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Development of Self-Assessment Indicators for Motorcycle Riders in Thailand: Application of the Motorcycle Rider Behavior Questionnaire (MRBQ)

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Received: 28 February 2020; Accepted: 31 March 2020; Published: 1 April 2020

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Abstract: The purposes of this research are (1) to create a motorcycle riding behavior measurement model for a Thai population by Motorcycle Rider Behavior Questionnaire (MRBQ) modification with exploratory factor analysis (EFA); (2) to verify the measurement model by second-order confirmatory factor analysis (second-order CFA); and (3) to define the guidelines of the self-assessment report for Thai people in terms of riding motorcycles. Collected data were distributed among four areas: metro-municipalities, municipalities, district municipalities, and non-municipalities from five regions. The sample consisted of 1516 motorcycle riders who were at least 20 years old. Of these riders, 91.4% had motorcycle riding licenses, 84.4% had over five years of experience in motorcycle riding, 75.5% used a motorcycle to go to work/study, and 82.1% used a helmet sometimes. Exploratory factor analysis (EFA) and second-order confirmatory factor analysis (second-order CFA) were used for measurement model creation. The results presented 26 indicators that were confirmed to compose the motorcycle riding behavior of Thai people at a statistical significance level of $\alpha = 0.05$; these were separated into four factors, namely, traffic error, control error, stunts, and safety equipment. The results of this MRBQ study can inform future study of the motorcycle riding behavior of Thai people.

Keywords: Motorcycle Rider Behavior Questionnaire (MRBQ); exploratory factor analysis (EFA); second-order confirmatory factor analysis (second-order CFA); self-report assessment

1. Introduction

Following Africa, the Southeast Asia region has the second-highest death rate from road accidents at a rate of 20.7 people per 100,000. Comparing all vehicles, 43% of accidents involve motorized two- and three-wheelers, and 74% of motorized accidents happened in Thailand. In the study of factors influencing rider behavior, the Motorcycle Rider Behavior Questionnaire (MRBQ) has been widely utilized to analyze motorcycle riding behavior and specify risky behavior that leads to accidents. The purpose of this research is to create a motorcycle riding behavior measurement model for a Thai population by MRBQ modification with exploratory factor analysis (EFA), to verify the measurement model by second-order confirmatory factor analysis (second-order CFA), and to define guidelines for a self-assessment report for a Thai population in terms of riding motorcycles.

Firstly, the background and importance of this research will be reviewed, and the research objectives are stated in Section 1.3. The procedure, materials, and participants are presented in Section 2. The results of the study, including statistical test values (reliability, correlation, and model estimates), are presented in Section 3. We discuss the research in Section 4. Finally, Section 5 concludes the paper, explains the limitations of the research, and proposes future work.

The contributions of this research can be used for the creation of a riding self-assessment report. The assessment process should be organized before the enrolment or renewal process of obtaining a motorcycle riding license. The self-assessment results can indicate the risky riding behavior levels of examinees. The related organization can primarily classify the behavior of riders and assign different intensive courses to let them realize risky behavior perception and improve riding habits.

1.1. Motorcycle Accident Situation

The WHO reported that 1.35 million people died from road accidents in 2016, a rate of 18.2 per 100,000 people. The highest death rate was for people aged between 5 and 29 years old. Considering geographical regions, the Southeast Asia region had the second-highest death rate from road accidents at a ratio of 20.7 per 100,000 people, following only Africa at a ratio of 26.6 per 100,000. Of these accidents, 43% involved motorized two- and three-wheelers [1]. Moreover, the WHO stated that Thailand had the highest death rate in the WHO Southeast Asia Region countries at 36.2 per 100,000 people, followed by the Democratic People's Republic of Korea at 20.80, Myanmar at 20.30, and Sri Lanka at 17.40 (Figure 1).

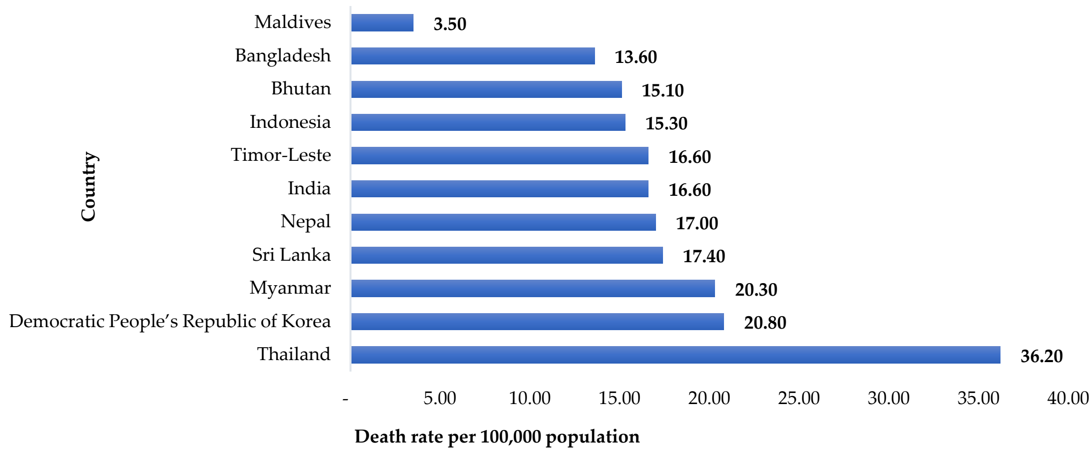

Figure 1. Ranking of rates of deaths in road accidents per 100,000 people. Source: WHO [1,2].

The WHO [1] also present Thai road accident death rates by road user category (Figure 2). These include Thai citizens who were riders of motorized two- and three-wheelers (74%), pedestrians (8%), passengers of four-wheeled cars and light vehicles (6%), and drivers of four-wheeled cars and light vehicles (6%).

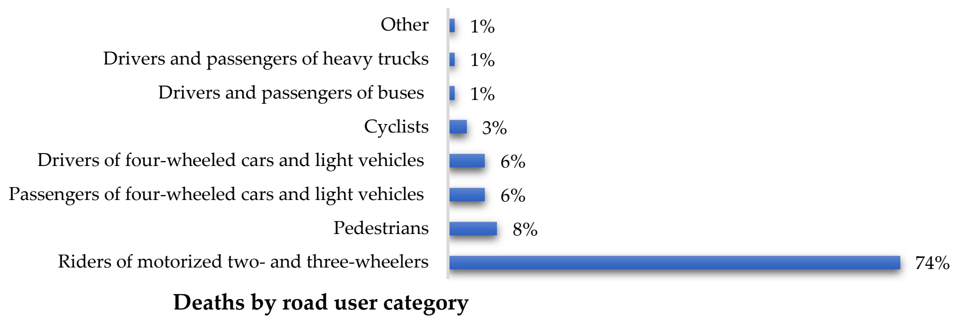

Figure 2. Road traffic accidents in Thailand. Source: WHO [1].

A worldwide status report shows that motorcycle accidents are the most serious accidents in Thailand. In 2019, the Department of Land Transport [3] reported that there were 21,222,053 registered motorcycles, comprising 53.87% of all vehicles, while car driving license holders made up 29.72%. Furthermore, there were 13,449,697 (39.88% of registered motorcycles) motorcycle riding license holders, including 1,144,168 temporary one-year licenses (8.51%), 6,339,641 five-year licenses (47.14%), and 6,339,641 lifelong licenses (44.36%). The Royal Thai Police [4] reported that 32,040, 33,138, and 40,431 motorcycle accidents occurred in the three years 2017, 2018, and 2019, respectively. The accident rate in 2019 increased from those in 2018 (by 22%) and 2017 (by 26%).

The above cumulative registered vehicles and driving license holder statistics show that Thai citizens mainly use motorcycles for traveling, and also show that motorcycles have the highest accident rate compared to other vehicles. Therefore, research into the use of motorcycles by Thai people and the aspects related to motorcycle accidents is a worthwhile area of research.

The causes of road accidents include humans, vehicles, and the environment. The human factor is the major factor in accidents [5,6]. The Royal Thai Police [7] state that the main causes of road accidents are the road user (65%), traffic signs/traffic lights (27%), the environment (2%), and other (6%). As cited in Evans [8], Shinar [6] states that human factors influence up to 95% of accidents, while road environment factors and vehicle factors influence 28% and 8%, respectively, as shown in Figure 3. Therefore, we focus on human factors in this research and aim to study the behaviors of motorcycle riders.

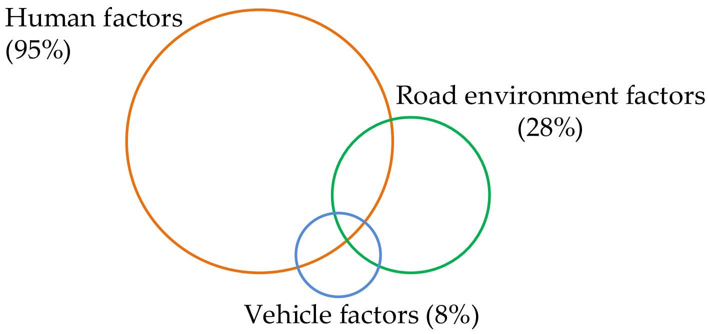

Figure 3. Factors related to road accidents. Source: Evans [8], Shinar [6].

1.2. Studies on Human Factors of Riding Behaviors

There are many factors related to riding behavior and accidents, and the studies concerning them are summarized in Table 1. Elliott et al. [9] were the first to study and develop the Motorcycle Rider Behavior Questionnaire (MRBQ) in order to determine factors influencing rider behavior. They used principal component analysis (PCA) to classify a model of factors that include traffic errors, control errors, speed violations, performance of stunts, and use of safety equipment. In total, there are 43 measurement items. Then, linear modeling was used, considering age, experience, mileage, and time duration of driving. This preliminary study found that traffic errors, control errors, and speed violations are factors that can predict the risk of an accident.

Table 1. Summary of motorcycle driving behavior from related research works.

Author	Method	Speeding Violations	Traffic Errors	Control Errors	Stunts	Safety Equipment	Demographics	Alcohol
Elliott et al. [9]	Principal component analysis (PCA), linear modeling	√	√	√	√	√	√	-
Özkan et al. [10]	descriptive statistics, regression, PCA, theory of planned behavior (TPB), health belief model (HBM), locus of control (LC)	√	√	√	√	√	√	-
Sakashita et al. [11]	Exploratory factor analysis (EFA), confirmatory factor analysis (CFA), possion regression	√	√	√	√	√	√	√
Stephens et al. [12]	Descriptive statistics, EFA	√	√	√	√	√	√	-
Lin and Kraus [13]	Haddon's matrix	√	-	-	-	-	√	√
Hongsranagon et al. [14]	Descriptive statistics	√	-	-	-	-	√	√
Stephan et al. [15]	Descriptive statistics, distribution, frequency	-	-	-	-	-	√	√
Vlahogianni et al. [16]	Reviews	√	√	√	√	√	√	√
Moskal et al. [17]	Descriptive statistics	-	-	-	-	-	√	√
Sukor et al. [18]	Quantitative analysis, structural equation modeling (SEM)	√	-	-	-	√	√	-
Keall and Newstead [19]	Descriptive statistics, logistic model	-	-	-	-	-	√	-
Chung and Wong [20]	Multi-group, path analysis	-	-	√	-	-	√	-
Kankrong Piyaprai [21]	Descriptive statistics, TPB	√	-	√	√	-	√	√
de Rome et al. [22]	Descriptive statistics	-	-	-	-	-	√	-
This research	EFA, second-order CFA	√	√	√	√	√	√	-

Further studies have also used the MRBQ. For example, Özkan et al. [10] implemented the MRBQ for Turkish citizens considering traffic errors, control errors, speed violations, performance of stunts, and use of safety equipment. The study found that annual mileage was highly correlated with rider accidents in the case of active and passive accidents and offenses, while rider age had a lower correlation. The stunt factor was the main factor in accidents and offenses, while speeding violations were the major factor in traffic violations. Sakashita et al. [11] implemented the MBRQ with a group of new drivers in Australia. To fit the sample group, confirmatory factor analysis (CFA) was used; the factors with factor adjustment became control errors, speeding violations, stunts, and protective gear. Another study by Stephens et al. [12] studied the correlation between MBRQ and accidents in Australia. The study found that drivers used safety equipment and refrained from risky behaviors. Although speeding violations and control errors did not frequently happen, they were correlated with the possibility of accidents. Moreover, behavior related to stunts increased the risk of accident.

There are several studies that evaluate accident risk with methods beyond the MRBQ. Lin and Kraus [13] studied factors including alcohol consumption, lack of riding experience, turning on the front light during daytime, riding license, speed, and risky motorcycle riding behavior and their relationship to injury. A study by Hongsranagon et al. [14] found that 33.8% of respondents had experienced an accident. The major factors were human behavior, e.g., safety law violation (76.8%) or drunk driving (65.0%). Stephan et al. [15] studied a group of young men aged between 15 and 19 years old who had engaged in drunk driving behavior. Vlahogianni et al. [16] concluded that risky behavior includes rider attitude, riding style, rider mistakes, traffic law violations, rider indecision, gender, age, experience, education, fatigue, alcohol, and additional safety equipment. A study by Moskal et al. [17] found that being male, not wearing a helmet, being aged between 14–20 years, alcohol level in the blood, and travel objective (to study/to work) are factors that increase a rider's risk of accidents. Sukor et al. [18] considered the influence of speeding violations and non-helmet-wearing on accidents involving motorcycle riders in Malaysia; psychological factors were found to effect risky behaviors, speeding, and helmet wearing behaviors.

Keall and Newstead [19] studied New Zealanders, among whom the use of motorcycles is increasingly popular, to address concerns about the increase in road accidents. The study found that motorcycle riders who are over 20 years old and live in urban areas have a risk of injury eight times higher than that for car drivers. Chung and Wong [20] studied a group of youths (18–28 years old) to examine and approximate the factors influencing risky behavior. The study found that expressions of anger affect risky riding behavior more in men than in women.

Finally, Kankrong Piyaprai [21] studied Thai teenagers and found that driving behavior in terms of breaking traffic laws, speeding violations, and chaotic riding put riders at the highest risk of accidents. De Rome et al. [22] studied the diversity of risk factors of motorcycle rider accidents relating to general information, namely, age, gender, types of riding license, occupation, education level, traveling behavior, number of riding hours per week, riding experience, traffic law violations in the past three years, near misses in the past one year and three years, and the use of additional safety equipment. The study results showed that this basic information on motorcycle riders can be utilized as a development and improvement guideline for different age groups of motorcycle riders. These studies are summarized in Table 1.

1.3. Research Objectives and Contributions

The above discussion has highlighted the need for research into motorcycle use in Thailand. Previous research has appropriately applied the MBRQ in the context of various geographical areas and study samples. However, there has so far been no research focused on a self-assessment prototype based on variables, indicators, or factors including a case study in Thailand, which has the world's top motorcycle accident rate, or measurement model analysis with second-ordered CFA.

The objectives of this research were (1) to create a motorcycle riding behavior measurement model for a Thai population by modifying the MRBQ with exploratory factor analysis (EFA); (2) to verify the measurement model via second-order confirmatory factor analysis (second-order CFA); and (3) to define the guidelines for a self-assessment report for Thai people in terms of riding motorcycles. Thus, our research questions are as follows: (1) Which indicators can be measured by MRBQ? (2) Which question items have a high loading factor and can be utilized in a prototype self-assessment report for motorcycle riders in Thailand? Lastly, we have defined a hypothesis, H_1, for this research. H_1 states that MRBQ can be appropriately utilized to study the motorcycle riding behavior of Thai people.

2. Materials and Methods

2.1. Procedure

The procedure of the research involved studying previous research related to motorcycle riding behaviors. The MBRQ was utilized as a tool to study and collect the data. The item–objective congruence index (IOC) was studied via questionnaire by experts who were specialists in screening research tools. Human research ethics application documents were submitted, and the ethics evaluation result was that the study was of low risk. Data were collected from across the country. The collected data were verified as following a normal distribution. We utilized exploratory factor analysis (EFA) to filter observed variables of the same group and eliminate some factors to fit with the model. Second-order confirmatory factor analysis (second-order CFA) was utilized to create a model confirming motorcycle riding behavior measurement in order to select variables and factors that could be used in a self-assessment report, as shown in Figure 4.

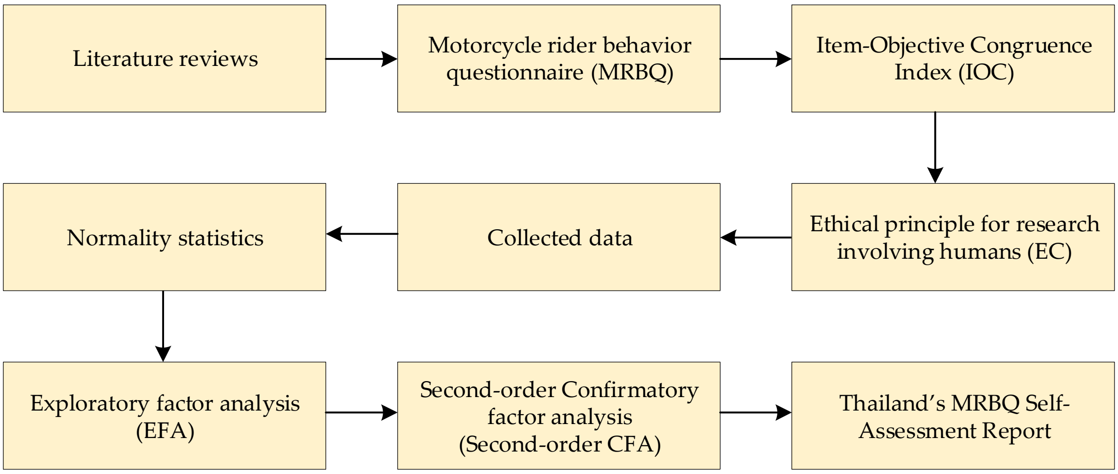

Figure 4. Research processing.

2.2. Materials and Participants

2.2.1. The Motorcycle Rider Behavior Questionnaire (MRBQ)

The Motorcycle Rider Behavior Questionnaire (MRBQ) was studied and created as a frequency evaluation report of motorcycle riding by Elliott et al. [9]. They developed the MRBQ based on the Driver Behavior Questionnaire (DBQ) by Reason et al. [23]. Elliott et al. [9] developed 43 MRBQ indicators, each with a 6-point scale (1 = never, 2 = sometimes, 3 = often, 4 = always, 5 = nearly all the time, 6 = all the time), and let questionnaire respondents select one answer per question item. Rider behaviors were measured in terms of five measurement factors, namely, traffic errors, speed violations, stunts, safety equipment, and control errors.

Traffic errors were the main factor in mistakes or wrong decisions made during motorcycle riding, with 13 indicators. Behaviors of riding over the speed limit were "speed violations", with 12 indicators. Moreover, thrill-seeking riding behaviors were defined by the factor of "stunts", with 7 indicators. The use of safety equipment to increase safety while riding formed the variable "safety equipment", with 8 indicators. Finally, "control errors" represented errors in vehicle control and slipping, with 7 indicators [9].

Furthermore, personal information was requested in the questionnaire, including gender, age, motorcycle riding license holding, type of motorcycle riding license, motorcycle riding experience, helmet wearing behavior, and purpose and frequency of riding.

2.2.2. Participants

The appropriate number of samples needed to analyze a model was presented by Golob [24] and is n = 15 times the number of observed indicators [25]. The MBRQ was used for collecting and surveying data with 38 observed indicators after the IOC process. Therefore, the number of samples had to be higher than 570 to be sufficient.

The samples in this research numbered 1516, collected from all parts of Thailand; this is enough for analysis according to the recommendation. The samples were distributed between four areas, which were metro-municipality, municipality, district municipality, and non-municipality areas, providing 268, 442, 587, and 219 samples, respectively. These were also from five regions, namely, the Bangkok metropolitan region, central region, northeastern region, north region, and south region, as shown in Table 2. Respondents were those above 20 years old with motorcycle riding ability and experience who did or did not have a riding license.

Table 2. The number of samples from each zone.

Address Zone	City/Municipal	Municipality	Municipal District	Outside the Municipality	Total
Bangkok Metropolis	59	80	99	63	301
Central	52	174	62	13	301
Northeastern	18	69	175	52	314
Northern	54	32	128	86	300
Southern	85	87	123	5	300
Total	268	442	587	219	1516

2.2.3. Sample Characteristics

The general data of the respondents are shown in Table 3. The respondents were males (59.6%) and females (40.4%) older than 20 years old. Most of them (39.2%) were 25–34 years old. Of the respondents, 91.4% had a motorcycle riding license while 8.6% did not. For the motorcycle riding license group, 70.3% had a five-year temporary license, 26.3% had 6–10 years of riding experience, and 24.7% had over 20 years of riding experience. For frequency of riding, 36.5% reported 4–6 days a week, while 35% reported riding every day. In terms of helmet wearing behavior, 61.3% responded with "often", while 20.8% responded "sometimes". The purpose of riding a motorcycle was to attend study/work for 75.5% of the respondents.

Table 3. Sample characteristics; n = 1516.

Personal Data	Quantity (Percentage)
Gender	
Male	903 (59.6)
Female	613 (40.4)
Age	
20–24 years old	201 (13.3)
25–34 years old	594 (39.2)
35–44 years old	427 (28.2)
45–54 years old	254 (16.8)
55–64 years old	33 (2.2)
>65 yearsold	7 (0.5)
Licensed rider	
Yes	1385 (91.4)
No	131 (8.6)
Type of rider license	
Temporary driving license (1 year)	94 (6.2)
Driving license (5 years)	1065 (70.3)
Permanent driving license	227 (15.0)
Riding experience	
0–5 years	237 (15.6)
6–10 years	399 (26.3)
11–15 years	302 (19.9)
16–20 years	204 (13.5)
>20 years	374 (24.7)
Riding frequency	
Everyday	531 (35.0)
4–6 days/week	554 (36.5)
1–3 days/week	431 (28.4)
Helmet wearing behavior	
Always	271 (17.9)
Often	929 (61.3)
Sometimes	316 (20.8)
Riding objective	
School/work	1144 (75.5)
Travel	159 (10.5)
Shopping	213 (14.1)

2.2.4. Hypothesis Testing

Regarding the hypothesis, H_1, of this research, the MRBQ was appropriately utilized to study the motorcycle riding behavior of Thai people from the 43 MRBQ indicators developed by Elliott et al. [9].

The hypothesis was tested using the following criteria of goodness-of-fit statistics: value of chi-square/df of <5 (Hu and Bentler [26]), root mean square error (RMSEA) of <0.08 [27,28], standardized root mean square residual (SRMR) of <0.08 [26], comparative fit index (CFI) of ≥0.90 [26], and Tucker–Lewis index (TLI) of ≥0.80 [29,30].

3. Results

3.1. Normality and Correlation

After the IOC process, 38 MBRQ indicators remained to collect data. EFA data analysis was utilized in factor analysis of the 38 observed indicators for the indicator grouping process. We considered only factors with a loading factor of ≥0.3 [31]. There were 26 such indicators for the measurement model analysis process. The Kaiser–Meyer–Olkin (KMO) statistic was 0.886, which was appropriate for factor analysis [32]. Indicators were grouped and separated into four groups: traffic errors (X1–X11), control errors (X12–X20), stunts (X21–X23), and safety equipment (X24–X26). These are shown in Table 4.

Table 4. Statistical analysis of normal distribution; n = 1516, KMO = 0.886.

Indicators	Questions	Mean	SD	Skewness	Kurtosis	Exploratory Factor Analysis (EFA) Factor Score			
						Traffic Errors	Control Errors	Stunts	Safety Equipment
Traffic errors	Cronbach 's α = 0.925								
X1	Turning into a side street from a main road without being wary of any pedestrians.	1.91	0.742	0.308	−0.649	0.742			
X2	Failing to notice a car from behind a parked vehicle until it is nearly too late.	1.88	0.676	0.412	0.124	0.702			
X3	Not stopping the motorcycle at zebra crossings to let pedestrians cross the road.	1.77	0.744	0.403	−1.107	0.795			
X4	Turning left into a main road without reducing speed and not noticing other vehicles.	1.99	0.736	0.266	−0.460	0.584			
X5	Ignoring the "GIVE WAY" sign when driving on narrow roads and not letting a driver from the other lane proceed.	1.92	0.845	0.328	−1.098	0.828			
X6	Overtaking without giving a signal in advance.	1.85	0.724	0.591	0.209	0.713			
X7	If there are no cars on the road, you continue to go straight while ignoring red traffic lights.	1.75	0.707	0.477	−0.619	0.800			
X8	Getting involved in unofficial "races" starting from traffic light junctions.	1.53	0.641	0.893	0.139	0.714			
X9	Overtaking in an overtaking-prohibited area.	2.11	0.730	−0.023	−0.803	0.582			
X10	Driving against the lane direction or the wrong way on a one-way street.	1.85	0.709	0.228	−0.998	0.670			
X11	Violating red traffic lights.	1.89	0.757	0.193	−1.237	0.704			
Control errors	Cronbach 's α = 0.887								
X12	Riding without caution about any vehicle pulling out in front of you and having difficulty stopping.	2.30	0.747	0.067	−0.364		0.692		
X13	When the vehicle ahead slows down or stops, you realize that you should stop your motorcycle immediately.	2.25	0.732	0.217	−0.164		0.722		
X14	Riding too close to the car in front. If there is an emergency, it will be difficult to stop.	2.21	0.688	−0.031	−0.438		0.814		
X15	Riding too fast into a corner or junction.	2.39	0.744	−0.056	−0.381		0.642		

Table 4. *Cont.*

X16	Failing to control the motorcycle when using high speed.	2.22	0.711	−0.006	−0.457		0.591		
X17	Braking too quickly on a slippery road.	2.25	0.804	0.000	−0.694		0.467		
X18	Having trouble with your visor or goggles fogging up.	2.29	0.663	−0.009	−0.274		0.721		
X19	Parking your motorcycle in a prohibited area.	2.18	0.846	−0.122	−1.178		0.580		
X20	Breaking speed limits at late night or early morning.	2.30	0.708	−0.050	−0.386		0.654		
Stunts	Cronbach ′s α = 0.747								
X21	Pulling away too quickly and your front wheel lifts off the road.	1.12	0.343	2.774	7.107			0.775	
X22	Purposely doing a wheel spin.	1.29	0.649	1.994	2.335			0.841	
X23	Cutting other vehicles off/overtaking at close range.	1.58	0.900	1.588	1.971			0.742	
Safety equipment	Cronbach ′s α = 0.831								
X24	Wearing motorcycle riding boots/protective trousers or jacket when riding.	1.74	0.953	1.501	2.572				0.869
X25	Wearing a protective riding suit for body, elbow, and shoulder protection.	1.62	0.875	1.331	1.227				0.695
X26	Wearing motorcycle gloves.	1.96	1.095	1.103	0.748				0.839

The results of statistical testing of the indicators show that the mean was 1.12–2.59, the standard deviation (SD) was between 0.343 and 1.095, skewness was between 0.000 and 2.774, and kurtosis was between −1.237 and 7.107. The skewness and kurtosis were lower than 3 and 10, respectively [33], as shown in Table 4.

The correlation of variables, after correlation testing at a p-value of <0.01, was between 0.297 and 0.624. The correlation values between traffic errors and control errors, stunts, and safety equipment were 0.624, 0.364, and 0.297, respectively. The correlation values of control errors with stunts and safety equipment were 0.386 and 0.290, respectively. Furthermore, the correlation value between stunts and safety equipment was 0.474, as shown in Table 5.

Table 5. Factor correlation analysis results in terms of correlation value.

Factors	Traffic Errors	Control Errors	Stunts	Safety Equipment
Traffic errors	1.00			
Control errors	0.624 **	1.00		
Stunts	0.364 **	0.386 **	1.00	
Safety equipment	0.297 **	0.290 **	0.474 **	1.00

** Significant at the 0.01 level (two-tailed).

3.2. Reliability

We tested the accuracy of indicators using Cronbach's alpha, which must be greater than or equal to 0.7 to indicate reliability [34]. The analysis results showed that traffic errors, control errors, stunts, and safety equipment had Cronbach's alpha values of 0.925, 0.887, 0.747, and 0.831, respectively, which met the criterion defined by Nunnally [34], as shown in Table 6.

The composite reliability index (CRI), as a measure of the internal consistency construct, and average variance extracted (AVE) values were analyzed for each factor with criteria of CRI ≥ 0.7 and AVE ≥ 0.5 [35]. The analysis results showed that the CRI values from traffic errors, control errors, stunts, and safety equipment were 0.922, 0.897, 0.731, and 0.706, respectively. The AVE values from traffic errors, control errors, stunts, and safety equipment were 0.716, 0.666, 0.733, and 0.662, respectively. All CRI and AVE values met the analysis criteria, as shown in Table 6.

Table 6. Results of second-order confirmatory factor analysis.

Indicators	Cronbach's α	Second-Order CFA				CRI	AVE
		Est.	Est./S.E.	p-Value	R^2		
Traffic errors		0.538	22.200	<0.001 **	0.290		
X1		0.629	38.335	<0.001 **			
X2		0.651	41.143	<0.001 **			
X3		0.759	62.027	<0.001 **			
X4		0.701	50.708	<0.001 **			
X5		0.836	95.812	<0.001 **			
X6	0.925	0.795	76.637	<0.001 **		0.922	0.716
X7		0.804	79.278	<0.001 **			
X8		0.565	32.211	<0.001 **			
X9		0.604	35.624	<0.001 **			
X10		0.740	58.965	<0.001 **			
X11		0.796	75.395	<0.001 **			
Control errors		0.584	24.032	<0.001 **	0.341		
X12		0.646	38.307	<0.001 **			
X13		0.622	36.391	<0.001 **			
X14		0.640	40.151	<0.001 **			
X15		0.674	44.594	<0.001 **			
X16	0.887	0.829	73.353	<0.001 **		0.879	0.666
X17		0.672	45.594	<0.001 **			
X18		0.572	30.304	<0.001 **			
X19		0.823	70.397	<0.001 **			
X20		0.512	24.541	<0.001 **			
Stunts		0.798	31.549	<0.001 **	0.639		
X21		0.558	25.244	<0.001 **			
X22	0.747	0.803	49.746	<0.001 **		0.731	0.733
X23		0.838	55.004	<0.001 **			
Safety equipment		0.824	30.796	<0.001 **	0.679		
X24		0.497	16.724	<0.001 **			
X25	0.831	0.774	56.816	<0.001 **		0.706	0.662
X26		0.716	57.452	<0.001 **			

Note: N = 1516. Standardized estimates and all CFA loadings are significant at α = 0.01; CRI, composite reliability index; AVE, average variance extracted; ** significant at 0.001 level.

3.3. Model Parameter Estimation

Confirmatory factor analysis (CFA) was used for the measurement of model creation. After the EFA analysis process, there were four factors (traffic errors, control errors, stunts, and safety equipment) for measuring motorcycle riding behavior with 26 indicators. Every indicator had a significance level of 0.01.

From the analysis results of H_2, the MRBQ can measure the motorcycle riding behavior of Thai people by second-order CFA. The top five indicators with the highest loading factors in terms of traffic errors were X5 "Ignoring the "GIVE WAY" sign when driving on narrow roads and not letting a driver from the other lane proceed", X7 "If no other cars are on the road, you continue to go straight without considering red traffic lights", X11 "Violating red traffic lights", X6 "Overtaking without giving a signal in advance", and X3 "Not stopping the motorcycle at zebra crossings to let pedestrians cross the road", with loading factors of 0.836, 0.804, 0.796, 0.795, and 0.759, respectively.

For control error factors, it was found that X16 and X19, "Failing to control the motorcycle when using high speed" and "Parking the motorcycle in prohibited area", had loading factors of 0.829 and 0.823, respectively. In terms of stunts, X23 "Cutting other vehicles off/overtaking at close range" and X22 "Purposely doing a wheel spin" had the highest loading factors at 0.838 and 0.803, respectively.

Among safety equipment factors, X25 "Wearing a protective riding suit for body, elbow, and shoulder protection" and X26 "Wearing motorcycle gloves" had the highest loading factors at 0.774 and 0.716, respectively, as shown in Table 6.

When creating measurement modes as second-order CFA to measure motorcycle riding behavior, the second-order CFA was created with the highest loading factors of 0.824 for safety equipment, 0.798 for stunts, 0.584 for control errors, and 0.538 for traffic errors. The R^2 values were 0.290, 0.341, 0.639, and 0.679, respectively.

The results of model measurement were chi-square = 873.345 and df = 182. Therefore, the goodness-of-fit statistics had values of chi-square/df = 4.79, which was lower than 5 (Hu and Bentler [26]). Furthermore, RMSEA = 0.050 (0.047–0.053) < 0.08 [27,28], SRMR = 0.041 < 0.08 [26], CFI = 0.973 ≥ 0.90 [26], and TLI = 0.952 ≥ 0.80 [29,30], which met the criteria, as shown in Figure 5.

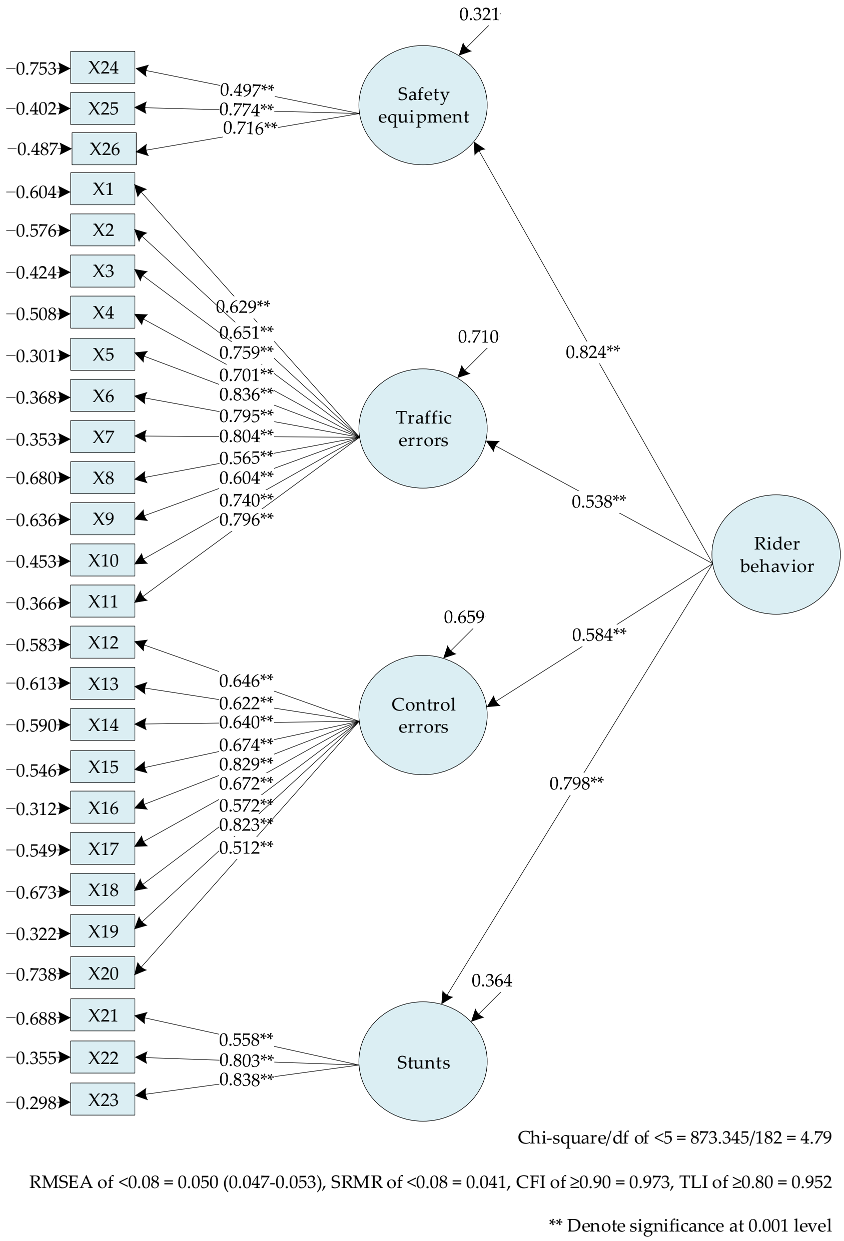

Figure 5. Second-order CFA.

The analysis of the model parameter estimation results show that, via the testing of hypothesis H_1, the MRBQ can be appropriately utilized to study the motorcycle riding behavior of a Thai population. The EFA analysis for variable grouping showed that the behaviors of Thai people can be grouped into four factors: traffic errors, control errors, stunts, and safety equipment. Speed violations were grouped with traffic errors. The goodness-of-fit model values of second-order CFA met all the criteria for hypothesis testing.

4. Discussion

In this study, we aimed to create a motorcycle riding behavior measurement model for a Thai population via modification of the MRBQ with exploratory factor analysis. We also aimed to verify the measurement model by second-order confirmatory factor analysis, which was used to verify measurement models in previous research by Elliott et al. [9], Özkan et al. [10], Sakashita et al. [11], Stephens et al. [12], and Vlahogianni et al. [11,16]. Furthermore, we aimed to define the guidelines of a self-assessment report for Thai people in terms of their motorcycle riding.

The MRBQ is a tool to study motorcycle riding behavior that was applied to Thai riders using 26 indicators (from the original 43 indicators) [9]. A factor analysis method was then used to analyze and separate the structures into four factors, which were traffic errors, control errors, stunts, and safety equipment; this was done according to Sakashita et al. [11], who studied novice riders. However, in this study, we collected data from experienced motorcycle riders (84.4% of respondents had more than five years of experience). In terms of previous research on factors, Özkan et al. [10] considered five factors: traffic errors, control errors, speed violations, stunts, and safety equipment. In this study, our factor results were similar to those found by Sakashita et al. [11]. However, there were different factors in our research, such as speed violations [11] and traffic errors. The highest-loading-value indicators were X5, X7, X11, X6, and X3 from the traffic error factor, X16 and X19 from the control error factor, X23 and X22 from the stunts factor, and X25 and X26 from the safety equipment factor.

When considering factors, we found that safety equipment had the highest loading factor value; this factor comprised indicators related to additional safety equipment, e.g., gloves and impact protection kit. Helmet wearing was not included in the measurement model because it was eliminated during the EFA analysis process. The personal information regarding helmets indicated that 17.9% of respondents always wear a helmet when riding a motorcycle, which is a very low value (Table 2).

For the stunts factor, we found that Thai respondents reported motorcycle riding behaviors of "cutting other vehicles off/overtaking at close range", and "purposely doing a wheel spin". In terms of control error factors, they reported "failing to control the motorcycle when using high speed" and "parking the motorcycle in a prohibited area", especially in the downtown zone where there are fewer parking areas for motorcycles compared with other vehicles. Riders park their motorcycles carelessly, which causes traffic jam problems.

Finally, among traffic errors combined with speed violations, the behaviors of "ignoring the 'GIVE WAY' sign when driving on narrow roads and not letting a driver from the other lane proceed" and "if there are no cars on the road, you continue to go straight without considering red traffic lights" were frequently reported by motorcycle riders. Because of the mobility advantages of motorcycles, riders can overtake other vehicles to reach the front area of an intersection when traffic jams. At the traffic light junction, they usually pause their motorcycles in front of the pausing area and drive through red traffic lights if there are not any vehicles around the junction. Most of the accidents at traffic light junctions happen between motorcycles and other vehicles.

5. Conclusions, Limitations, and Future Work

In this study, we aimed to test and apply tools based on the MRBQ, from its 43 original questions, to measure the motorcycle riding behavior of Thai people. This research showed that the measurement model that was appropriate for Thai riders comprised 26 indicators from four factors. The results of this study were utilized to create a riding self-assessment report, which was the defined objective of the research. The assessment was organized before enrolment or renewal of a motorcycle riding license. The self-assessment report let riders perceive the risk level of their own riding behavior. Furthermore, organizations related to screening riding behaviors can match the different intensity levels of training courses to riders in order to provide risk awareness of their riding behaviors and improve riding behaviors using the MRBQ [9]. The data collection and analysis of this model were based on a 6-point scale. We have not yet defined what scores of the self-assessment report match with risk levels; this is our future objective in order to utilize the research in a real situation.

Future works will evaluate the risk levels of indicators. We will analyze factors and indicators from the measurement model in terms of structural equation modeling (SEM) to find factors affecting motorcycle riding behavior and define a sustainable solution guideline for problems that occur due to human factors.

The limitation of this research was that it did not include those younger than 20 years old. Data were not collected from this group. Thailand allows 15-year-old applicants to enroll for a motorcycle riding license, and there are many motorcycle riders who are younger than 15 years old, especially in rural areas. The obstacle to collecting data from those under 20 years old is the associated human research ethics requirements, as they are a vulnerable population. Respondents have to get permission from their parents before responding to our questionnaire, which makes it difficult to collect data. Thus, we had no data from teenagers. If we could also collect data from teenagers, the analysis results may differ from those presented in this research.

Author Contributions: Conceptualization, S.J.; data curation, S.U.; formal analysis, S.J. and S.U.; funding acquisition, S.J.; methodology, S.J. and D.W.; supervision, V.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Suranaree University of Technology Research and Development Fund, Grant number IRD7-704-62-12-07, and the APC was funded by Suranaree University of Technology.

Acknowledgments: The authors would like to thank the Suranaree University of Technology Research and Development Fund.

Conflicts of Interest: The authors declare no conflict of interest.

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