Istraživanja i projektovanja za privredu
ISSN 1451-4117
DOI:10.5937/jaes0-39785
www.engineeringscience.rs

Journal of Applied Engineering Science
Vol. 21, No. 1, 2023
Original Scientific Paper
Paper number: 21(2023)1, 1062, 176-187

ANALYZING THE EFFECT OF ROAD PERFORMANCE INDICATORS ON PENALTIES FOR LATE FULFILLMENT IN ROAD SERVICE LEVELS

Tisara Sita*, Agus Taufik Mulyono, Suryo Hapsoro Tri Utomo

Faculty of Engineering, Universitas Gadjah Mada, Indonesia

** tisarasita@mail.ugm.ac.id*

The long segment policy for national road preservation comprising routine maintenance work, both road routine and condition routine maintenance, preventive maintenance, and holding with widening, rehabilitation, and reconstruction of several road sections into a single contract had been implemented in Indonesia since 2016. Reliable road performance indicators including road pavement, road shoulders, drainage, road equipment, road complementary buildings, and clearances have an impact on-road performance. Therefore, an analysis must be carried out to obtain indicators for each road performance influencing Penalties for Late Fulfillment in Road Service Levels (PLRSL) charged to contractors if they could not meet the road performance indicators based on the specified repair response time. This study aims to improve the road service level through the compliance of road performance indicators on the success of sustainable construction projects. The Structural Equation Modeling (SEM) analysis results indicated that the road performance indicator in the road preservation program had a significant effect of 77.0% on the determination of PLRSL. In addition, road pavement, drainage, road shoulder, clearance, complementary buildings, and road equipment contributed statistically significant effect on the road performance indicator with values of 88.0%, 81.4%, 80.9%, 79.1%, 78.1%, and 51.3%, respectively. These results should be a concern for contractors and the government. With a clear understanding of the significant indicators in the context of the road maintenance project, these findings could potentially contribute to the development of comprehensive pavement handling on road maintenance programs related to the quality performance of the construction projects.

Keywords: road performance indicators, construction project management, road preservation, financial penalties

1 INTRODUCTION

Indonesia's infrastructure quality ranking released by the World Economic Forum (2012-2019) [1] has risen from 92nd in 2012 to 72nd in 2019, although in 2019 it fell compared to 2017, which was 52nd. Meanwhile, Indonesia Global Competitiveness Index (GCI) was ranked at 50th in 2019, a decrease from 2015's achievement which was placed at 37th. The GCI ranking and Indonesia Infrastructure Competitiveness is shown in Fig. 1. In addition, Indonesia's road quality ranking places in the middle and below Singapore, Malaysia, China, and Thailand.

Fig. 1. GCI Ranking and Indonesia Infrastructure Competitiveness in 2010-2019 [1]

Road implementation fund in the 2015-2019 Strategic Plan of the Directorate General of Highways has a total State Budget plan for roads of around Rp278.18 trillion. Nevertheless, in fact, only Rp211.97 trillion (76.20% of the plan) was obtained. A study by the National Development Planning Agency in 2014 stated that the ideal cost of road investment was around Rp1,274 trillion for the period of 2015-2019 [1]. It is indicated that there was a budget backlog in the implementation of national roads. The proportion of the 2015-2019 State Budget allocation for national road preservation programs and improvement of existing roads and bridges was 54.99%, whereas 24.55% was allocated for the construction of new roads and bridges, and 20.46% for management and technical support.

The national road preservation system in Indonesia, particularly the routine maintenance of roads which was formerly conducted by self-management at each Commitment-Making Officer or Area/Project Manager as the manager of road sections, had since 2016 evolved into a long segment plan. The Directorate General of Highways through the Directorate of Road Preservation implemented a long segment policy for national road preservation, which combined routine maintenance work, both road routine and condition routine maintenance, preventive, holding work with road widening, rehabilitation, and reconstruction of many road sections into single contract [2].

The quality of road maintenance work on a long segment foundation is one of the indications of success in the strategy of attaining the longevity of a road pavement plan. Division 10 [3] stipulated that contractor should carry out the fulfillment of road service levels based on road performance indicators. The fulfillment of the road service level was applied to all work outcomes included in the scope of management comprising road pavement work, road shoulders, road drainage, road equipment, road supplementary buildings (if any), and plant control [4; 5]. If the contractors are unable to meet the road performance indicators based on the stated repair response time, they will be subjected to financial penalties in the form of withdrawals from payments per day in accordance with Equation 1.

$$D = 0.01 \times H \times \frac{Pjc}{Pjl} \times Nlp \qquad (1)$$

where:

D : Amount of withholding payment

H : Number of days of delay in repair of road service level fulfillment

Pjc : Length of the defective road (does not meet performance indicators) in the specified road segment (segment length of at least 100 meters)

Pjl : Length of road in the contract based on the scope of work

Nlp : Value of scope of work in contract

The analysis to identify the problems and challenges that exist in the road preservation control with the long segment system is still quite new. It is necessary so that the effectiveness and efficiency of the implementation of long segment-based national road preservation can be gauged and more accurate and precise handling program can be implemented.

Reliable road performance indicators including road pavement, road shoulders, drainage, road equipment, road complementary buildings, and clearances, will affect PLRSL and affect road performance. Therefore, it is necessary to carry out an analysis to determine indicators for each road performance indicator that affects PLRSL.

2 METHODS

2.1 Research Sites and Analysis Method

The study was conducted in the work region of the National Road Implementation Center of Central Java and Special Region of Yogyakarta which involves parties who handle national road projects. This study consists of road performance factors and indicators that had the potential to affect PLRSL. The factors and indicators were derived through a literature review, field observations, and interviews with project executors.

Data analysis is a quantitative analysis of the factors of road performance and their indicators that affect the PLRSL. Using the SEM model [6; 7], the correlation between the factors and their indicators regarding the PLRSL was analyzed. The correlation between road pavement, road shoulders, drainage, road equipment, road complementing buildings, clearance, and PLRSL can be modeled graphically with more flexible assumptions with this SEM. Another advantage of the SEM method is that the model testing may be conducted as a whole, allowing the weight of each variable to be estimated based on its individual weight analysis [8].

2.2 Characteristics of Respondents

There were 149 respondents who completed the questionnaire, including 74 government’s staff as service user and 75 contractors. Due to the mismatch between the education level and the educational background, two samples were omitted, leaving 147 samples for further analysis. The number of samples satisfied the SEM procedure's minimum criterion of 100 samples [9].

2.3 Data Collection Technique

According to Roh et al. [10], the quality of data collection is dependent on the precision of the data collection techniques. This study was a quantitative study that collected primary data in the field using a questionnaire. According to de Souza et al. [11], in order to generate valid and reliable data, the questionnaire had to be verified for validity and reliability before being distributed to respondents. In this study, questionnaire responses were tested for validity and reliability. The validity test employed the product moment correlation technique developed by Pearson with Equation 2. This analysis was conducted by combining the scores of each variable with the total score. The r-count results were then used to test the significance of the correlation results by comparing the t-count and t-table values, as shown in Equation 3. Significant correlations between variables and the total score indicated that these variables could aid in identifying the factors that influenced PLRSL in the region of National Road Implementation Center of Central Java and Special Region of Yogyakarta. The test employed a two-part test with the significance level of 5%.

$$r = \frac{n(\sum XY)-(\sum X \sum Y)}{\sqrt{[s\sum X^2-(\sum X)^2-[n\sum Y^2-(\sum Y)^2]}} \qquad (2)$$

where:

r : correlation coefficient
ΣX : total score of each X item
ΣY : total score of each Y item
s : number of samples

The results of the r-count were then compared to the t-count and t-table values of the t-test to determine the significance of the correlation results. If t-count > t-table (two-way test with a significance level of 0.05), then the characteristic is valid, and vice versa. The t-count formula used Equation 3.

$$t_{count} = \frac{r\sqrt{(n-2)}}{\sqrt{(1-r^2)}} \tag{3}$$

where:

t_{count} : significance level (to be compared with the t_{table})
r : correlation coefficient
n : number of samples

The reliability test of the questionnaire data used the Cronbach's alpha (α) technique**,** following Equations 4 and 5:

$$\boldsymbol{r_{11}} = \left(\frac{k}{k-1}\right)\left(1-\frac{\sum \sigma b^2}{\sigma t^2}\right) \tag{4}$$

where:

r_{11} : attribute reliability
k : number of items
σt^2 : total variance
$\Sigma\sigma b^2$: number of item variants

$$\boldsymbol{\sigma^2} = \frac{\sum X^2\left(\frac{(\sum X)}{n}\right)}{n} \tag{5}$$

where:

n : number of research subjects
X : chosen score

A construct or variable was declared reliable if it contributed Cronbach's alpha (α) > 0.70. Otherwise, if Cronbach's alpha (α) < 0.70, then the construct is not reliable [12].

2.4 Data Analysis Method

SEM was used to determine the relationship between the factors in this study. According to Wang and Wang [13], SEM is a combination of two distinct statistical methods: (1) the measurement section that linked observed variables to latent variables through psychological and psychometric confirmatory factor models, and (2) the structural section that linked latent variables using simultaneously produced regression equations (simultaneous equation modeling) in statistics.

Fig. 2 depicts the relationship model between variables that would be provided based on the results of the literature review and field-specific problems.

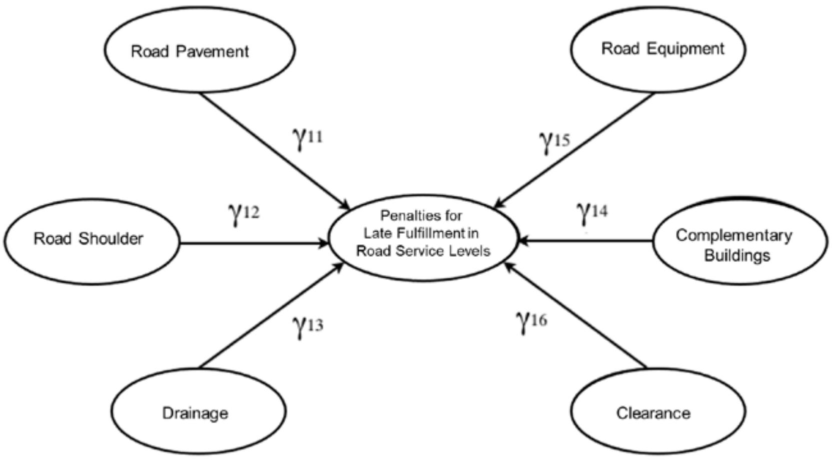

Fig. 2. Model of causality relationship between factors

Table 1 summarizes the factors associated with the variables that influence the PLRSL. SEM method cannot be utilized to create a new model without the existing theory's base [13], as Table 1 includes the references that support the selection of variables and their indicators.

Based on the causal relationship, the structural model equation can be stated as Equation 6.

$$PLRSL = \gamma_{11}P + \gamma_{12}B + \gamma_{13}D + \gamma_{14}L + \gamma_{15}G + \gamma_{16}C + \zeta \quad (6)$$

where:

PLRSL : Penalties for Late Fulfillment in Road Service Levels
γ : Parameters to describe the direct relationship of exogenous variables to endogenous variables
γ_{11}P : Relationship between "Road Pavement" as exogenous construct and PLRSL as endogenous construct
γ_{12}B : Relationship between "Road Shoulder" as exogenous construct and PLRSL as endogenous construct
γ_{13}D : Relationship between "Drainage" as exogenous construct and PLRSL as endogenous construct
γ_{14}L : Relationship between "Road Equipment" as exogenous construct and PLRSL as endogenous construct
γ_{15}G : Relationship between "Road Complementary Building" as exogenous construct and PLRSL as endogenous construct
γ_{16}C : Relationship between "Clearance" as exogenous construct and PLRSL as endogenous construct
ζ : Measurement error in the structural equation

Table 1. Model-related constructs and indicators (processed from various sources)

Constructs	Measured Variables/Indicators	Code	References
Fulfillment of Road Performance Indicators	Response time	Y1	[3; 14]
	Traffic volume (vehicles/day)	Y2	
	Complaints/community reports	Y3	
	Road lengths that do not meet road performance indicators per 100 m	Y4	
	Amount of Independent Cost Estimate	Y5	
	Amount of contract value	Y6	
	Amount for value of scope of work in contract	Y7	
Road Pavement	Pothole, diameter < 10 cm, depth < 4 cm	X1	[3; 14-16]
	Pothole, diameter > 10 cm, depth > 4 cm	X2	
	Cracking, width < 3 mm, area 5% each 100 m	X3	
	Cracking, width < 3 mm, area 5% each 100 m	X4	
	Depression, width < 3 cm, area 5% each 100 m	X5	
	Depression, width > 3 cm, area 5% each 100 m	X6	
	Pavement roughness (overlay), IRI < 4 mm/m	X7	
	Rutting, depth 6-13 mm	X8	
	Rutting, depth 13-25 m	X9	
	Rutting, depth > 25 mm	X10	
	Raveling	X11	
	Pavement edge drop	X12	
	Uneven patching	X13	
Road Shoulder	Pothole, diameter < 20 cm, depth < 10 cm	X14	[3; 14-16]
	Pothole, diameter > 20 cm, depth > 10 cm	X15	
	Elevation, gap between height and pavement edge < 5 cm	X16	
	Elevation, gap between height and pavement edge > 5 cm	X17	
	Depression, depth < 10 cm, area > 3% each 100 m	X18	
	Depression, depth > 10 cm, area > 3% each 100 m	X19	
	Potholes on the road shoulder	X20	
Drainage	Dirty drainage channels	X21	[3; 14-16]
	Damaged structures on drainage channels	X22	
	Blockage of drainage channel < 10%	X23	

Constructs	Measured Variables/Indicators	Code	References
	Blockage of drainage channel > 10%	X24	
	Deformation and erosion on the slopes of the embankment and not functioning properly	X25	
	Unstable excavated slope, not strong enough to withstand erosion, and not work properly	X26	
Road Equipment	Road and traffic signs are not installed correctly according to the provisions, structurally not sturdy, and some poles are bent	X27	[3; 15; 17; 16]
	No temporary signs are installed for the prevention of traffic accidents caused by irreparable road damage	X28	
	Horizontal separators on the median or pavement are not strong and do not work properly	X29	
	Horizontal separators on the median or pavement of their surfaces cannot be seen clearly at night	X30	
	Road markings unclear, faded	X31	
	Guardrails are structurally unsteady, not installed properly, and damaged	X32	
Complementary Buildings	Slip Road: a decrease of more than 5 cm from the plan elevation of the closing surface	X33	[3; 15; 16]
	Soil Retaining Wall has structural damage and is functioning properly	X34	
	Soil Retaining Wall cracks in the walls and foundation	X35	
	Soil Retaining Wall occurs a fracture of the building structure which results in damage to the building structure	X36	
Clearance	There are wild plants in the road space	X37	[3; 15; 16]
	Wild plants with a height > 10 cm in the road space and/or interfere with visibility for the safety of road users	X38	
	There are billboards/banners that interfere with visibility	X39	
	There is dirt/garbage, sand/soil, debris, or other obstructions	X40	

The structural equation model describes a highly intricate correlation and causation relationship between several components and variables. The complex issue could be circumvented using item parceling or composite methods that reduce the number of measurement indicators for each construct prior to SEM analysis [4; 18; 19]. It was based on the notion that the more complicated the model, the larger the sample size necessary, and the more measurement items, the more complex the model. Reducing the number of measurement indicators was required because it simplified the model, hence minimizing the impact of sample size on the results. It is in line with McNeish [20], who stated that it should be employed with a simple model and a modest sample size.

Research on SEM testing with the composite method or model simplification was a statistical approach for parceling or aggregating items (combining indicators) and using composite results as indications of latent structures [21]. Incorporating indicators into one or more "packages" or parcels and employing these packets as indicators of the latent construct was referred to as parceling or composite methods [22]. As depicted in Fig. 3, a package could be constructed by randomly or nonrandomly combining two or more indicators into one package (subset-item-parcel) or by merging all indicators into one composite package (all-item-parcel) [23]. Combining the all-item-parcel and the subset-item-parcel approach yielded this composite method approach.

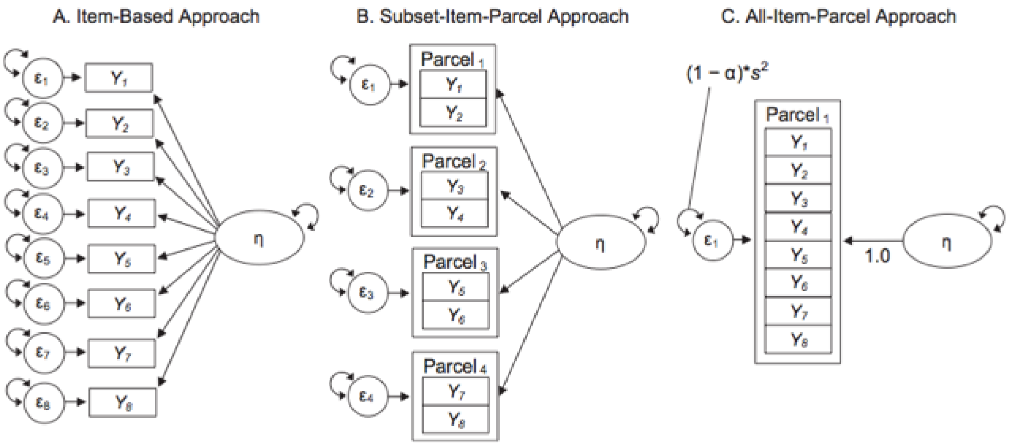

Fig. 3. Item parceling or composite method [9]

3 RESULTS AND DISCUSSION

3.1 Data Quality Testing

Testing the validity and reliability of data was used to assess the quality of the data. Since the t-count value of all indicators was greater than the t-table value (1.976), all indicators can be used to measure factors that influence financial PLRSL. As indicated in Table 2, the Cronbach's alpha value for each factor > 0.70, indicating that the questionnaire's variables, which were the elements that influenced the PLRSL, are very reliable.

3.2 Analysis of the Effect of Road Performance Indicators on PLRSL

The structural equation model outlines the causative relationship among constructs. If one variable or indicator in a construct change, the causality relationship, and other variables or indicators will also change [24]. The path diagram illustrating the causal relationship among constructs and their indicators is based on the conducted theoretical research. Fig. 4 shows the causal relationship among constructs.

Fig. 4 describes a highly complex correlation and causality relationship among structural equation model with many constructs and indicators. Before conducting the SEM analysis using the composite or item parceling methods, the number of measurement indicators of each construct should be minimized. It is based on the notion that the more complicated the model, the larger the sample size necessary, and the more measurement items, the more complex the model. With 147 samples, several markers, and complex models, the sample size is still relatively tiny. Reducing the number of measurement indicators was required because it simplified the model, hence minimizing the impact of sample size on the results.

The composite method or simplification of the structural equation model used in this study was the all-item parcel approach [9]. This model added a new construct, namely the “Road Performance Component (RPC)” which had indicators in the form of factors that had been composited. The RPC construct was analyzed for its effect on the PLRSL construct. Modification of the model using the item parceling approach can be seen in Fig. 5 for the relationship between RPC as exogenous construct and PLRSL as endogenous construct and the relationship between the manifest variables and the RPC construct.

Table 2. Reliability test results

Indicator	Cronbach’s alpha value (α)
Road Pavement Factor	0.953
Road Shoulder Factor	0.925
Drainage Factor	0.914
Road Equipment Factor	0.946
Complementary Building Factor	0.910
Clearance Factor	0.917
PLRSL Factor	0.911

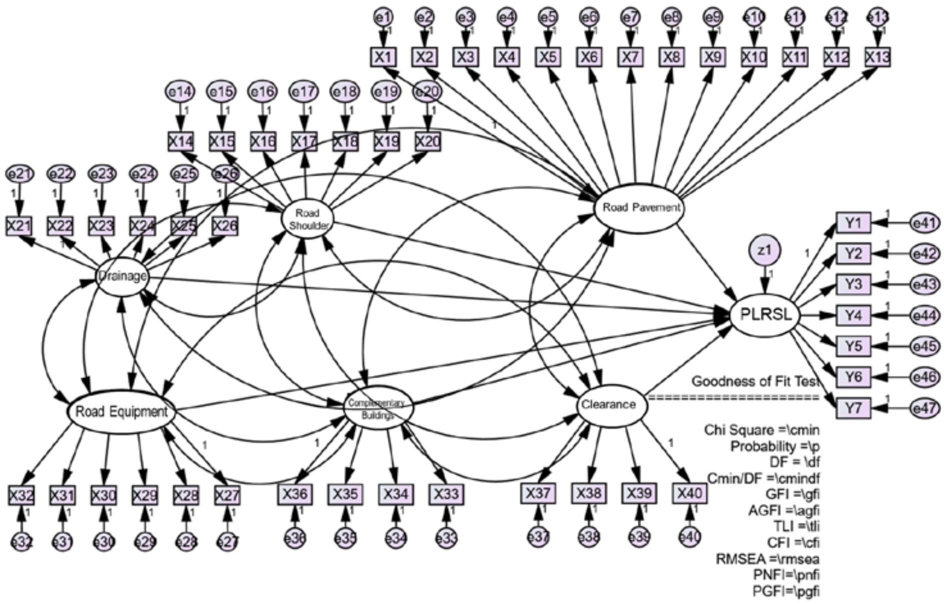

Fig. 4. Model path diagram of causality relationships among constructs

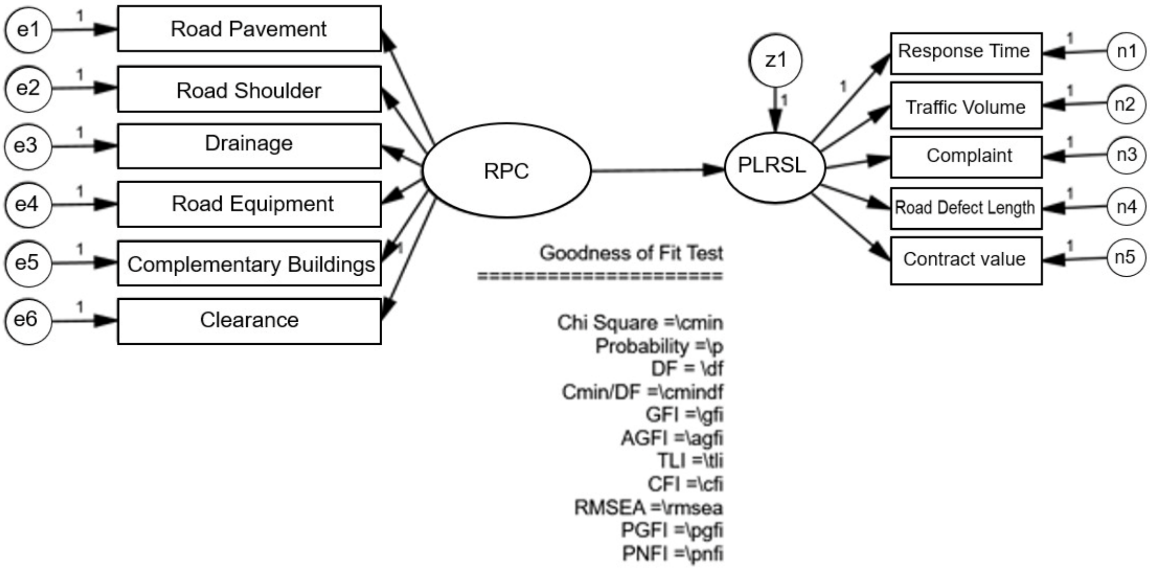

Fig. 5. Modification of the model with item parceling

Table 3. CFA result of each construct

Code	Standardized Regression	Code	Standardized Regression	Code	Standardized Regression	Code	Standardized Regression
Road Pavement		**Road Shoulder**		**Road Equipment**		**Clearance**	
X1	0.755	X14	0.785	X27	0.799	X37	0.808
X2	0.933	X15	0.834	X28	0.909	X38	0.830
X4	0.883	X17	0.842	X29	0.856	X39	0.917
X6	0.901	X19	0.930	X30	0.873	X40	0.883
X7	0.780	X20	0.775	X31	0.889	**Financial Penalties**	
X10	0.854	**Drainage**		X32	0.860	Y1	0.844
X11	0.857	X21	0.725	**Complementary Buildings**		Y2	0.767
X13	0.780	X22	0.789	X33	0.965	Y3	0.841
-	-	X24	0.890	X34	0.798	Y4	0.799
-	-	X25	0.820	X36	0.877	Y5	0.824
-	-	X26	0.800	-	-	-	-

3.3 *Construct Unidimensionality Testing using Confirmatory Factor Analysis (CFA)*

CFA aims to assess indicators that define a latent variable (construct) that cannot be directly measured. CFA is designed to assess the multidimensionality of a theoretical construct. The empirical analysis aims to validate the model that has been formed and estimate the parameters that are built based on theories [25]. The measurement model in the CFA has two basic tests: (1) test of the suitability of the measurement model; and (2) test of the significance of factor weights or convergent validity (loading factor or λ).

The CFA measurement must use factor weights because the constructed test is used to confirm that the formed variable can together with other variables explain a latent variable. According to Ab Hamid et al. [26], the convergent validity criterion which is considered to have good validity is 0.70, while the convergent validity of 0.50-0.60 is still acceptable. This study used a cut-off point of 0.50. This means if the factor weight is lower than 0.50, the construct forming indicator is considered not to have the same dimensions as other indicators to explain a construct. The results of the CFA test on exogenous and endogenous constructs that have a significant effect on PLRSL is provided in Table 3.

3.4 *Full Structural Equation Modeling Testing (Full SEM Model)*

After completing CFA, estimation of Full SEM Model was tested by only including indicators that had been tested with CFA. The aim of evaluating the structural relationship model is to establish the relationship between the modeled constructs (latent variables). The conceptual framework of the proposed theoretical model has a structural relationship, namely the correlation relationship between exogenous factors and the causal relationship between the component factors of RPC and PLRSL. In Fig. 6, structural relationship modeling is depicted. The structural equation model depicted in Fig. 6 illustrates a highly complex correlation and causality relationship between numerous components and indicators.

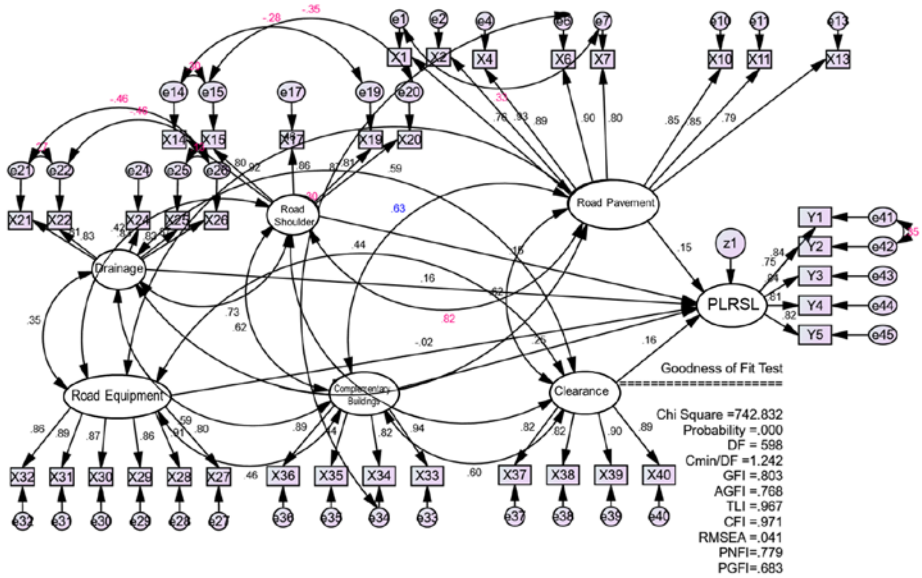

Fig. 6. Full model structural

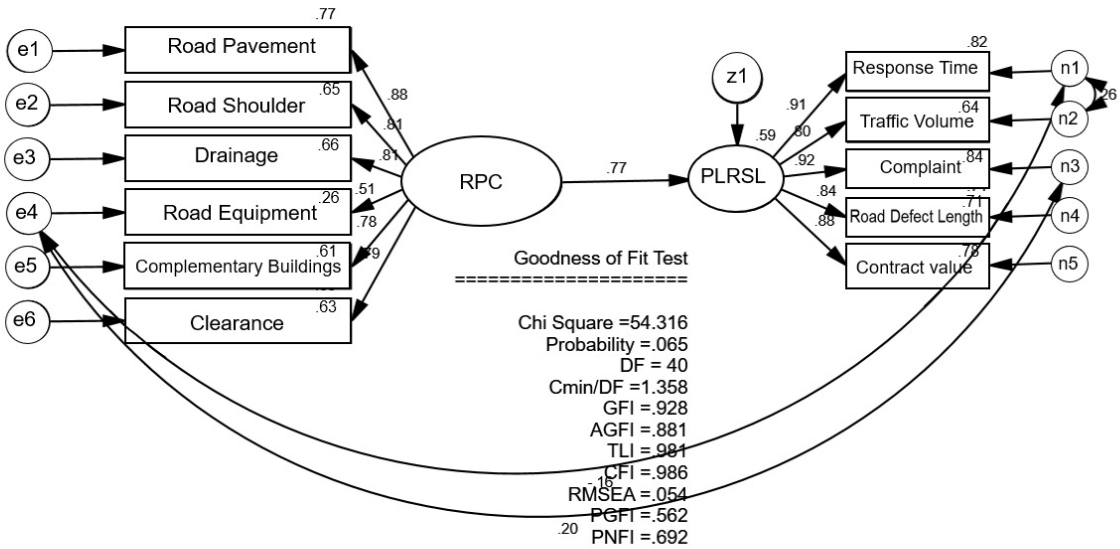

Fig. 7. The results of the full SEM model re-estimation test

In this model, the composite method or simplification of the structural equation model will combine the all-item parcel approach method and the subset-item parcel approach method [9]. In order to perform a composite or parceling item, the weight of each indicator or manifest to be composited multiplied by the weight factor acquired while estimating the CFA is added together.

The model adds a new construct, namely the RPC, which includes indicators in the form of composited components. The RPC was analyzed for its effect on PLRSL. As indicated in Fig. 7, this construct became an exogenous construct with indicators in the form of composite RPC. Fig. 7 shows the result of the chi-square test for the entire re-estimation of the SEM model. With a probability of p = 0.065 and a value of chi-square = 54.316, it can be inferred that the model is fit. Table 4 demonstrates that the other parameter values in the model already fulfill the necessary criteria.

Table 4. The Goodness of Fit (GOF) values at the initial and final models of the full SEM model

Goodness-of-Fit Index	Cut-off Value	Initial Model	Final Model
Chi-square	Expected small	78.059	54.316
Significance	≥ 0.05	0.001	0.065
Cmin/degree of freedom (df)	≤ 2.00	1.815	1.358
GFI	≥ 0.90	0.910	0.928
RMSEA	≤ 0.05 to 0.08	0.075	0.054
AGFI	≥ 0.90	0.862	0.881
TLI	≥ 0.90	0.957	0.981
PNFI	≥ 0.50	0.593	0.562
PGFI	≥ 0.50	0.727	0.692

Table 5. Standardized regression weight of relationship among constructs and indicators in the full SEM model

			Estimate
PLRSL	<---	RPC	.770
Road Pavement	<---	RPC	.880
Road Shoulder	<---	RPC	.809
Drainage	<---	RPC	.814
Road Equipment	<---	RPC	.513
Complementary Buildings	<---	RPC	.781
Clearance	<---	RPC	.791
Response Time	<---	PLRSL	.906
Traffic Volume	<---	PLRSL	.802
Complaint	<---	PLRSL	.916
Road Defect Length	<---	PLRSL	.840
Contract value	<---	PLRSL	.884

The form of the equation from the results of the full SEM model analysis can be seen in Equations 7 to 18.

$$\text{RPC} = 0.770\ \text{PLRSL} + \zeta \quad (7)$$
$$\text{Road Pavement} = 0.880\ \text{RPC} + e \quad (8)$$
$$\text{Road Shoulder} = 0.809\ \text{RPC} + e \quad (9)$$
$$\text{Drainage} = 0.814\ \text{RPC} + e \quad (10)$$
$$\text{Road Equipment} = 0.513\ \text{RPC} + e \quad (11)$$
$$\text{Complementary Buildings} = 0.781\ \text{RPC} + e \quad (12)$$
$$\text{Clearance} = 0.791\ \text{RPC} + e \quad (13)$$
$$\text{Response Time} = 0.906\ \text{PLRSL} + e \quad (14)$$
$$\text{Traffic Volume} = 0.802\ \text{PLRSL} + e \quad (15)$$
$$\text{Complaint} = 0.916\ \text{PLRSL} + e \quad (16)$$
$$\text{Road Defect Length} = 0.840\ \text{PLRSL} + e \quad (17)$$
$$\text{Contract Value} = 0.884\ \text{PLRSL} + e \quad (18)$$

where:

PLRSL : Constructs of Penalties for Late Fulfillment in Road Service Levels
RPC : Road Performance Components
ζ (zeta) : Structural error observed in an endogenous construct
e : Measurement error, related to manifest variables in exogenous constructs
n : Measurement error, related to manifest variables in endogenous constructs

The convergent validity value or factor weight about standardized regression weight is shown in Table 5. The RPC construct comprises 6 variables, while the PLRSL construct comprises 5 variables. According to the results of the analysis, the relationship between the constructs of RPC and PLRSL has a significant effect with a standard parameter of 0.770. It indicates that the construction management variables consisting of pavement factors, road shoulders, drainage, road equipment, complementary buildings, and clearances have a significant effect on PLRSL within the work area of National Road Implementation Center of Central Java and Special Region of Yogyakarta.

The results of the full SEM model analysis regarding the effect of road performance indicators on PLRSL in the research sites indicate that road performance indicators have a significant effect on PLRSL of 77.0%. This means that failure in road performance indicators will affect the PLRSL by 77%.

First, the road pavement contributes statistically significant to the road performance indicators at 88.0%. This is in line with Morecroft [27], who asserted that inadequate road maintenance and mismanagement causing delays in management will led to an accumulation of fallacies in the road network, necessitating larger costs to restore damaged roads in particular with budgeting restrictions [28-31]. Because it impacted the degree of road service, the road pavement is, therefore, the most critical component to address [32].

Second, drainage contributes statistically significantly at 81.4% to the road performance indicators. Inadequate drainage exacerbates pavement deterioration and raises annual maintenance costs [33]. Inadequate design, construction, and maintenance of drainage structures, as well as negative community behavior, are the primary causes of drainage issues.

Furthermore, the road shoulder contributes a statistically significant at 80.9% to the road performance indicators. The qualities of road shoulder have a significant impact on its performance [34]. The width of the road shoulder must be adequate to accommodate stopped cars. Wide shoulders provide temporary parking space and boost road capacity by enhancing driving convenience. Adequate shoulders can protect the pavement structure's edges from deterioration and provide the pavement with lateral support.

Meanwhile, the clearance provides a statistically significant contribution of 79.1% to the road performance indicators. Division 10 [3] stated that at the time of bidding, the contractor must be deemed to have carried out a thorough on-site inspection during the bidding period and to have known the actual conditions in the field by taking into account the traffic volume, the residual strength of the existing pavement, weather conditions, level of pavement damage, road shoulders, plants in the road space, drainage system, damage to other complementary buildings, signs condition, road markings, and other road equipment for the safety of road users [35; 36].

In addition, the statistically significant contribution of complementary buildings to the road performance indicators is 78.1%. According to Indonesian of Office of Highways [3], the maintenance work on the performance of existing road auxiliary buildings along the road included in the contract, regardless of the size or type of road auxiliary buildings, should include regular inspections of the structure's main components, preparation of detailed inspection reports, and routine cleaning of the place which is susceptible to damage if abandoned.

The road equipment factor gives a statistically significant contribution of 51.3% to the road performance indicators. One of the notions associated with road infrastructure was "self-explaining road," which referred to roads that could deliver explanations to road users through road equipment. First introduced in the Netherlands, the self-explaining road idea encouraged drivers to adopt behaviors that were consistent with road design (Theeuwes, 1998 in [17]). Using several techniques, including the most cost-effective road markings and road signs, the concept sought to provide drivers with information about impending situations in a straightforward and simple manner.

The results of the analysis of PLRSL in the research sites can be concluded that the following indicators are the determining factors for the success of PLRSL: (1) community reports/complaints, which are statistically significant at 91.6%; (2) response time, which is statistically significant at 90.6%; (3) the value of contract, which is statistically significant at 88.4%; (4) the length of the road that does not meet the road performance indicators/defect, which is statistically significant at 84.0%; and (5) statistically significant traffic volume at 80.2%.

Performance measurement and the selection of appropriate indicators are crucial for the successful establishment and implementation of a Performance-Based Maintenance Contract since performance indicators and objectives direct contractors in obtaining the desired maintenance results [37]. In addition, Tahan et al. [38] emphasized the importance of developing suitable metrics for evaluating performance-based maintenance contracts. There are instances where road administrations use incorrect performance metrics to evaluate the efficacy and efficiency of contractors. In addition, Performance-Based Maintenance Contract performance measurement has been proposed by Abu Samra et al. [39]: (1) Level of Service (LOS): the extent to which performance targets are met; (2) Timeliness of Response: response times for service requests or maintenance needs to be evaluated; (3) Safety Procedures: implementation of safety programs by contractors; (4) Quality of Services: customer perception with respect to asset conditions and contractor performance; and (5) Cost-Efficiency: cost savings (if any) obtained because of engaging contractors to perform Performance-Based Maintenance Contract services.

4 CONCLUSION

The results indicated that road performance indicators, such as road pavement, road shoulders, drainage, road equipment, complementary buildings, and clearance, have a significant effect on PLRSL, which affected the level of road service. These should be concerns with both contractors and government officials. If the contractor cannot fulfill the road performance indicators within the given response time, it will be liable to financial consequences that can result in cost overruns. Therefore, this study results are to enhance the level of road service through the achievement of road performance indicators to ensure the success of sustainable construction projects. This is essential for facilitating the management of sustainable road preservation projects and encouraging project managers to attain a high level of road service.

5 REFERENCES

[1] Direktorat Jenderal Bina Marga. (2020). Rencana Strategis Direktorat Jenderal Bina Marga 2020-2024. Dirjen Bina Marga, Jakarta.

[2] Correia, M. G., e Bonates, T. de O., Prata, B. de A., Júnior, E. F. N. (2022). An integer linear programming approach for pavement maintenance and rehabilitation optimization. International Journal of Pavement Engineering, vol. 23, no. 8, 2710–2727, DOI: 10.1080/10298436.2020.1869736

[3] Direktorat Jenderal Bina Marga. (2020). Surat Edaran Direktur Jenderal Bina Marga Nomor 16.1/SE/Db/2020 tentang Spesifikasi Umum Bina Marga 2018 untuk Pekerjaan Konstruksi Jalan dan Jembatan (Revisi 2). Dirjen Bina Marga, Jakarta

[4] Meškėnas, A., Gribniak, V., Kaklauskas, G., Sokolov, A., Gudonis, E., Rimkus, A. (2017). Experimental investigation of cracking behaviour of concrete beams reinforced with steel fibres produced in Lithuania. The Baltic Journal of Road and Bridge Engineering, vol. 12, no. 2, 82–87, DOI: 10.3846/bjrbe.2017.10

[5] Vaitkus, A., Gražulytė, J., Kleizienė, R., Vorobjovas, V., Šernas, O. (2019). Concrete Modular Pavements – Types, Issues And Challenges. The Baltic Journal of Road and Bridge Engineering, vol. 14, no. 1, 80-103, DOI: 10.7250/bjrbe.2019-14.434

[6] Durdyev, S., Ismail, S., Ihtiyar, A., Abu Bakar, N. F. S., Darko, A. (2018). A partial least squares structural equation modeling (PLS-SEM) of barriers to sustainable construction in Malaysia. Journal of Cleaner Production, vol. 204, 564–572, DOI: 10.1016/j.jclepro.2018.08.304

[7] Zhang, Y., Vennapusa, P., White, D. J. (2019). Assessment Of Designed And Measured Mechanistic Parameters Of Concrete Pavement Foundation. The Baltic Journal of Road and Bridge Engineering, vol. 14, no. 1, 37-57, DOI: 10.7250/bjrbe.2019-14.432

[8] Kineber, A. F., Othman, I., Oke, A. E., Chileshe, N., Buniya, M. K. (2021). Impact of Value Management on Building Projects Success: Structural Equation Modeling Approach. Journal of Construction Engineering and Management, vol. 147, no. 4, DOI: 10.1061/(ASCE)CO.1943-7862.0002026

[9] Hair, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Thiele, K. O. (2017). Mirror, mirror on the wall: a comparative evaluation of composite-based structural equation modeling methods. Journal of the Academy of Marketing Science, vol. 45, no. 5, 616-632, DOI: 10.1007/s11747-017-0517-x

[10] Roh, Y., Heo, G., Whang, S. E. (2021). A Survey on Data Collection for Machine Learning: A Big Data - AI Integration Perspective. IEEE Transactions on Knowledge and Data Engineering, vol. 33, no. 4, 1328-1347, DOI: 10.1109/TKDE.2019.2946162

[11] de Souza, A. C., Alexandre, N. M. C., Guirardello, E. de B., de Souza, A. C., Alexandre, N. M. C., Guirardello, E. de B. (2017). Propriedades psicométricas na avaliação de instrumentos: avaliação da confiabilidade e da validade. Epidemiologia e Serviços de Saúde, vol. 26, no. 3, 649–659, DOI: 10.5123/S1679-49742017000300022

[12] McNeish, D. (2018). Thanks coefficient alpha, we'll take it from here. Psychological Methods, vol. 23, no. 3, 412–433, DOI: 10.1037/met0000144

[13] Wang, J., Wang, X. (2019). Structural equation modeling: Applications using Mplus. John Wiley & Sons, New York.

[14] Asian Development Bank. (2018). Guide To Performance-Based Road Maintenance Contracts. Asian Development Bank, Manila.

[15] Roza, E., Sriono. (2020). Analisis Pengaruh 6 (enam) Komponen Jalan terhadap Kinerja Ruas Jalan Berbasis Aplikasi Android. Jurnal HPJI, vol. 6, no. 1, 29–42.

[16] The World Bank. (2017). Procurement of Performance-Based Management and Maintenance of Roads Output Based Service Contract. The World Bank, Washington DC.

[17] Babić, D., Fiolic, M., Babić, D., Gates, T. (2020). Road Markings and Their Impact on Driver Behaviour and Road Safety: A Systematic Review of Current Findings. Journal of Advanced Transportation, DOI: https://doi.org/10.1155/2020/7843743

[18] Hasan, M., Lu, M. (2021). Error Propagation Model for Analyzing Project Labor Cost Budget Risks in Industrial Construction. Journal of Construction Engineering and Management, vol. 147, no. 4, DOI: 10.1061/(ASCE)CO.1943-7862.0002010

[19] Nguyen, L. D., Tran, D. Q. (2021). Measurement of Fuzzy Membership Functions in Construction Risk Assessment. Journal of Construction Engineering and Management, vol. 147, no. 4, DOI: 10.1061/(ASCE)CO.1943-7862.0002015

[20] McNeish, D. (2017). Multilevel Mediation With Small Samples: A Cautionary Note on the Multilevel Structural Equation Modeling Framework. Structural Equation Modeling, vol. 24, no. 4, 609–625, DOI: 10.1080/10705511.2017.1280797

[21] Rose, N., Wagner, W., Mayer, A., Nagengast, B. (2019). Model-Based Manifest and Latent Composite Scores in Structural Equation Models. Collabra: Psychology, vol. 5, no. 1, DOI: 10.1525/collabra.143

[22] Enders, C. K., Mansolf, M. (2018). Assessing the fit of structural equation models with multiply imputed data. Psychological Methods, vol. 23, no. 1, 76–93, DOI: 10.1037/met0000102

[23] Epskamp, S., Rhemtulla, M., Borsboom, D. (2017). Generalized Network Psychometrics: Combining Network and Latent Variable Models. Psychometrika, vol. 82, no. 4, 904–927, DOI: 10.1007/s11336-017-9557-x

[24] Henseler, J. (2017). Bridging Design and Behavioral Research With Variance-Based Structural Equation Modeling. Journal of Advertising, vol. 46, no. 1, 178–192, DOI: 10.1080/00913367.2017.1281780

[25] Spławińska, M. (2019). Methodology For Determining Reliable Traffic Parameters For Current Analysis Of Performance Of Motorways And Expressways. The Baltic Journal of Road and Bridge Engineering, vol. 14, no. 1, 104–123, DOI: 10.7250/bjrbe.2019-14.435

[26] Ab Hamid, M. R., Sami, W., Mohmad Sidek, M. H. (2017). Discriminant Validity Assessment: Use of Fornell; Larcker criterion versus HTMT Criterion. Journal of Physics: Conference Series, vol. 890, 012163, DOI: 10.1088/1742-6596/890/1/012163

[27] Morecroft, J. (2020). System Dynamics, Systems Approaches to Making Change: A Practical Guide. Springer London, 25–88, DOI: 10.1007/978-1-4471-7472-1_2

[28] Ramachandran, S., Rajendran, C., Amirthalingam, V. (2019). Decision Support System for the Maintenance Management of Road Network Considering Multi-Criteria. International Journal of Pavement Research and Technology, vol. 12, no. 3, 325–335, DOI: 10.1007/s42947-019-0039-7

[29] Samith, A., Bandara, S. (2021). Development of evaluation criteria for routine maintenance work in performance-based road maintenance contracts. Proceedings of the Transportation Research Forum 2021, p. 27-28.

[30] Torres-Machi, C., Pellicer, E., Yepes, V., Chamorro, A. (2017). Towards a sustainable optimization of pavement maintenance programs under budgetary restrictions. Journal of Cleaner Production, vol. 148, 90–102, DOI: 10.1016/j.jclepro.2017.01.100

[31] Ahmed, S., Vedagiri, P., Krishna Rao, K. V. (2017). Prioritization of pavement maintenance sections using objective based Analytic Hierarchy Process. International Journal of Pavement Research and Technology, vol. 10, no. 2, 158–170, DOI: 10.1016/j.ijprt.2017.01.001

[32] Olita, S., Diomedi, M., Ciampa, D. (2020). Alternative Formula for Rigid Pavement Stress Calculation in Corner Load Conditions. The Baltic Journal of Road and Bridge Engineering, vol. 15, no. 5, 59–79, DOI: 10.7250/bjrbe.2020-15.507

[33] Qiao, Y., Dawson, A. R., Parry, T., Flintsch, G., Wang, W. (2020). Flexible Pavements and Climate Change: A Comprehensive Review and Implications. Sustainability, vol. 12, no. 3, 1057, DOI: 10.3390/su12031057

[34] Sutradhar, R., Pal, M. (2020). Assessment of Pavement Shoulder Condition in Rural Roads. International Journal on Emerging Technologies, vol. 11, no. 1, 91–100.

[35] Wysokowski, A. (2020). Impact of Traffic Load Randomness on Fatigue of Steel Bridges. The Baltic Journal of Road and Bridge Engineering, vol. 15, no. 5, 21–44, DOI: 10.7250/bjrbe.2020-15.505

[36] Leonavičienė, T., Pukalskas, S., Pumputis, V., Kulešienė, E., Žuraulis, V. (2020). Investigation of Factors That Have Affected the Outcomes of Road Traffic Accidents on Lithuanian Roads. The Baltic Journal of Road and Bridge Engineering, vol. 15, no. 5, 1-20, DOI: 10.7250/bjrbe.2020-15.504

[37] Glas, A. H., Henne, F. U., Essig, M. (2018). Missing performance management and measurement aspects in performance-based contracting. International Journal of Operations & Production Management, vol. 38, no. 11, 2062–2095, DOI: 10.1108/IJOPM-09-2016-0571

[38] Tahan, M., Tsoutsanis, E., Muhammad, M., Abdul Karim, Z. A. (2017). Performance-based health monitoring, diagnostics and prognostics for condition-based maintenance of gas turbines: A review. Applied Energy, vol. 198, pp. 122–144, DOI: 10.1016/j.apenergy.2017.04.048

[39] Abu Samra, S., Osman, H., Hosny, O. (2017). Optimal Maintenance and Rehabilitation Policies for Performance-Based Road Maintenance Contracts. Journal of Performance of Constructed Facilities, vol. 31, no. 1, DOI: 10.1061/(ASCE)CF.1943-5509.0000928

Paper submitted: 24.08.2022.

Paper accepted: 14.10.2022.

This is an open access article distributed under the CC BY 4.0 terms and conditions