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THE SERVICE QUALITY OF ROADS IN TAIWAN FROM THE POINT OF VIEW OF ROAD USERS AND DRIVERS

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Key words: road service quality, road user, car driver, motorcycle driver, analytic hierarchy process (AHP), structural equation modeling (SEM).

ABSTRACT

This study uses an analytic hierarchy process (AHP) and structural equation modeling (SEM) to explore how respondents without engineering backgrounds view the road service quality in Taiwan. First, a first-stage questionnaire is conducted in Taiwan's Taoyuan County to develop an "Assessment Framework of Road Service Quality from the Point of View of Road Users". The framework is used to assess the views of road users on road service quality. A second-stage questionnaire measures the priority placed by road users on the different aspects and assessment items of road service quality. The AHP results show that road users are most concerned about "road safety", followed by "road surface". In addition, as car and motorcycle drivers have a more direct perception of road service quality, the study develops a separate "Assessment Frameworks of Road Service Quality from the Point of View of Car and Motorcycle Drivers" for car and motorcycle drivers in Hsinchu County, Taiwan. According to the SEM results, car and motorcycle drivers have the highest concern about "road damage and smoothness" and "driving space", respectively. The findings of this study can be a reference for road authorities and road engineers when monitoring and managing road service quality.

I. INTRODUCTION

The total highway length in Taiwan has grown from 15,040 km in 1966 to 21,856 km in 2012 (not including 20,198 km of urban road). Road density (km/km^2) increased from 0.791 in 1991 to 1.168 by the end of 2012. The road network has already reached a high level of coverage and convenience (Directorate General of Highways Taiwan, 2013; MOTC Taiwan, 2013). The construction of new roads reached a peak in the 1990s, with an average of 496.82 km of new road built per year between 1991 and 2001, before the beginning of a decline. This reveals that the possibilities for future expansion of the road network are extremely limited. Furthermore, between 2008 and 2011, the number of confirmed state compensations and the total amounts paid due to poor road maintenance and management were 91 cases (US$722,400) in 2008, 68 cases (US$795,000) in 2009, 77 cases (US$983,600) in 2010, and 47 cases (US$524,600) in 2011. The three leading causes for state compensation are road construction, potholes or depressions on pavements, and manhole covers, indicating that problems with roads often result in damage to well-being and property. Therefore, road maintenance and management have become a vital task for all levels of governments, which have implemented various strategies (such as the Smooth Roads Project (PCC Taiwan, 2013)) to ensure smooth, safe, and unobstructed roads. Even so, the general public has a number of criticisms and expectations for improvements in current road service quality, which could directly affect citizen satisfaction with the government. Therefore, it is important to percept the road users' concern.

Road service quality is generally assessed by road engineers based on their professional expertise (Shah et al., 2013). Research to seek the general public assessment on road service quality is rare. This study, directed at respondents without engineering backgrounds, uses an analytic hierarchy process (AHP) to develop a project, "Assessment Framework of Road Service Quality from the Point of View of Road Users", to assess the views of road users on road service quality. For car and motorcycle drivers, this study develops a separate "Assessment Frameworks of Road Service Quality from the Point of View of Car and Motorcycle Drivers", using structural equation modeling (SEM) to understand which aspects and assessment items of road service quality are of most concern to car and motorcycle drivers. The results of this study can provide a reference for road authorities and road engineers when monitoring and managing road service quality.

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This article is organized as follows: the second section reviews the literature related to AHP and SEM; the third section develops the "Assessment Framework of Road Service Quality from the Point of View of Road Users" and uses AHP to assess the views of road users on road service quality; the fourth section develops the separate "Assessment Frameworks of Road Service Quality from the Point of View of Car and Motorcycle Drivers" and uses SEM to understand which aspects and assessment items of road service quality are of most concern to car and motorcycle drivers; and the fifth section compares the differences in these frameworks and presents further discussion.

II. LITERATURE REVIEW

1. Analytic Hierarchy Process (AHP)

AHP is a multi-criteria decision making (MCDM) method that provides a hierarchical structure to combine the intuitive rational and irrational values with a pairwise comparison approach (Saaty, 2005; Saaty, 2008). Saaty (1988) proposed AHP to assist in MCDM problems to overcome the difficulties related to the categorical and simple linear weighted average criteria ranking methods. The ultimate goal of AHP is to gain priorities based on sets of pairwise comparisons. Respondents compare pairs of elements against a given criterion and judge the intensity of importance of one element over the other based on the hierarchical structure (Yang et al., 2012). The pairwise comparisons are transformed into a numerical value of the discrete 9-value scale (Saaty, 2001). The details of AHP operation can be easily found in the literature.

AHP has been widely used in many fields. Almeida et al. (2012) considered a set of variables influencing the functioning of roads to process the prioritization of earth roads maintenance based on AHP. Manca and Brambilla (2011) proposed a methodology to assess the efficiency of preparedness activities in case of road tunnel accidents. Quantitative assessment of and the relative contribution of indexes were analyzed using AHP. Ramadhan et al. (1999) used AHP to determine the rational weights of importance of pavement maintenance priority ranking factors. Sun and Gu (2011) integrated the advantages of AHP and fuzzy logic theory and developed a new approach for pavement condition assessment and project prioritization. Tsita and Pilavachi (2012) used AHP to evaluate seven different alternative fuel modes for the Greek road transport sector. Zhang and Yang (2011) developed a questionnaire to collect the experiences of experts in Liaoning in northeast of China to find the local weights for the four pavement performance indices (pavement surface condition index (PCI), riding quality index (RQI), rutting depth index (RDI), and skid resistance index (SRI)) based on AHP.

Researchers examining the point of view of road users typically focus on the service quality of traffic facilities and traffic safety, whereas research on roads using AHP focuses on transport management, road performance indicators, and road maintenance activities. This study uses AHP to explore road service quality from the point of view of road users.

2. Structural Equation Modeling (SEM)

SEM uses a combination of quantitative and qualitative data to estimate and test causal relationships. SEM is a form of covariance analysis that allows the testing of *a priori* hypotheses concerning the causality among variables. The model includes latent variables that cannot be directly observed and manifest variables, which are observable. Latent variables can be examined by measuring the observed variables. SEM assesses the statistical relationships among the latent variables, which represent theoretical constructs that underlie measured observations, i.e., the observed variables (Yeh et al., 2010). SEM is divided into a measurement model and a path model. The measurement model presents the relationship between the latent variables (road service quality and assessment aspects) and the observed variables (assessment items), such as the relationships between road damage and smoothness and uneven pavement, as well as others. The path model presents the relationships between the latent variables (road service quality and assessment aspects), such as the relationship between road service quality and road construction.

The views of road users on road service quality are complex and cannot be directly quantified by data. Therefore, it is difficult to use general linear regression and factor analysis to describe the relationships between the views of road users and road service quality. SEM can deal with multiple dependent variables and estimate multiple equations simultaneously, whereas general linear regression can only estimate one equation. SEM does not have a limitation on the number of variables, and is hence considered as the best approach. Since SEM takes the confirmatory approach rather than the exploratory approach, there is no difficulty in hypothesis testing. SEM takes measurement error into account in both dependent variables and independent variables, as well as latent variables composed by a number of measurement variables (Punniyamoorthy et al., 2011). In addition, SEM also can simultaneously estimate the reliability and validity of variables. SEM supports theory-driven empirical research (Yihua and Tuo, 2011). Therefore, this study chooses SEM as the basis theory model of the empirical study of road service quality.

Hassan and Abdel-Aty (2011) thoroughly examine drivers' responses under low visibility conditions and quantify the impacts and values of various factors found to be related to driver compliance and driver satisfaction with variable speed limits and changeable message signs instructions in different visibilities, traffic conditions, and on two types of roadways: freeways and two-lane roads. This study adopted explanatory factor analysis (EFA) and SEM approaches to analyze a self-reported questionnaire survey carried out among 566 drivers in Central Florida, USA. In light of the Uses and Gratification Theory, Reychav and Wu (2014) proposed a conceptual research model to measure how users' different needs and gratifications with mobile technologies impact their learning outcomes. A field study with 182 young drivers who participated

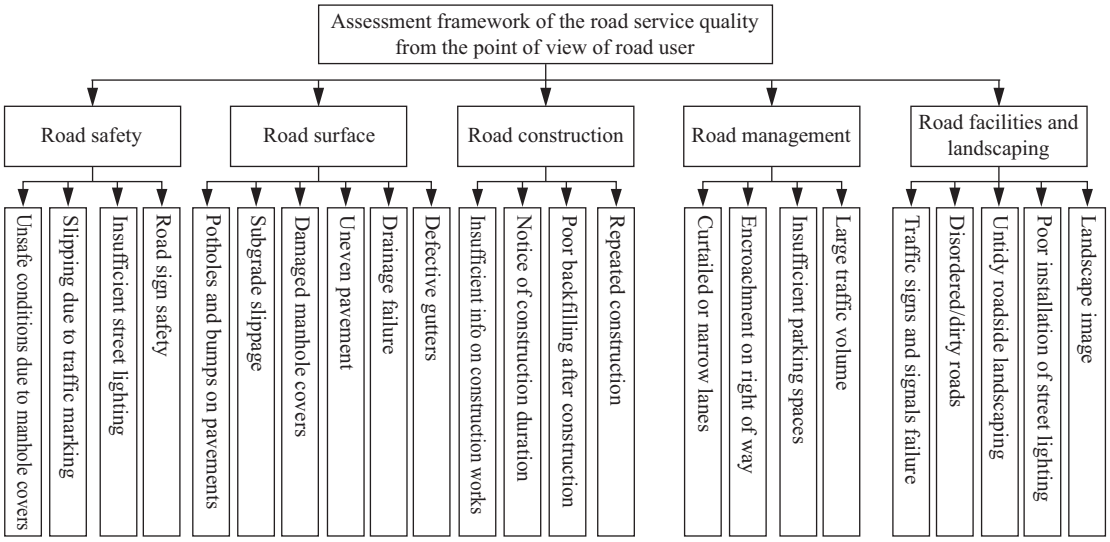

Fig. 1. Assessment framework of road service quality from the point of view of road users.

in a mobile road safety training program was conducted just before they took their license exam on site. A SEM approach was utilized to test the research model. Sato and Akamatsu (2008) modeled and predicted the influence of a vehicle's velocity and the relative position between a driver's vehicle and a vehicle to the front or rear at the onset of driver preparations for making a right turn at an intersection. Repeated experiments were carried out on a public road to measure driver preparations. SEM was applied to estimate these relationships quantitatively.

Research related to drivers focuses on issues such as road signs and reflection of road markings. In addition, SEM is rarely used in research on road service quality. This study uses SEM to identify which areas of road service quality are of concern to car and motorcycle drivers.

III. ROAD SERVICE QUALITY FROM THE POINT OF VIEW OF ROAD USERS

We first design a prototype "Assessment Framework of Road Service Quality from the Point of View of Road Users" based on the existing literature, using a first-stage questionnaire to revise the framework so that it fits as closely as possible to the actual perceptions of road users. This first-stage questionnaire includes basic question items such as whether the respondent has any professional expertise concerning roads, perception of road service quality in the city or township where the respondent currently lives (excellent, good, fair, poor, or very poor), and suggestions for improvements in road service quality in the city or township where the respondent currently lives. Next, pairwise comparison matrices are designed in the second-stage questionnaire based on the revised framework above. The AHP is conducted to analyze the second-stage questionnaire to understand the priority road users place on the different aspects and assessment items of road service quality. The two-stage questionnaire is directed at residents of Taiwan's Taoyuan County who do not have engineering backgrounds (Liu, 2009).

1. Assessment Framework

The 195 valid responses for the first-stage questionnaire show respondents' perceptions of road service quality in the city or township where they currently live. A total of 109 (55.9%) respondents rate road service quality as "good", followed by 57 (29.2%) of respondents who rate it as "fair", showing that while respondents generally accept current road service quality, there is still room for improvement. Respondents who chose "poor" or "very poor" identified unsafe conditions due to manhole covers, insufficient street lighting, poor backfilling after construction, repeated construction, curtailed or narrow lanes, and encroachment on right of way as areas in need of improvement. Respondents are most concerned with the aspects of "road safety" and "road surface". Further statistical tests show that respondents have different areas of concern in road service quality depending on the city or township in which they live. The "Assessment Framework of Road Service Quality from the Point of View of Road Users" is as shown in Fig. 1.

2. AHP Analysis

The pairwise comparison matrices are designed in the second-stage questionnaire based on the framework in Fig. 1. A total of 39 valid questionnaires are returned. The weights for the aspects and assessment items are calculated using the AHP, as shown in Table 1. Respondents in Taoyuan County are most concerned about the aspects of road safety and road surface. The assessment items for unsafe conditions due to manhole covers, damaged manhole covers, insufficient street lighting, potholes and bumps on pavements, and uneven pavement are of most concern.

Table 1. The weights for the aspects and assessment items in the road user's framework.

Aspect (weights)	Assessment items (weights)	Relative weights	Ranks
Road surface (0.342)	Potholes and bumps on pavements (0.280)	0.096	4
	Subgrade slippage (0.035)	0.012	17
	Damaged manhole covers (0.336)	0.115	2
	Uneven pavement (0.187)	0.064	5
	Drainage failure (0.097)	0.033	10
	Defective gutters (0.065)	0.022	12
Road facilities and landscaping (0.028)	Traffic signs and signals failure (0.141)	0.004	21
	Disordered/dirty roads (0.213)	0.006	18
	Untidy roadside landscaping (0.094)	0.003	22
	Poor installation of street lighting (0.514)	0.014	15
	Landscape image (0.038)	0.001	23
Road safety (0.394)	Unsafe conditions due to manhole overs (0.554)	0.218	1
	Slipping due to traffic marking (0.121)	0.048	8
	Insufficient street lighting (0.281)	0.111	3
	Road sign safety (0.044)	0.017	14
Road construction (0.138)	Insufficient information on construction works (0.040)	0.006	19
	Notice of construction duration (0.309)	0.042	9
	Poor backfilling after construction (0.450)	0.062	6
	Repeated construction (0.202)	0.028	11
Road management (0.098)	Curtailed or narrow lanes (0.054)	0.005	20
	Encroachment on right of way (0.609)	0.060	7
	Insufficient parking spaces (0.206)	0.020	13
	Large traffic volume (0.130)	0.013	16

IV. ROAD SERVICE QUALITY FROM THE POINT OF VIEW OF CAR AND MOTORCYCLE DRIVERS

Car and motorcycle drivers have a more direct perception of road service quality. As cars and motorcycles are two distinct modes of transport, their road service quality needs are not the same. This study examines road service quality for car and motorcycle drivers in Taiwan's Hsinchu County, using SEM for analysis to understand which areas of road service quality are of concern for drivers (Chen, 2010).

1. Assessment Frameworks

We first design a prototype "Assessment Framework of Road Service Quality from the Point of View of Car Drivers" and a prototype "Assessment Framework of Road Service Quality from the Point of View of Motorcycle Drivers" based on the existing literature, before making revisions according to the questionnaire so that they fit as closely as possible with the actual perceptions of drivers. The assessment frameworks are as shown in Fig. 2. The four aspects for the two assessment frameworks are "road damage and smoothness", "driving space", "road construction", and "traffic signals, markings, and signs". The two frameworks have sixteen and nineteen assessment items for car and motorcycle drivers, respectively. Differences between the assessment items for the two assessment frameworks occur in the aspects of "driving space" and "traffic signals, markings, and signs".

2. SEM Analysis

The drivers who responded to the questionnaire survey did not generally have professional expertise concerning roads, and judged road service quality on the basis of their own perceptions as drivers. The study assumes that the four aspects (latent variables) affect driver assessment of road service quality, as shown in Fig. 3. However, since cars and motorcycles are two different modes of transport, the assessment items (observed variables) for the two vehicle types are not exactly the same. Fig. 2 shows the sixteen and nineteen observed variables for car and motorcycle drivers, respectively.

Hoyle (1995) recommends a sample size of at least 100-200 in SEM. This study distributed 250 questionnaires according to the population ratio of cities and townships in Hsinchu County, Taiwan. In addition to the basic question items, respondents could choose the car and/or motorcycle questionnaire according to their usual mode of transport. Respondents were asked to judge the level of influence of the aspects and assessment items on road service quality (very low, low, average, high, or very high). The questionnaire was delivered on a one-to-one basis. Respondents were able to seek clarification on any question item from the interviewer if necessary, reducing the chance of missing items and increasing the reliability of the questionnaire. In total, 250 valid questionnaires were completed. There were 209 and 198 respondents for car and motorcycle questionnaires, respectively.

Cronbach's α was used to conduct the reliability analysis of the questionnaires. The Cronbach's α for the car and motorcycle questionnaires is in the range 0.814 to 0.934, showing that the overall reliability of the questionnaire is good (Cronbach, 1951). Following confirmatory factor analysis (CFA), we discovered a correlation between assessment items. The correlation raises difficulties in understanding driver assessments of road service quality. Therefore, we used EFA to revise the assessment frameworks (Gorsuch, 1983).

1) Car Drivers

We used the overall Kaiser-Meyer-Olkin Measure of

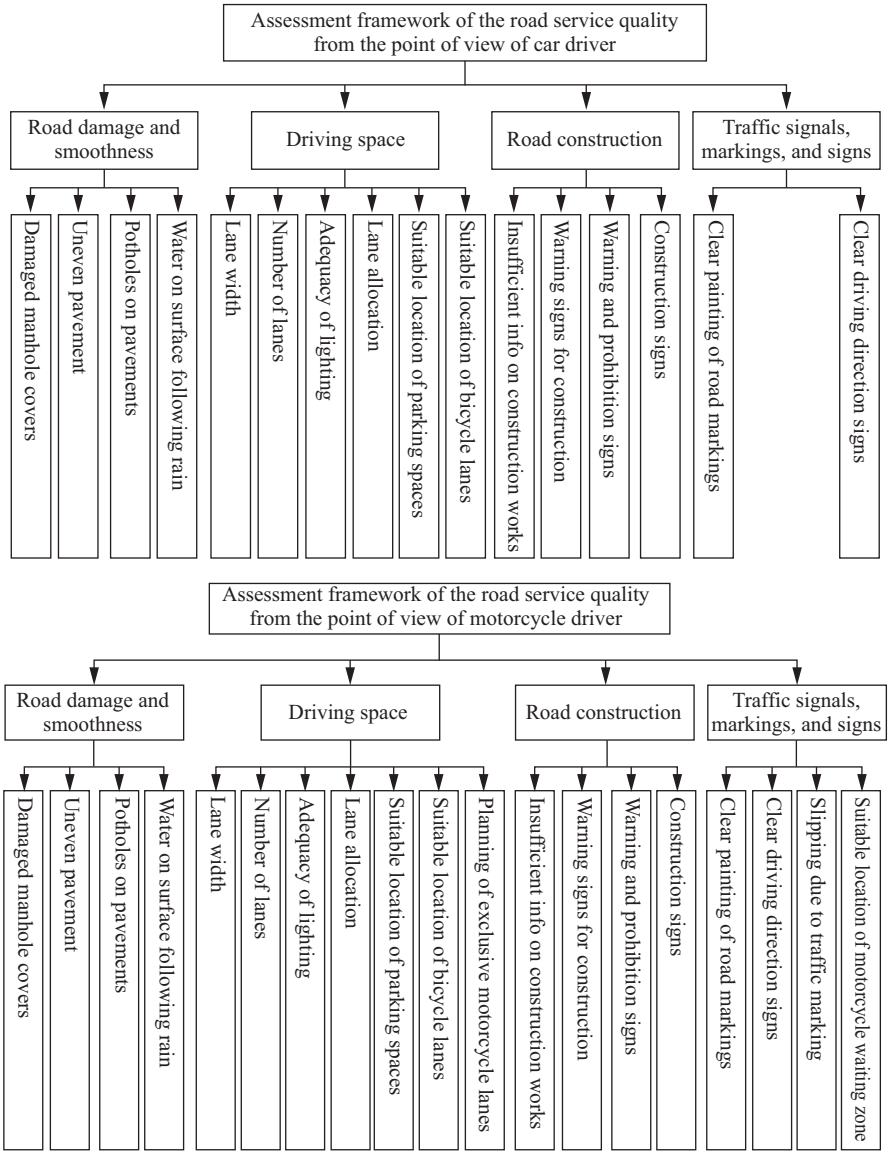

Fig. 2. Assessment frameworks of road service quality from the point of view of car (upper) and motorcycle (lower) drivers.

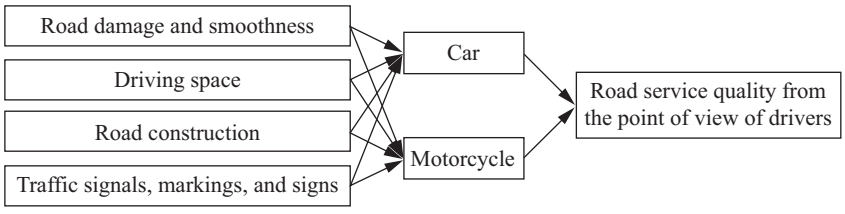

Fig. 3. The assumptions of driver assessment of road service quality.

Sampling Adequacy (KMO MSA) and the individual MSA to assess the appropriateness of using factor analysis on the framework (Cerny and Kaiser, 1977). The KMO value was 0.860, with a significance of 0.000 ($< \alpha = 0.01$), whereas the MSA value ranged from 0.783 and 0.916, showing that the assessment items were suitable for factor analysis. The study used principal component analysis (PCA) to extract three common factors. These three common factors explain 67.457% of the variance. Varimax orthogonal rotation was used to obtain the factor-loading matrix. From this matrix, we selected assessment items with an absolute value of factor loading of greater than 0.7, reducing the number of assessment items from sixteen to eleven. The common factors were named according to the assessment items selected for each common

Table 2. The revised assessment framework for car drivers and the offending estimate test.

Aspects	Assessment items	Factor loading λ	Standardized coefficient
Road construction and traffic management	Warning signs for construction	0.79	0.86
	Warning and prohibition signs	0.92	0.95
	Construction signs	0.93	0.95
	Clear painting of road markings	0.74	0.71
	Clear driving direction signs	0.72	0.73
Driving space	Lane width	0.61	0.74
	Number of lanes	0.50	0.61
	Adequacy of lighting	0.66	0.80
Road damage and smoothness	Damaged manhole covers	0.54	0.60
	Uneven pavement	0.68	0.86
	Potholes on pavements	0.58	0.81

factor. The three aspects and eleven assessment items following the revisions are shown in Table 2. This study used the LInear Structural RELations (LISREL) (Scientific Software International, Inc., 2013) computer program to obtain the path diagram, as shown in Fig. 4. Before carrying out a goodness of fit estimate of the model, it is first necessary to test whether the model produces an offending estimate (Hair et al., 1998). Table 2 shows that the eleven observed variables are reasonable and that there is no offending estimate. Therefore, the goodness of fit can be estimated. Table 4 shows the indices of goodness of fit. The indices satisfy the criteria of goodness of fit, indicating that the model has an acceptable goodness of fit.

The above analysis demonstrates that when car drivers are assessing road service quality, they are most concerned about "construction signs" for the "road construction and traffic management" aspect, "adequacy of lighting" for the "driving space" aspect, and "uneven pavement" for the "road damage and smoothness" aspect. This result matches the actual experiences of respondents with roads in Hsinchu County, as contained in the questionnaire, showing that the model of road service quality for car drivers established in this study is reasonable, and reflects the issues of road service quality that are of most concern to car drivers.

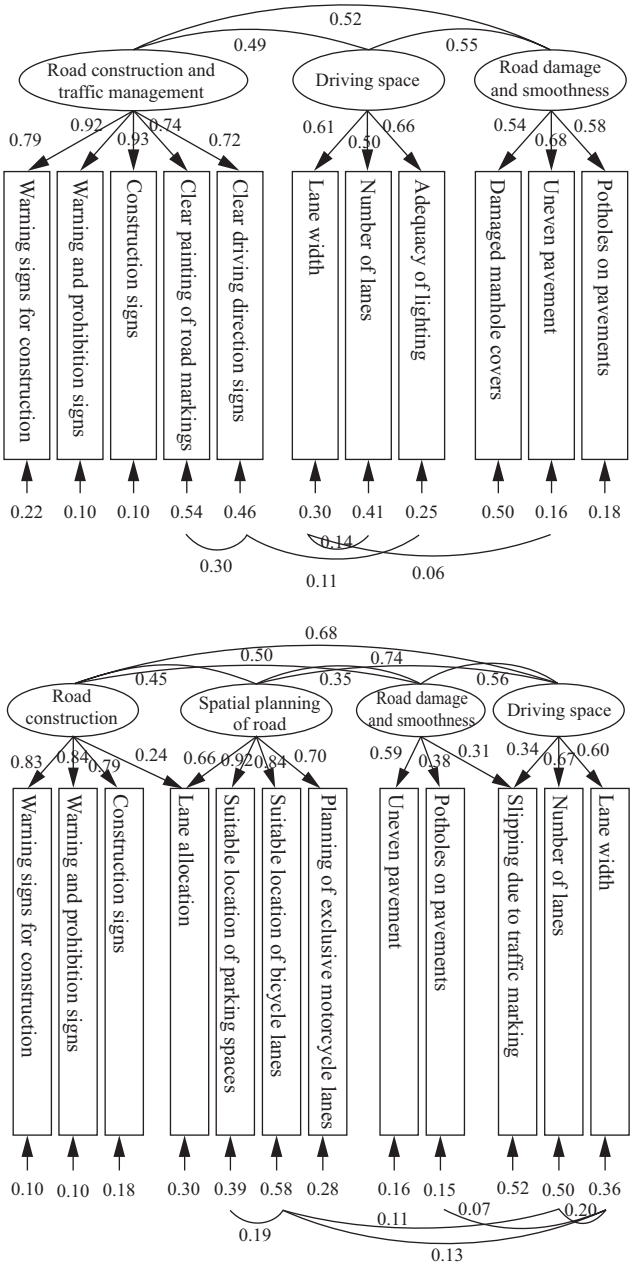

Fig. 4. Path diagrams for car (upper) and motorcycle (lower) drivers.

2) Motorcycle Drivers

We used the overall KMO MSA and the individual MSA to assess the appropriateness of using factor analysis on the framework. The KMO value was 0.871, with a significance of 0.000 ($< \alpha = 0.01$), whereas the MSA value ranged from 0.778 and 0.926, showing that the assessment items were suitable for factor analysis. This study used PCA to extract five common factors. These five common factors explain 76.609% of the variance. Varimax orthogonal rotation was used to obtain the factor-loading matrix. From this matrix, we selected assessment items with an absolute value of factor loading greater than 0.7, reducing the number of assessment items from nineteen to thirteen. The common factors are named according to the assessment items selected for each common factor. We tested the model for offending estimates and found that the standardized coefficient for "clear painting of road markings" was higher than the acceptable threshold of 0.95. After this assessment item was removed, the revised assessment framework contained four aspects and twelve assessment items, as shown in Table 3. This study used LISREL computer program to obtain the path diagram, as shown in Fig. 4. Table 3 shows

Table 3. The revised assessment framework for motorcycle drivers and the offending estimate test.

Aspects	Assessment items	Factor loading λ	Standardized coefficient
Road construction	Warning signs for construction	0.83	0.92
	Warning and prohibition signs	0.84	0.94
	Construction signs	0.79	0.88
Spatial planning of road	Lane allocation	0.66	0.68
	Suitable location of parking spaces	0.92	0.83
	Suitable location of bicycle lanes	0.84	0.74
	Planning of exclusive motorcycle lanes	0.70	0.80
Road damage and smoothness	Uneven pavement	0.59	0.83
	Potholes on pavements	0.38	0.70
Driving space	Slipping due to traffic marking	0.34	0.37
	Number of lanes	0.67	0.69
	Lane width	0.60	0.71

Table 4. The indices of goodness of fit for car and motorcycle driver frameworks.

Indices	Acceptable threshold	Car driver	Motorcycle driver
RMSEA	< 0.08	0.065	0.065
GFI	> 0.90	0.940	0.940
NFI	> 0.90	0.970	0.970
NNFI	> 0.90	0.980	0.970
CFI	> 0.90	0.980	0.980
χ^2/df ratio	< 2.00	1.800	1.800

Table 5. Comparisons of assessment aspects for road users, car drivers, and motorcycle drivers.

Areas	Taoyuan County, Taiwan	Hsinchu County, Taiwan	
Respondents	Road user	Car driver	Motorcycle driver
Aspects (by rank)	Road safety	Road damage and smoothness	Driving space
	Road surface	Road construction and traffic management	Road construction
	Road construction	Driving space	Road damage and smoothness
	Road management		Spatial planning of road
	Road facilities and landscaping		

that the twelve observed variables are reasonable and that there is no offending estimate. Therefore, the goodness of fit can be estimated. Table 4 shows the indices of goodness of fit. The indices satisfy the criteria of goodness of fit, indicating that the model has an acceptable goodness of fit.

The above analysis demonstrates that when motorcycle drivers are assessing road service quality, they are most concerned about "warning and prohibition signs" for the "road construction" aspect, "suitable location of parking spaces" for the "spatial planning of road" aspect, "uneven pavement" for the "road damage and smoothness" aspect, and "number of lanes" for the "driving space" aspect. This result matches the actual experiences of respondents with roads in Hsinchu County, as contained in the questionnaire, showing that the model of road service quality for motorcycle drivers established in this study is reasonable, and reflects the issues of road service quality that are of most concern to motorcycle drivers.

V. COMPARISON

The fourth section examined the aspects and assessment items of road service quality of concern to car and motorcycle drivers. The issues of concern, from those of most concern to those of least concern, are shown below:

1. Car drivers
   - Road damage and smoothness: uneven pavement → potholes on pavements → damaged manhole covers
   - Road construction and traffic management: construction signs → warning and prohibition signs → warning signs for construction → clear painting of road markings → clear driving direction signs
   - Driving space: adequacy of lighting → lane width →

number of lanes

2. Motorcycle drivers
   - Driving space: number of lanes → lane width → slipping due to traffic marking
   - Road construction: warning and prohibition signs → warning signs for construction → construction signs
   - Road damage and smoothness: uneven pavement → potholes on pavements
   - Spatial planning of road: suitable location of parking spaces → suitable location of bicycle lanes → planning of exclusive motorcycle lanes → lane allocation

In addition, Table 5 compares the assessment aspects of road service quality for the road users in the third section and car and motorcycle drivers in the fourth section.

VI. CONCLUSION

This study is directed at respondents without engineering backgrounds to develop an "Assessment Framework of Road Service Quality from the Point of View of Road Users" for road users in Taiwan's Taoyuan County, which is used to assess the views of road users on road service quality. The AHP results show that the respondents are most concerned about the "road safety" aspect, followed by the "road surface" aspect. Furthermore, as car and motorcycle drivers have a more direct perception of road service quality, the study developed separate "Assessment Frameworks of Road Service Quality from the Point of View of Car and Motorcycle Drivers" for car and motorcycle drivers in Hsinchu County, Taiwan. The SEM analysis shows that car and motorcycle drivers have the highest expectations for "road damage and smoothness" and "driving space", respectively. The results of this study can provide a reference for road authorities and road engineers when monitoring and managing road service quality.

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