (deliberate infringement of some regulated or socially accepted code of behavior). Subsequently, a 28-item version of the DBQ further divided violations into ordinary violations and aggressive violations (*14, 24, 25*). The DBQ has been generally applied and shown to be useful in numerous countries (*25–28*).

With the use of survey data, several studies have been conducted to associate attitudes with various risky driving behaviors (*14–16, 29, 30*). To explore their relationships, models such as the theory of reasoned action (*31*) and its extension, the theory of planned behavior (*32*), have been frequently applied. The theory of reasoned action and the theory of planned behavior models hypothesize that the influential effect from attitude to behavior is mediated through intended behavior. To represent the theoretical framework of the models, Bentler and Speckart (*33*) first applied a structural equation model to determine the relationships between attitudes, intentions, and behavior in a study of college students, and found that attitudes have a direct effect on subsequent driving behavior without being mediated by intentions. In the following studies, the structural equation model has been increasingly applied in exploring the attitude–behavior relationship among different driver groups, such as young drivers (*16*) and general drivers (*29, 30*).

Risk perception is also related to driving behavior. Many studies have found that risk perception is negatively associated with risky driving behavior (*34*), which means that drivers with a higher level of perceived risk for a particular behavior have less possibility of taking part in that behavior. However, there is some controversy about the effect. Several studies indicate that risk perception may be a consequence, not a cause, of behavior (*35*). Moreover, some researchers cast doubt on whether risk perception relates to behavior. Ulleberg and Rundmo (*16*) did not find a significantly casual relationship between risk perception and driving behavior when controlling for attitudes. Since only two items were included within the perception scale in Ulleberg and Rundmo's study (*16*), Machin and Sankey (*18*) doubted whether risk perception was adequately represented. Hence, in their study four scales were employed to represent risk perception; two specific scales were found to significantly affect speeding behavior. Accordingly, it seems advisable to include specific risk perception scales in exploring the perception–behavior relationship. With these applications, the structural equation model was increasingly employed (*16–18*).

To fulfill the objectives of the present research, a DBQ was employed to measure aberrant driving behavior. Measures about drivers' risk perception and risk-taking attitudes were incorporated into the survey by adding relevant question items to the standard DBQ. On the basis of previous research, the relationships between risk perception, risk-taking attitudes, and driving behavior were investigated and established for occupational drivers of public transportation.

METHOD

Research Strategy

A survey was conducted with the extended DBQ to collect the information of demographics, risk perception, risk-taking attitudes, and aberrant driving behavior among taxi and bus drivers in Wuhan, China. To validate the survey approach, the internal consistency of all the scales of risk perception, attitudes, and aberrant driving behavior was first assessed with Cronbach's alpha coefficients. Second, the differences between the taxi and bus driver groups in the scales of risk perception, attitudes, and aberrant driving behavior were examined by applying one-way analysis of variance (ANOVA). The step was used to determine whether the two driver groups should be examined aggregately or separately. Third, the significant factors affecting at-fault crash occurrence were identified from the factors of drivers' demographics, exposure, and aberrant driving behavior by developing a binary logit model. At-fault crashes in this analysis were determined when at least one human error was self-reported. Analysis on at-fault crashes only is more helpful to reveal the factors contributing to crash occurrence, while non-at-fault crashes are generally used to measure driving exposure, such as in the induced-exposure method (*36*). Finally, the influential paths from risk perception and attitudes to the identified risky behavior scales were explored by developing a structural equation model, and in addition, the direct and indirect effects of risk perception and attitudes on the behavior scales were estimated.

Measurements

The questionnaire used in this study consists of measurements for drivers' demographics, driving-related experiences, risk perception, risk-taking attitudes, and aberrant driving behavior. While the 28-item version DBQ was adopted for measuring aberrant driving behavior (*25*), we designed additional items to measure risk perception and risk-taking attitudes; these items are shown in Table 1.

The demographic part in the questionnaire includes driver's age, gender, driving experience (i.e., how long have you held a driving license?), annual driving mileage, education level (i.e., have you studied in high school?), at-fault crash history (i.e., have you been involved in at-fault crashes more than 2 years ago?), and at-fault crashes (i.e., have you been involved in at-fault crashes within the recent 2 years?).

As shown in Table 1, risk perception was measured by three scales: worry and insecurity (emotion-based risk perception); likelihood of crash; and concern (cognition-based risk perception). These scales have been applied by Rundmo and Iversen (*17*). In detail, the worry and insecurity scale contains four items related to worrying about traffic risk. The likelihood of crash scale consists of four items related to assessing the possibility of crash for oneself and others in the future,

TABLE 1 Descriptive Statistics for Items Measuring Risk Perception and Attitudes

Measuring Item	Mean	SD
Risk Perception Scales		
1. Emotion-based risk perception: worry and insecurity		
1.1 Feeling unsafe that you yourself could be injured in a traffic crash?	2.63	1.002
1.2 Worried for yourself being injured in a traffic crash?	2.46	1.009
1.3 Feeling unsafe that persons could be injured in a traffic crash?	2.61	0.946
1.4 Worried for persons being injured in a traffic crash?	2.75	0.942
2. Cognition-based risk perception: probability assessment		
2.1 How probable do you think it is for yourself to be involved in a traffic crash?	2.44	0.946
2.2 How probable do you think it is for yourself to be injured in a traffic crash?	2.39	0.959
2.3 How probable do you think it is in general for persons to be involved in a traffic crash?	2.96	1.069
2.4 How probable do you think it is in general for persons to be injured in a traffic crash?	3.07	1.035
3. Concern		
3.1 How concerned are you about traffic risks and are thinking that you yourself could be victimized?	3.48	0.969
3.2 How concerned are you about traffic risks and are thinking that others could be victimized?	3.71	1.012
Risk-Taking Attitude Scales		
1. Attitude toward rule violations and speeding		
1.1 Many traffic rules must be ignored to ensure traffic flow.	1.80	1.002
1.2 It makes sense to exceed speed limits to get ahead of "Sunday drivers."	1.98	0.969
1.3 Traffic rules must be respected regardless of road and weather conditions.	2.42	1.257
1.4 Speed limits are exceeded because they are too restrictive.	1.88	0.966
1.5 It is acceptable to drive when traffic lights change from yellow to red.	2.21	1.011
1.6 Taking chances and breaking a few rules does not necessarily make bad drivers.	2.04	0.999
1.7 It is acceptable to take chances when no other people are involved.	1.77	0.889
1.8 Traffic rules are often too complicated to be carried out in practice.	2.05	1.017
1.9 If you are a good driver it is acceptable to drive a little faster.	1.88	0.870
1.10 When road conditions are good and nobody is around driving at 160 km/h is OK.	1.44	0.766
1.11 Punishments for speeding should be more restrictive.	3.02	1.260
2. Attitude toward the careless driving of others		
2.1 It is ok to ride with someone who speeds if that is the only way to get home at night.	1.69	0.802
2.2 It is ok to ride with someone who speeds if others do.	1.73	0.808
2.3 I do not want to risk my life and health by riding with an irresponsible driver.	2.89	1.427
3. Attitude towards drinking and driving		
3.1 I would never drive after drinking alcohol.	2.24	1.360
3.2 I would never ride with someone I knew that had been drinking alcohol.	2.57	1.258

NOTE: All the items were measured on five-point Likert scales ranging from "strongly disagree" to "strongly agree."

and the concern scale includes two items related to the concern about traffic risks and being victimized. For risk perception, the scales for all the items ranged from "1: not possible/no concern at all" to "5: very possible/concern." A high score means that the driver perceives high risk.

Risk-taking attitudes were measured with 16 items grouped with three scales, conforming to prior research (*29, 30*). The three scales—namely attitude toward rule violations and speeding, attitude toward the careless driving of others, and attitude toward drinking and driving—consisted of 11, three, and two items, respectively (see Table 1 for details). Responses were given on a five-point scale from "strongly disagree" to "strongly agree." Five scores, 1 through 5, were assigned to the items to ensure that a high score on an item indicates low preferences for risk-taking in traffic.

Self-reported aberrant driving behavior was measured by the 28-item DBQ, which was categorized into four scales: aggressive violations (three items), ordinary violations (nine items), errors (eight items), and lapses (eight items). On the DBQ, respondents were asked to assess, on a six-point scale from "1: never" to "6: all the time," how often they commit each of the question items. The mean score of each scale was obtained in terms of the items within the scale. A high score on a scale indicated a frequent occurrence of the driving behavior.

Statistical Analysis

Cronbach's Alpha Coefficients

Cronbach's alpha is a coefficient of consistency that measures how well a set of variables or items measures a single, unidimensional latent construct (*37*). In this study, the alpha coefficient was applied to evaluate the internal consistency of the risk perception, risk-taking attitudes, and aberrant driving behavior scales. A Cronbach's alpha of .6 to .7 indicates acceptable reliability (*38*).

Analysis of Variance

The differences between two groups (taxi drivers taxi and bus drivers) in risk perception, risk-taking attitudes, and aberrant driving behavior were tested by applying one-way ANOVA. As a preliminary analysis, variances of the two groups should be examined to establish whether they are homogeneous. If so, the following analysis could be conducted by using Student–Newman–Keuls or least-significant difference test methods; otherwise, the method of Tamhane's T2 is more suitable (*39*). Usually, a p-value above .05 indicates a nonsignificant difference.

Logit Model

A binary logit regression model was applied to identify significant factors affecting at-fault crash occurrence from occupational drivers' demographics, driving-related experiences, and aberrant driving behavior scales. Specifically, at-fault crash occurrence, represented as a dummy variable (i.e., 1 denotes being involved in at-fault crashes, and 0 denotes none), was specified as the response variable; other factors (for example, aberrant driving behavior scales) were specified as explanatory variables. The estimated parameter for an explanatory variable can be interpreted as the additive effect on the log odds ratio (OR) for a unit change in the variable (*40*). A large OR (>1) indicates that when the explanatory variable increases the driver is more likely to be involved in at-fault crashes, while a small OR (<1) means a smaller possibility of being involved in at-fault crashes when the explanatory variable increases.

Structural Equation Model

A structural equation model, as a confirmatory technique, was used to explore the causal relationships between risk perception, risk-taking attitudes, and risky driving behavior by using the LISREL 8.7 program (*41*). It is expected that drivers' perception of risk could influence their attitude (*42*), while risk perception and attitude could have effects on behavior (*18, 30*). Hence, a structural equation modeling analysis was performed to explore a conceptual path model with three-level influential paths from risk perception to attitudes, and then to risky driving behavior. The direct effects of risk perception on attitudes were also considered. Accordingly, the scales of risk perception were specified as exogenous variables in the structural equation model, while the scales of risk-taking attitudes and risky driving behavior were specified as endogenous variables.

The significance of influential paths can be tested by *t*-value. A *t*-value above 1.96 or under −1.96 indicates a significant path. Some commonly used fit indices are applied to measure the model fitting to the data: the root mean square error of approximation (RMSEA), the goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), and the comparative fit index (CFI). An RMSEA of 0.08 or less and a GFI, an AGFI, and a CFI above 0.90 indicate a good model's fit (*43*).

DATA

The survey was carried out among occupational drivers working for a taxi company and a bus company, which are the two largest public transportation providers in Wuhan City. A total of 350 questionnaires were sent out to the drivers who attended a routine meeting in each company. Before the survey, a preliminary introduction of the survey purpose was presented in order to ensure the validity of data. In the end, 162 and 180 questionnaires were received from the two companies, respectively. After excluding those lacking answers to the majority of the questions, a respective 120 and 128 valid questionnaires remained. The summary statistics of the demographics for the 248 respondent drivers are shown in Table 2. All the scales of risk perception, attitudes, and driving behavior were obtained by summing the scores on the items within each scale.

As shown in Table 2, the remaining 248 respondents were mainly male (94%), between 31 and 50 years old (81.5%), and had an average mileage of 88.4 thousand kilometers per year. Of these, 97% had more than 5 years driving experience, 83% did not receive a high school education or higher, 16% were involved in at-fault crashes more than 2 years ago, and 21% were involved in at-fault crashes within the recent 2 years.

RESULTS

Reliability Analysis

The internal consistency, number of items, means, and standard deviations for all the scales of risk perception, risk-taking attitudes, and aberrant driving behavior are listed in Table 3. It shows that, at a 0.6 to 0.7 level, the reliability of the scales is generally acceptable and thus confirms that the survey approach is valid. Exceptionally, the Cronbach's alpha coefficients for careless driving of others and drinking and driving are less than 0.6. A probable explanation is that both scales consist of few items (*16*).

Examination of Differences in Scales

With all the measures of risk perception, attitudes, and aberrant driving behavior as the dependent variables and driver group (1 denotes taxi drivers; 2 denotes bus drivers) as the fixed factor, the Levene's test for homogeneity of variances indicated that the four measures of driving behavior did not satisfy the assumption of homoscedasticity (p-value < .05). Hence, the Tamhane's T2 test was used to analyze the differences of the behavior measures between the two groups. The results of one-way ANOVA for all the scales are listed in Table 4. At a 0.05 level, it was found that all the scales of risk perception, attitude, and driving behavior were not significantly different across the taxi and bus driver groups. Hence, the survey data related to taxi and bus drivers were investigated aggregately in the following analyses.

TABLE 2 Descriptive Statistics for Demographics of Respondent Drivers

Variable	Mean	SD	Min.	Max.
Driver age (1 if ≤ 30; 2 if 31–50; 3 if >50)	1.95	0.43	1	3
Gender (1 if male; 2 if female)	1.06	0.24	1	2
Annual mileage (in ten thousand kilometers)	8.84	3.46	3	20
Driving experience (1 if ≤ 5 years; 2 if > 5 years)	1.97	0.18	1	2
Education level (1 if not having high school education experience or higher; 2 if others)	1.17	0.38	1	2
At-fault crash history (1 if being involved in crashes more than 2 years ago; 0 if none)	0.16	0.37	0	1
At-fault crash within recent 2 years (1 if being involved in at-fault crashes; 0 if none)	0.21	0.41	0	1

TABLE 3 Descriptive Statistics and Cronbach's Alpha for All Scales

Measure	Number of Items	Mean (Range 1–5)	SD	Cronbach's Alpha
Risk Perception Scales				
Worry and insecurity	4	2.61	0.79	.82
Likelihood of crash	4	2.71	0.76	.75
Concern	2	3.60	0.86	.67
Risk-Taking Attitude Scales				
Rule violations and speeding	11	2.04	0.59	.82
Careless driving of others	3	2.10	0.66	.43
Drinking and driving	2	2.41	1.06	.48
Aberrant Driving Behavior Scales				
Aggressive violations	3	1.78[a]	0.74	.76
Ordinary violations	9	1.75[a]	0.65	.88
Errors	8	1.70[a]	0.65	.87
Lapses	8	1.70[a]	0.63	.87

[a]Range 1–6.

Risk Factor Analysis

Eleven factors, including four aberrant driving behavior scales and seven factors related to drivers' demographics and driving-related experiences, were used as explanatory variables in the logit model. To make the coefficients of driving behavior scales comparable, the total scores were standardized by the number of items.

TABLE 4 Analysis of Variance for Risk Perception, Attitudes, and Driving Behavior

Measure	Mean Square		*F*-Value	*p*-Value
	Between Group	Within Group		
Risk Perception Scales				
Worry and insecurity	0.03	9.93	<.01	.96
Likelihood of crash	33.31	9.16	3.64	.06
Concern	2.64	2.94	.90	.35
Risk-Taking Attitude Scales				
Rule violations and speeding	6.73	42.2	.16	.69
Careless driving of others	1.54	3.94	.39	.53
Drinking and driving	0.29	4.54	.06	.80
Aberrant Driving Behavior Scales				
Aggressive violations	2.19	4.92	.45	.51
Ordinary violations	10.92	34.15	.32	.57
Errors	1.63	27.36	.06	.81
Lapses	46.52	25.40	1.83	.18
Degree of freedom between groups		1		
Degree of freedom within groups		246		

TABLE 5 Significant Risk Factors Affecting At-Fault Crash Occurrence

Variable	β	Wald	Exp(β)	*p*-Value
Constant	−5.12	58.59	0.01	<.001
At-fault crash history				
Involvement	1.65	14.99	5.21	<.001
Noninvolvement[a]	—	—	—	
Aggressive violation behavior	0.97	6.94	2.64	.008
Ordinary violation behavior	0.85	3.91	2.34	.048

[a]Reference in categorical variable.

The Wald forward stepwise method was employed to identify significant variables, and it was found that three explanatory variables were finally kept in the model. Within these variables, the variable of aggressive violation behavior entered the model first, followed by the variable of at-fault crash history; the last variable entered was ordinary violation behavior. Table 5 shows the estimation results.

The OR is presented in Table 5 as Exp(β). The OR calculated for the variable of at-fault crash history is 5.21, meaning that the odds of at-fault crash involvement would increase by 421% for the drivers who had been involved in a crash more than 2 years ago compared with those who had not been involved. Moreover, among the behavior factors, the OR calculated for aggressive violation behavior is 2.64, meaning that when the score on the factor increases by one unit, the odds of at-fault crash involvement would increase by 164%. Similarly, when the score on the factor of ordinary violation behavior increases by one unit, the odds of at-fault crash involvement would increase by 134%.

Influential Path Analysis

The two factors of risky driving behavior identified in the logit model, aggressive violation and ordinary violation behaviors, were further investigated to explore which specific scales of risk perception and attitudes have significant effects on them.

In the initial structural equation model, all the scales of risk perception (three scales) and attitudes (three scales) were related to the two risky driving behaviors. Specifically, the initial paths include those (*a*) from the risk perception scales to the risk-taking attitude scales, (*b*) from the risk perception scales directly to the risky driving behavior scales, and (*c*) from the attitude scales to the risky behavior scales. The proposed model was fitted iteratively. It was found that the influential paths from attitude toward the careless driving of others and attitude toward drinking and driving to both of the risky driving behavior scales were not significant (*t*-values were between −1.96 and 1.96); hence the two attitude scales were dropped from the model. The worry and insecurity scale was also eliminated due to the nonsignificant paths from itself to attitude toward rule violations and speeding and to both of the risky driving behavior scales. The final model with standardized path coefficients is presented in Figure 1. The model explained 31% and 36% of total variance in aggressive and ordinary violation behavior, respectively. The fit statistics for the final model indicated that it is a good fit to the data: $\chi^2 = 5.38$, degrees of freedom = 5, GFI = 0.99, AGFI = 0.97, CFI = 1.00, and RMSEA = 0.018.

As shown in Figure 1, it was found that the attitude toward rule violations and speeding scale was the only variable with a directly

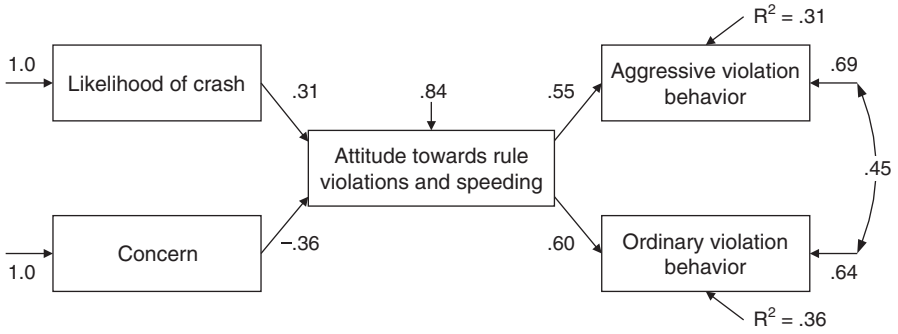

FIGURE 1 Path diagram of relationships among risk perception, attitudes, and risky driving behavior (n = 248; χ^2 = 5.38; degrees of freedom = 5; GFI = 0.99; AGFI = 0.97; CFI = 1.00; RMSEA = 0.018).

significant effect on both the risky driving behavior factors, while the likelihood of crash and concern scales had an indirect effect on the behavior factors mediating through the attitude toward rule violations and speeding scale. Based on the standardized path coefficients estimated, the direct and indirect effects of the two risk perception scales and the one attitude scale on both the risky driving behavior factors were calculated. The results, shown in Table 6, show that on both behavior factors of aggressive violation and ordinary violation, the attitude toward rule violations and speeding scale has positively direct effects of 0.55 and 0.60, respectively, which means that when the measure of the attitude scale increases by one unit, measures of the aggressive violation and ordinary violation behaviors would increase by 0.55 and 0.60 units, respectively. Moreover, it was also found that on the two violation behavior factors, the scale of likelihood of crash has indirect effects of 0.17 and 0.19, and the risk perception scale of concern has indirect effects of 0.20 and 0.22, respectively.

DISCUSSION OF RESULTS

Anonymous questionnaire surveys can help to collect reliable information about driving behavior as well as about risk perception and risk-taking attitudes among the occupational drivers of this analysis. The DBQ has been widely used in measuring self-reported driving behavior. The internal consistency of the four behavior scales developed in this study is acceptable, which is consistent with several studies aimed at general public drivers (*14, 25*). Moreover, similar to previous research in investigating risk perception (*17*) and risk-taking attitudes (*30*), the related scales also have acceptable reliability in this study.

TABLE 6 Effects of Perception and Attitude-Related Scales on Risky Driving Behavior

	Aggressive Violation		Ordinary Violation	
Variable	Direct	Indirect	Direct	Indirect
Risk Perception Scales				
Likelihood of crash	—	0.17	—	0.19
Concern	—	–0.20	—	–0.22
Risk-Taking Attitude Scales				
Rule violations and speeding	0.55	—	0.60	—

Although the taxi and bus drivers were from two different transportation companies, in this study no significant differences were found between them regarding the scales of risk perception, attitudes, and driving behavior on the basis of ANOVA results. This may be expected for two reasons. First, the two companies have similar systems in safety administration for occupational drivers, such as regular traffic-safety training and daily work-quality assessments. Second, both the taxi and bus drivers are in the same traffic context, that is, they experience the traffic enforcement intensity, public consciousness of traffic safety, and so forth.

Of the four aberrant driving behaviors, only violation behavior factors (aggressive violations and ordinary violations) were found to significantly affect at-fault crashes within the recent 2 years. Previous studies also show that drivers who report higher levels of violations during the course of their driving tended to be overrepresented in crash involvement (*13, 30, 44*). This finding suggests that a powerful intervention in the taxi and bus drivers' commission of violations would be an effective means to reduce their risks of being involved in at-fault crashes. In addition to the behavior factors, at-fault crash history is the only significant factor affecting crash occurrence. This finding implies that the taxi and bus drivers who had previously been involved in at-fault crashes may have higher crash risk in future.

As an exposure to crash risk, annual mileage was not found to be associated with crash involvement, which conforms to a study on truck drivers (*44*). This may be due to the fact that the taxi and bus drivers have a relatively high and approximately uniform annual mileage compared with general drivers. Sullman et al. (*44*) argued that there may be a threshold level of annual mileage, beyond which the effect of increasing exposure on crash risk would be negligible.

Low education level was not found to have a significant influence on crash rates reported. The result is consistent with previous studies (*22, 45, 46*). Although several studies have also found that drivers who were young, male, or had less driving experience, or some combination of these factors, were more likely to be involved in crashes (*23, 44*), this study did not find similar results. This may be due to the fact that the occupational drivers were almost exclusively male (94%), middle-aged (81.5%), and experienced (97% with 5-year driving experience).

Among the scales of risk-taking attitudes, drivers' attitudes toward rule violations and speeding was the only scale having direct influence on both of the risky driving behavior scales. The attitude scale accounted for 31% and 36% of the total variance in aggressive

violation and ordinary violation, respectively. This finding indicates that the taxi and bus drivers who have a relatively high level in this specific attitude related to violations of traffic rules and speeding (e.g., "speed limits are exceeded because they are too restrictive" or "if you are a good driver it is acceptable to drive a little faster") tend to commit aggressive violation and ordinary violation behaviors. Hence, a meaningful intervention would be to target this specific attitude for changing risky driving behavior. Iversen (*30*) also identified that this specific attitude is most important in relation to risky driving behavior.

Risk perception was not found to have direct effects on risky driving behavior. This result conforms to several previous studies (*16*). However, two specific scales of risk perception, likelihood of crash and concern, were found to have indirect effects on risky driving behavior through their influence on drivers' attitude toward rule violations and speeding. Within the effects identified, it may be plausible that likelihood of crash has a positive influence on risky driving behavior. To explain a similar finding, Machin and Sankey (*18*) argued that drivers who take more risky driving behavior may also think of themselves as at high risk of crashes, and therefore the perception factor of likelihood of crash may be a consequence of risky driving behavior.

As the other significant scale related to risk perception, concern has a negatively indirect influence on risky driving behavior. McKenna and Horswill (*47*) also found concern made a significant contribution to the prediction of risky driving behavior. This finding shows that taxi and bus drivers who lack concern on traffic risks and injuries tend to be involved in crashes. Hence, this study suggests that more attention should be paid to the risk perception scale of concern when trying to change the risky driving behavior of taxi and bus drivers.

Since risk perception, risk-taking attitudes, and risky driving behavior were measured at the same time in this study, it may be problematic to claim that risk perception and attitudes could predict behavior. However, as self-reported driving behaviors have been proved to be relatively stable over time (*16, 30*), it is rational to assume that the current driving behavior makes a reliable indicator of future behavior. Hence, the relationship established among risk perception, attitudes, and current driving behavior could shed light on the correction of future risky driving behavior and thus improve the safety of public transportation drivers.

CONCLUSION

This study aims to identify significant factors affecting the safety of occupational drivers in public transportation (i.e., taxi and bus) and to establish the influential paths from risk perception and risk-taking attitudes to risky driving behavior. Preliminary analyses showed that all the scales of risk perception, risk-taking attitudes, and aberrant driving behavior have acceptable reliability. Moreover, there is no significant difference found between taxi and bus drivers regarding the scales. Hence, a research strategy of aggregate analysis was employed without distinguishing between taxi and bus drivers.

With respect to the significant factors affecting at-fault crashes, two violation behaviors (aggressive violations and ordinary violations) were identified as having a positive influence on at-fault crash occurrence. Moreover, it was found that drivers with a crash history are more prone to future crashes. In the structural equation model developed, three scales related to risk perception and risk-taking attitudes were found to have significant effects on risky driving behavior. Among these, only the specific attitude scale of attitude toward rule violations and speeding has a direct effect on risky driving behavior, while two scales of risk perception (likelihood of crash and concern) have indirect effects on risky driving behavior through their influence on the attitude toward rule violations and speeding. The results indicate that drivers with a lack of concern about traffic risks and with positive attitudes toward rule violation and speeding tend to be at high risk of crashes.

To sum up, these findings suggest that there is a need to focus on specific aspects of risk perception and attitudes in the planning of road safety campaigns aimed at public-transportation occupational drivers. Specifically, more driver education programs related to bad influences on and consequences of traffic crashes may be expected to reinforce drivers' concern about traffic risks. Moreover, to change drivers' attitudes toward rule violations and speeding, many education efforts may be conducted to emphasize the importance of obeying traffic rules and the strong relationship between rule violations and crash risks.

The use of self-reports would seem to be a problem if there were a large variance between self-reported information and actual data. However, various studies have reported good agreements between self-reported behavior and observed driving behavior (*48*) and between the crash rates reported and actual ones (*49*). Moreover, the participants would report minor crashes probably not recorded in official databases and hence may be more complete than official records. The combined use of self-reported and police-reported crash records may be recommended in future studies to address the crash-underreporting concern.

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REFERENCES

1. Wuhan Land Resources and Planning Bureau. *2008 Annual Report on Wuhan Transport Development.* Wuhan, China, 2009.
2. Standing Committee of Wuhan People's Congress. *Regulations of Wuhan City on Urban Public Transportation.* Wuhan, China, 2004.
3. Standing Committee of Wuhan People's Congress. *Regulations of Wuhan City on Urban Taxis for the Public.* Wuhan, China, 2004.
4. Chen, K., and Y. Wang. Distribution Characteristics and Countermeasures of Urban Traffic Accidents. *Journal of Traffic and Transportation Engineering,* Vol. 3, No. 1, 2003, pp. 84–87 (in Chinese).
5. Chin, H. C., and H. Huang. Safety Assessment of Taxi Drivers in Singapore. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2114,* Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 47–56.
6. Clarke, D., P. Ward, C. Bartle, and W. Truman. Work-Related Road Traffic Collisions in the UK. *Accident Analysis and Prevention,* Vol. 41, No. 2, 2009, pp. 345–351.
7. Dalziel, J. R., and R. F. Job. Motor Vehicle Accidents, Fatigue and Optimism Bias in Taxi Drivers. *Accident Analysis and Prevention,* Vol. 29, No. 4, 1997, pp. 489–494.
8. Gander, P. H., N. S. Marshall, I. James, and L. L. Quesne. Investigating Driver Fatigue in Truck Crashes: Trial of a Systematic Methodology. *Transportation Research Part F,* Vol. 9, No. 1, 2006, pp. 65–76.
9. Af Wåhlberg, A. E. If You Can't Take The Heat: Influences of Temperature on Bus Accident Rates. *Safety Science,* Vol. 46, No. 1, 2008, pp. 66–71.
10. Fernandez, W. G., J. L. Park, and J. Olshaker. An Observational Study of Safety Belt Use Among Taxi Drivers in Boston. *Annals of Emergency Medicine,* Vol. 45, No. 6, 2005, pp. 626–629.

11. Wong, S. C., C. W. Wong, and N. N. Sze. Attitudes of Public Light Bus Drivers to Penalties to Combat Red Light Violations in Hong Kong. *Transport Policy,* Vol. 15, No. 1, 2008, pp. 43–54.
12. Rumar, K. The Role of Perceptual and Cognitive Filters on Observed Behavior. In *Human Behavior and Traffic Safety* (L. Evans and R. C. Schwing, eds.), Plenum Press, New York, 1985.
13. Parker, D., R. West, S. Stradling, and A. Manstead. Behavior Characteristics and Involvement in Different Types of Traffic Accident. *Accident Analysis & Prevention,* Vol. 27, No. 4, 1995, pp. 571–581.
14. Parker, D., T. Lajunen, and S. Stradling. Attitudinal Predictors of Interpersonally Aggressive Violations on the Road. *Transportation Research Part F,* Vol. 1, No. 1, 1998, pp. 11–24.
15. Social Attitudes to Road Traffic Risk in Europe (SARTRE). *The Attitude and Behaviour of European Car Drivers to Road Safety.* Brussels, Belgium, 1998.
16. Ulleberg, P., and T. Rundmo. Personality, Attitudes and Risk Perception as Predictors of Risky Driving Behavior Among Young Drivers. *Safety Science,* Vol. 41, No. 5, 2003, pp. 427–443.
17. Rundmo, T., and H. Iversen. Risk Perception and Driving Behavior Among Adolescents in Two Norwegian Counties Before and After a Traffic Safety Campaign. *Safety Science,* Vol. 42, No. 1, 2004, pp. 1–21.
18. Machin, M. A., and K. S. Sankey. Relationships Between Young Drivers' Personality Characteristics, Risk Perceptions, and Driving Behavior. *Accident Analysis and Prevention,* Vol. 40, No. 2, 2008, pp. 541–547.
19. Mirza, S., M. Mirz, H. Chotani, and S. Luby. Risky Behavior of Bus Commuters and Bus Drivers in Karachi, Pakistan. *Accident Analysis and Prevention,* Vol. 31, No. 4, 1999, pp. 329–333.
20. Rosenbloom, T., and A. Shahar. Differences Between Taxi and Nonprofessional Male Drivers in Attitudes Towards Traffic-Violation Penalties. *Transportation Research Part F,* Vol. 10, No. 5, 2007, pp. 428–435.
21. Burns, P. C., and G. J. S. Wilde. Risk Taking in Male Taxi Drivers: Relationships Among Personality, Observational Data and Driver Records. *Personality and Individual Differences,* Vol. 18, No. 2, 1995, pp. 267–278.
22. Peltzer, K., and W. Renner. Superstition, Risk Taking and Risk Perception of Accidents Among South African Taxi Drivers. *Accident Analysis and Prevention,* Vol. 35, No. 4, 2003, pp. 619–623.
23. Reason, J., A. Manstead, S. Stradling, J. Baxter, and K. Campbell. Errors and Violations on the Roads: A Real Distinction? *Ergonomics,* Vol. 33, Nos. 10 & 11, 1990, pp. 1315–1332.
24. Lawton, R., D. Parker, A. S. R. Manstead, and S. G. Stradling. The Role of Affect in Predicting Social Behaviors: The Case of Road Traffic Violations. *Journal of Applied Social Psychology,* Vol. 27, No. 14, 1997, pp. 1258–1276.
25. Lajunen T., D. Parker, and H. Summala. The Manchester Driver Behavior Questionnaire: A Cross-Cultural Study. *Accident Analysis and Prevention,* Vol. 36, No. 2, 2004, pp. 231–238.
26. Åberg, L., and P. A. Rimmö. Dimensions of Aberrant Driver Behavior. *Ergonomics,* Vol. 41, No. 1, 1998, pp. 39–56.
27. Kontogiannis, T., Z. Kossiavelou, and N. Marmaras. Self-reports of Aberrant Behavior on the Roads: Errors and Violations in a Sample of Greek Drivers. *Accident Analysis and Prevention,* Vol. 34, No. 3, 2002, pp. 381–399.
28. Xie, C. Q., and D. Parker. A Social Psychological Approach to Driving Violations in Two Chinese Cities. *Transportation Research Part F,* Vol. 5, No. 4, 2002, pp. 293–308.
29. Iversen, H., and T. Rundmo. Attitudes Towards Traffic Safety, Driving Behavior and Accident Involvement Among the Norwegian Public. *Ergonomics,* Vol. 47, No. 5, 2004, pp. 555–572.
30. Iversen, H. Risk-Taking Attitudes and Risky Driving Behavior. *Transportation Research Part F,* Vol. 7, No. 3, 2004, pp. 135–150.
31. Ajzen, I., and M. Fishbein. *Understanding Attitudes and Predicting Social Behavior.* Prentice Hall, Englewood Cliffs, N.J., 1980.
32. Ajzen, I. The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes,* Vol. 50, No. 2, 1991, pp. 179–211.
33. Bentler, P. M., and G. Speckart. Models of Attitude–Behavior Relations. *Psychological Review,* Vol. 86, No. 5, 1979, pp. 452–464.
34. Cohn, L. D., S. Macfarlane, C. Yanez, and W. K. Imai. Risk-Perception: Differences Between Adolescents and Adults. *Health Psychology,* Vol. 14, No. 3, 1995, pp. 217–222.
35. Horvath, P., and M. Zuckerman. Sensation Seeking, Risk Appraisal, and Risky Behavior. *Personality and Individual Differences,* Vol. 14, No. 1, 1992, pp. 41–52.
36. Huang, H., and H. C. Chin. Disaggregate Propensity Study of Red Light Running Crashes Using Quasi-Induced Exposure Method. *ASCE Journal of Transportation Engineering,* Vol. 135, No. 3, 2009, pp. 104–111.
37. Cronbach, L. J. Coefficient Alpha and the Internal Structure of Tests. *Psychometrica,* Vol. 16, No. 3, 1951, pp. 297–334.
38. Nunnally, J. *Psychometric Theory,* 2nd ed. McGraw-Hill, New York, 1978.
39. Sahai, H., and M. Ageel. *The Analysis of Variance: Fixed, Random, and Mixed Models.* Birkhäuser Press, Boston, Mass., 2000.
40. Agresti, A. *Logistic Regression, Categorical Data Analysis,* 2nd ed. John Wiley & Sons, Inc., Hoboken, N.J., 2002.
41. Jöreskog, K. G., and D. Sörbom. *LISREL 8.7 for Windows: Structural Equation Modeling with the SIMPLIS Command Language.* Scientific Software International, Lincolnwood, Ill., 2004.
42. Sjöberg, L., B. E. Moen, and T. Rundmo. *Explaining Risk Perception: An Evaluation of the Psychometric Paradigm in Risk Perception Research.* Report 84. Norwegian University of Science and Technology, Trondheim, Norway, 2004.
43. Hu, L., and P. M. Bentler. Evaluating Model Fit. In *Structural Equation Modeling: Concepts, Issues and Applications* (R. H. Hoyle, ed.), Sage Publications, London, 1995.
44. Sullman, M. J. M., M. L. Meadows, and K. B. Pajo. Aberrant Driving Behaviors Amongst New Zealand Truck Drivers. *Transportation Research Part F,* Vol. 5, No. 3, 2002, pp. 217–232.
45. Koh, D., C. N. Ong, and W. O. Phoon. A Psychophysiological Profile of Taxi Drivers in Singapore. *Journal of Human Ergology,* Vol. 15, No. 2, 1986, pp. 147–154.
46. Lourens, P. F., J. A. Vissers, and M. Jessurum. Annual Mileage, Driving Violations, and Accident Involvement in Relation to Drivers' Sex, Age, and Level of Education. *Accident Analysis & Prevention,* Vol. 31, No. 5, 1999, pp. 593–597.
47. McKenna, F. P., and M. S. Horswill. Risk Taking from the Participants' Perspective: The Case of Driving and Accident Risk. *Health Psychology,* Vol. 25, No. 2, 2006, pp. 163–170.
48. West, R., D. French, R. Kemp, and J. Lander. Direct Observation of Driving, Self Reports of Driving Behavior and Accident Involvement. *Ergonomics,* Vol. 36, No. 5, 1993b, pp. 557–567.
49. West, R. *Accident Script Analysis.* TRL Report 274. Transport Research Laboratory, Wokingham, Berkshire, United Kingdom, 1997.

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