THE RELATIONSHIP OF SAFETY AND COMPONENTS OF TOLL ROADS SERVICE

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Abstract

Indonesia uses Minimum Service Standard to provide the good service on toll road while Korea uses Level of Service and Information Technology System to measure the service on toll road. With a different implementation of service on a toll road, there is a different result on safety. This study shows exactly which component has a big effect to influence the road safety based on Korean and Indonesian experts, and shows the weight of those components in affecting the road safety. This study uses descriptive-quantitative method with questionnaire data collection techniques. An analysis was performed using the Structural Equation Modeling method. The result shows that the contribution of toll road service based on Korean expert data (24.1%) is larger compared to that of Indonesian expert data (21.4%) in improving the road safety. The most important component of toll road service to improve the road safety based on Korean expert data is toll road condition (90.8%), and the second is safety tools (85.6%). On the other hand, the most important component of toll road service to improve the road safety based on Indonesian expert data is safety tools (74.2%), and the second is toll road condition (54%). Based on both results, the component which has the biggest effect on the road safety is human factor and the second is the road.

Keywords: toll road service, road safety, Structural Equation Modeling, human factor

Abstrak

Indonesia menggunakan Standar Pelayanan Minimal untuk memberikan pelayanan yang baik di jalan tol sedangkan Korea menggunakan Tingkat Layanan dan *Information Technology System* untuk mengukur layanan di jalan tol. Dengan implementasi layanan yang berbeda, terdapat hasil yang berbeda pada keselamatan di jalan tol. Penelitian ini menunjukkan secara tepat komponen yang memiliki pengaruh besar untuk mempengaruhi keselamatan jalan berdasarkan tenaga ahli Korea dan tenaga ahli Indonesia, serta menunjukkan bobot komponen yang mempengaruhi keselamatan jalan. Penelitian ini menggunakan metode deskriptif- kuantitatif dengan teknik pengumpulan kuesioner data. Analisis dilakukan dengan menggunakan metode Structural Equation Modeling. Hasil analisis menunjukkan bahwa kontribusi layanan jalan tol berdasarkan data tenaga ahli Korea (24,1%) lebih besar dibandingkan dengan data tenaga ahli Indonesia (21,4%) dalam meningkatkan keselamatan di jalan. Komponen yang paling penting dari layanan jalan tol untuk meningkatkan keselamatan di jalan berdasarkan data tenaga ahli Korea kondisi jalan tol (90,8%), dan yang kedua adalah alat pengaman (85,6%). Di sisi lain, komponen yang paling penting dari layanan jalan tol untuk meningkatkan keselamatan di jalan berdasarkan data tenaga ahli Indonesia adalah alat pengaman (74,2%), dan yang kedua adalah kondisi jalan tol (54%). Berdasarkan kedua hasil tersebut, komponen terbesar yang memiliki pengaruh pada keselamatan jalan adalah faktor manusia dan yang kedua adalah jalan.

Kata-kata kunci: pelayanan jalan tol, keselamatan jalan, *Structural Equation Modeling*, faktor manusia

INTRODUCTION

As one of public infrastructure, road is an important thing to support economic, social, defence and security activities. Indonesia uses Minimum Service Standard to support people’s activities and provide the good service on toll roads. On the other hand, Korea uses Level of Service (LOS) and Information Technology System (ITS) to measure the service on toll roads. With a different implementation of service give a different result on safety. This research will show exactly which components has a big effect to influence the road safety, and shows the weight of that components in affecting the road safety.

The objectives of this study are to determine the influence of toll roads service components to road safety by Korean and Indonesian experts, and also to determine the difference of toll roads service components that affect the road safety based on Korean and Indonesian experts. The result will helps the stakeholder to make decisions in terms of improving service related to safety by improving service to this components.

According to Highway Research Board (2000) there are three performance measures of a basic freeway segment are density (passenger cars/kilometer/line), speed (the average speed of passenger cars), and volume-to-capacity (v/c) ratio. The measure used to provide an estimate of the level of service is density. because density increases as flow increases up to capacity, resulting in measure of effestiveness that is sensitive to a broad range of flows. The three measures of speed, density, and flow or volume are interrelated. The six Levels of Service (LOS) on the highway are: A, B, C, D, E, and F. LOS A is the best quality of service and LOS F is the worst. Valdivia (2009) stated that LOS C is recommended in order to provide desirable safety conditions at multilane high-speed arterial corridors and signalized intersections even in the early morning period. These results shown that less congested roads are not necessarily the safer, it is contradict the consensus that less congested roads has a less crash event.

Korea Expressway Corporation wrote that Information Technology (ITS) can provide one-stop information services, real-time on-site information, a statistic analysis and customized data, consisting mainly of GIS digital mapping, structure management system, traffic control system, pavement management system and tunnel management system. ITS is based on 3 components namely: Expressway Traffic Management System (ETMS), Expressway Toll Collection System (ETCS), and Tunnel Traffic Management System (TTMS). On ETMS, all information collected through Close-Circuit Television (CCTV), Vehicle Detection System (VDS), and information from customers, is taken together and analyzed in the traffic information center. This is a traffic network system which provides the analyzed information in real-time trough Variable Message Sign (VMS), internet, mobile phone, navigations, and the traffic broadcasting.

For ETCS, Korea Expressway Corporation installed Automatic Toll Collection System (ATCS) in 1994. In 2007, Hi-pass Electronic Toll Collection (HETC) was installed. It reduces the congestion on toll gate dramatically (and it is reduce 40 thousand tons of Emission), and allows users to use expressway more conveniently because never stop at toll gates. Korea Expressway Corporation also installed Weigh-In-Motion (WIM). The purpose of the installation of WIM is to detect weight (all, axle) and height. WIM have an error rate about 5%, for (0-10) km/h and 10%, for (10-30) km/h. Moreover, the Korea Expressway Corporation installed Hi-Speed Weigh-In-Motion (HS-WIM). HS-WIM has the same function with WIM. The difference is, HS-WIM can detect cars from 0 km/h to 255 km/h.

The Minimum Service Standard (MSS) for the toll road in Indonesia was just renewed in 2014 because the previous MSS did not meet the needs of toll road users in terms of service. The new MSS includes toll road conditions, the average travel speed, accessibility, mobility, safety, rescue units/rescue and relief services, environment, and rest area. Makmur et al (2015) stated that 6 indicators in the MSS could not always be met by the toll road operators, and only 71% of all indicators could be met.

RESEARCH METHODOLOGY

This research uses descriptive quantitative study with questionnaire data collection techniques. The scale of measurement variables in questionnaire is refers to the Likert scale, between 1-4 (1 is the worst and 4 is the best relationship between indicator to safety). This scale will indicate approval or disapproval of a series of statements from an object. The object to be studied is the opinion of the expert in Indonesia and South Korea regarding toll roads service and safety.

The questionnaire results will be analyzed with Structural Equation Modeling (SEM) method by using AMOS program. SEM is use to measure and express the relationship between endogenous (safety components) and exogenous (toll roads service components) latent variable. The reason for using SEM due to measurement problems can be solved by the measurement model while the second issue related to causal relationships can be solved using latent variable models.

The first step in analyzing of SEM is to develop the initial theory. From the literature review concluded the road safety on toll road will be affected by the variable of toll road condition, accessibility, mobility, safety tools, unit aid/rescue and relief service, rest area, level of service, and intelegent transport system. Mathematically, the initial theory in this research is:

$$\text{Road Safety} = \beta 1 \text{ x toll road condition} + \beta 2 \text{ x accessibility} + \beta 3 \text{ x mobility} + \beta 4 \text{ x safety tools} + \beta 5 \text{ x unit aid,rescue and relief service} + \beta 6 \text{ x rest area} + \beta 7 \text{ x level of service} + \beta 8 \text{ x intelegent transport system} + \text{measurement error.} \quad (1)$$

The next step is to develop the path model and test of their respective latent variables with confirmatory factor analysis (CFA). Than estimate the structural model as a full model by simply entering the indicators that have been declared valid on confirmatory factor analysis. Indicators that have been declared valid on confirmatory factor analysis are indicators that have meets the criteria of the goodness of fit. Similar to CFA, a model that have been declared valid on full model is a model that have meets the criteria of goodness of fit.

The model is invalid in the CFA can be modified so that the model becomes valid, and can be used to the full path model. But in the full model, a model which is declared invalid can be composited so the model becomes valid. If the model is still invalid, then the model must be changed, it is called reformulation model.

DATA ANALYSIS

Confirmatory Factor Analysis

Before analyzing the full structural model, the factors that make up each variable is tested. The test is done using the Confirmatory Factor Analysis (CFA) model. The full model structural analysis uses indicators that have been declared valid on the CFA. CFA model resume is depicted in the table below.

Table 1 The Resume of Confirmatory Factor Analysis and Full Path Model

Road Safety		Loading Factor	
		Indonesia	Korea
Y1	Human Factor	0.924	0.804
Y2	Road	0.791	0.785
Y3	Vehicle	0.714	0.556
Y4	Environment	0.525	0.545
Toll Road Condition			
X1	Skid resistance on pavement	0.818	0.867
X2	Roughness on pavement	0.861	0.692
X3	No-pothole on pavement	0.858	0.810
X4	Rutting on pavement	0.556	0.710
X5	Cracking on pavement	0.529	0.505
X9	Median Concrete Barrier (MCB)	0.877	0.667
X10	Guard rail condition	0.919	0.750
X12	No-pothole on roadside	0.660	0.579
X13	Rutting on roadside	0.602	-
X14	Cracking on roadside	0.575	-
X15	Rounding	0.564	0.791
Accessibility			
X16	The average speed transaction on open gate system	0.693	0.630
X17	The average speed transaction on close gate system	0.839	0.847
X18	The average speed transaction on ATC	0.903	0.991
X19	Number of queue	0.751	0.633
Mobility			
X20	The quickness of handling traffic congestion	0.893	0.894
X21	The quickness of handling by highway patrol	0.702	0.806
X22	The quickness of handling by towing car	0.572	0.851
X23	The quickness of handling by ambulance	0.585	0.820

Table 1 The Resume of Confirmatory Factor Analysis and Full Path Model (Continued)

Road Safety		Loading Factor	
		Indonesia	Korea
Safety Tools			
X24	Roadsign	0.774	0.520
X25	Road markings	0.878	0.581
X26	Guide post and reflector	0.897	0.520
X29	Road lighting	0.653	0.775
X30	Anti-glare	0.663	0.655
X31	Fence of road	0.632	-
X32	Safety fence	0.756	-
X33	Handling of accidents	0.620	0.902
X34	Security and law enforcement	0.637	0.810
Unit Aid/Rescue and Relief Service			
X35	Availability of ambulance	0.920	0.520
X36	Availability of towing car	0.777	0.538
X37	Existence oh highway police	0.782	0.939
X38	Existence oh highway patrol	0.961	0.922
X39	Availability of rescue car	0.956	0.637
X40	Information system	0.851	0.585
Rest Area			
X41	Road condition in rest area	0.710	0.760
X42	Entrance/Exit ramp	0.986	0.617
X44	Car park	0.648	0.544
X45	Lighting	0.992	0.625
X46	Gas stations	0.908	0.516
X47	Garage	0.811	-
Level of Service			
X49	Density	0.972	0.951
X50	Speed	0.674	0.746
X51	V/C Ratio	0.809	0.847
X52	Traffic flow	0.639	0.771
Information Technology System			
X53	Close-Circuit Television (CCTV)	0.778	0.866
X54	Vehicle Detection System (VDS)	0.524	0.818
X55	Dedicated Short Range Communication (DSRC)	0.566	0.727
X57	Traffic Information System	0.777	0.884
X58	Variable Message Signs (VMS)	0.798	0.853
X60	Traffic Broadcast	0.570	0.735
X61	Smart Interchange	-	0.626
X62	Hi-pass Electronic Toll Collection	-	0.694
X63	Installation of detector on pavement	0.557	0.734
X64	The Usage of WIM and HS-WIM	0.539	0.814

Full Path Model

Full path model analysis uses indicators that have been declared valid on the CFA. Structural equation model is based on causality or causal relationships that is the changes of one variable will result in changes to other variables.

Based on path model analysis and standardized regression weight output, most parameter goodness of fit that is used to form a research model shows the model does not fit and some of the constructs have negative correlation, indicating that the construct of negative-value are not consistent with the theory built. If structural equation models that we generate shapes do not fit the model equation, it is replaced by an early model with other models, called reformulation of models. Reformulation of the model was to develop a new theory to build a new structural equation model. Development of a model based on a new theory in this research is to add a new exogenous construct consisting of indicators that have been composited in first test. The exogenous construct is toll road service that consist of toll road condition, accessibility, mobility, safety tools, unit aid, rest area, LOS, and IT System indicators. The theory built on the new model is:

$$\text{Safety} = \beta 0 \times \text{Toll Road Service} + \varepsilon \quad (2)$$
$$\text{Toll Road Condition} = \beta 1 \times \text{Toll Road Service} + \varepsilon \quad (3)$$
$$\text{Accessibility} = \beta 2 \times \text{Toll Road Service} + \varepsilon \quad (4)$$
$$\text{Mobility} = \beta 3 \times \text{Toll Road Service} + \varepsilon \quad (5)$$
$$\text{Safety Tools} = \beta 4 \times \text{Toll Road Service} + \varepsilon \quad (6)$$
$$\text{Unit Aid} = \beta 5 \times \text{Toll Road Service} + \varepsilon \quad (7)$$
$$\text{Rest Area} = \beta 6 \times \text{Toll Road Service} + \varepsilon \quad (8)$$
$$\text{LOS} = \beta 7 \times \text{Toll Road Service} + \varepsilon \quad (9)$$
$$\text{ITS} = \beta 8 \times \text{Toll Road Service} + \varepsilon \quad (10)$$

with:
β = Loading factor; and
ε = Measurement error.

Based on the analysis of full structural model (after reformulation model), all parameters shows the results that fit. This means that the indicator forming the construct of toll road service gives appropriate result. The full structural model (after reformulation model) resume is depicted in the Table 2.

Table 2 The Resume of Full Structural Model (After Reformulation Model)

Toll Road Service Component	Loading Factor	
	Indonesia	Korea
Toll Road Condition	0.540	0.908
Accessibility	0.146	0.255
Mobility	0.346	0.125
Safety Tools	0.742	0.856
Unit Aid/Rescue and Relief Service	0.380	0.600
Rest Area	0.009	0.280
Level of Service	0.342	0.306
Information Technology System	0.348	0.564

Based on Korean expert data shows that toll road service has contributed (loading factor) 0.241 to improve the road safety. On the other hand, based on Indonesian expert data shows that toll road service has contributed (loading factor) 0.214 to improve the road safety. The contribution (loading factor) of road safety component to improve the road safety is shown in the Table 3.

Table 3 The Loading Factor Of Road Safety Component to Improve The Road Safety

Road Safety Component		Relation to Safety	
		Indonesia	Korea
Y1	Human Factor	0.924	0.804
Y2	Road	0.791	0.785
Y3	Vehicle	0.714	0.556
Y4	Environment	0.525	0.545

CONCLUSION AND RECOMMENDATION

Some of toll road service components have considerable effect on the safety on toll roads. This study identifies these components and analyze the extent of their influence on the toll road safety. Identifying these components on the toll road service aims to define the right strategy to improve the safety of toll roads. The conclusions of this research are:

1) The analysis result based on Korean expert data shows that toll road service has contributed 24.1% to improve the road safety. Toll road service component contributed to the toll road service in improving road safety. Those components are: Toll Road Conditions that have the greatest contribution (90.8%), safety tools (85.6%), unit aid/rescue and relief service (60%), ITS (56.4%), LOS (30.6%), rest area (28%), accessibility (25.5%) and mobility (12.5%). Meanwhile, the components that affect the road safety, namely: Human factor (80.4%), road (78.5%), vehicle (55.6%), and environment (54.5%).
2) The analysis result based on Indonesian expert data shows that toll road service has contributed 21.4% to improve the road safety. Toll road service component contributed to the toll road service in improving road safety. Those components are: Safety tools that have the greatest contribution (74.2%), Toll Road Condition (54%), unit aid/rescue and relief service (38%), ITS (34.8%), mobility (34.6%), LOS (34.2%), accessibility (14.6%), and rest area (9%). Meanwhile, the components that affect the road safety, namely: Human factor (92.4%), road (79.1%), vehicle (71.4%), and environment (52.5%).
3) The analysis result shows that the contribution of toll road service based on Korean expert data is larger as compared to Indonesian expert data in improving the road safety. The most important component of toll road service to improve the road safety based on Korean expert data is toll road condition, and the second is safety tools. On the other hand, the most important component of toll road service to improve the road safety based on Indonesian expert data is safety tools, and the second is toll road condition. Based on both result, the component that have the biggest affect to road safety is human factor, and the second is the road; ITS is also very important to be applied on the toll road to provide a real time information service, since using ITS minimize the human factor and monitor the road condition in real time.

This study only gives general description about the relationship of the toll road access to road safety. Recommendations to stakeholders and for next studies should include the dominant toll road service components such as safety tools, toll road condition, and the unit aid/rescue and relief service must be done seriously. One effort that can be used is to apply the ITS on the toll roads, so that these components can be monitored in real time and LOS can be used as a control. This study gives the general description of the relationship between toll road service and road safety, future research could add comfort as endogenous latent variable.

REFERENCE

Highway Research Board. 2000. *Highway Capacity Manual*. Washington, DC.

Makmur, A., Rajagukguk, R.P., and Santosa, W. 2015. *The Evaluation of the Fulfillment of Toll Roads Minimum Service Standard Indicator in Indonesia*. The 18th FSTPT International Symposium, Bandar Lampung.

Valdivia, A.M.A. 2009. *Level-of-Service and Traffic Safety Relationship: An Exploratory Analysis of Signalized Intersections and Multilane High-Speed Arterial Corridors*. Unpublished dissertasion. University of Central Florida. Orlando, FL.