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Evaluation of the Sustainability Indicator for Road Infrastructure in Indonesia

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Abstract The quality of road infrastructure in Indonesia is ranked 64th out of 137 countries studied behind Singapore which was placed 2nd, Malaysia 23rd, Brunei Darussalam 33rd, and Thailand 59th. Therefore, the main objective of this research was to analyze the sustainability indicators for the road infrastructures in the country and also to evaluate the effect of these indicators based on the perceptions of civil servants and contractors. The process involved conducting a literature review to identify the variables and indicators while a survey was used to gauge the perceptions of the respondents. The data obtained were analyzed using the Structural Equation Modeling with a Partial Least Square approach. The results showed the most influential indicator for existing and expected road infrastructures were road lighting with a loading factor of 0.904 and environmental assessment process with 1.000 respectively according to the government employees. Meanwhile, the construction company employees believed it was the environmental assessment process with 1.000 as well as pedestrian access, bicycle route, and public transportation with 1.000 respectively. The usefulness of this research is to produce indicators that can be used by infrastructure managers to improve their performance by seeking the development and maintenance of the right infrastructure so that it can be used according to the needs of the user.

Keywords Sustainability Indicator, Road Infrastructure, Indonesia Road Indicator

1. Introduction

The government of most developing countries usually focuses on accelerating sustainable development while eradicating poverty and fighting climate change [1-3]. Infrastructure development is, however, one of the main factors to achieve these three goals. Indonesia is one of the developing countries observed to be accelerating its infrastructure development to facilitate the movement of people and goods [4]. The process is required to be based on sustainability principles [5, 6]. Sustainability in this sense refers to achieving a better quality of life under present economic, social, and environmental conditions while considering the future.

The lack of optimal infrastructure is observed to be reducing the competitiveness of the Indonesian economy. This is indicated by the Global Competitiveness Report (2018) which ranked the country as the 75th in terms of road infrastructure quality behind those from the same region such as Malaysia, Brunei Darussalam, and Thailand among 140 countries surveyed [7].

[8, 9] also highlighted the importance of implementing the concept of sustainability into infrastructure projects due to its positive impact on the environment [10]. This is, however, observed not to be fully effective in Indonesia due to the fact that each city has its own specific limiting factors. Therefore, this research aimed to analyze the road infrastructure indicators in Indonesia based on their sustainability and evaluate the influence of these

indicators based on the perceptions of government and construction company employees.

2. Literature Review

There are existing and newly developed tools currently being used in the decision-making process which involves estimating the short, medium, and long-term outcomes of investments across social, economic, and environmental dimensions [5, 6, 11-18].

Most of these tools are, however, not useful for end-users. Therefore, this research reviewed relevant literature and uses a quantitative method through a survey conducted using a questionnaire to identify and evaluate the sustainability factors in road infrastructure [19-21].

The issue of sustainability is a pressing topic in both industrialized and developing countries [22]. [23] said road projects can have a positive effect on road users when considering the environment, improve traffic safety, support sustainable economic growth.

3. Research Method

The literature review was used to categorize the research variables into two which are the latent and manifest variables [24, 25]. The 6 latent and 20 manifest variables identified in this study are, therefore, presented in Table 1.

The questionnaire was also divided into two sections with the first consisting of questions related to demographic characteristics while the second focuses on those related to the variables and other factors measured using the Likert scale which ranges from a very positive to a very negative score. The respondents were selected using a non-probability sampling method considering their working background in road infrastructure development in Indonesia. Those selected for this research were experts with extensive experience varying from regulating offices and government sectors to road infrastructure contractors. The Government Employees (GEs) include officials from the Public Works office of the Jakarta Province Government and the Transportation and Infrastructure Technology Center while the Construction Company Employees (CEs) include individuals working in a state-owned construction company.

A descriptive analysis and Partial Least Square–Structural Equation Modelling (PLS-SEM) were used in this study. The descriptive analysis was used to evaluate the demographics of the respondents while PLS-SEM was applied to analyze the small number of samples which was made to be the minimum value of the ten times the greatest number of the indicators used for the latent variables [26]. This approach was used in this study based on the fact that it does not require assuming the sample distribution. Meanwhile, the first step in the PLS-SEM was to test the outer model in order to determine the connection between latent variables and their indicators. This involved a convergent and discriminant validity as well as the composite reliability test. The next step was the analysis of the sample using the structural model test or inner model to visualize the connection between each latent variable based on the research theory. It is important to note that the latent variables were measured using R-square and t-test values while Smart PLS 3.0 was applied for analysis purposes. The research model based on the latent variables and indicators is, therefore, presented in Figure 1.

Table 1. Specific data of Column/Row

Variable	Indicator	Code		CEEQUAL (2018)	CEEQUAL (2017)	Umer et al. (2016)	Avenue & Minato (2012);	Muench, Anderso, Bevan (2010)	Litman (2008)
		Existing	Expectation						
Economy and Resource Efficiency	Contractor Guarantee	E1	HE1			√		√	
	Cost analysis to reach economic efficiency	E2	HE2			√	√	√	√
	High durability road	E3	HE3			√			
Social	Pedestrian access, bicycle path, and designated lane for public transport	S1	HS1			√	√	√	√
	Intelligent Transportation Systems (ITS)	S2	HS2			√			
	Urban landscape	S3	HS3			√		√	
Environment 1	Tree replacement	SU1	HSU1	√					
	Energy efficiency	SU2	HSU2		√	√	√	√	
	Warm Mix Asphalt (WMA)	SU3	HSU3			√		√	
	Cool pavement	SU4	HSU4			√		√	
Environment 2	Permeable road area	T1	HT1			√		√	
	Zero Runoff	T2	HT2		√	√		√	
	Reusing road waste	T3	HT3	√	√	√		√	
	Recycled road material	T4	HT4	√	√	√		√	
Project Requirement	Environmental review process	P31	HP31				√	√	√
	Low impact road construction	P32	HP32				√	√	
	Road maintenance	P33	HP33		√			√	
Safety	Safety audit	K1	HK1			√	√	√	√
	Street lighting	K2	HK2		√				
	Road guard rail	K3	HK3	√					

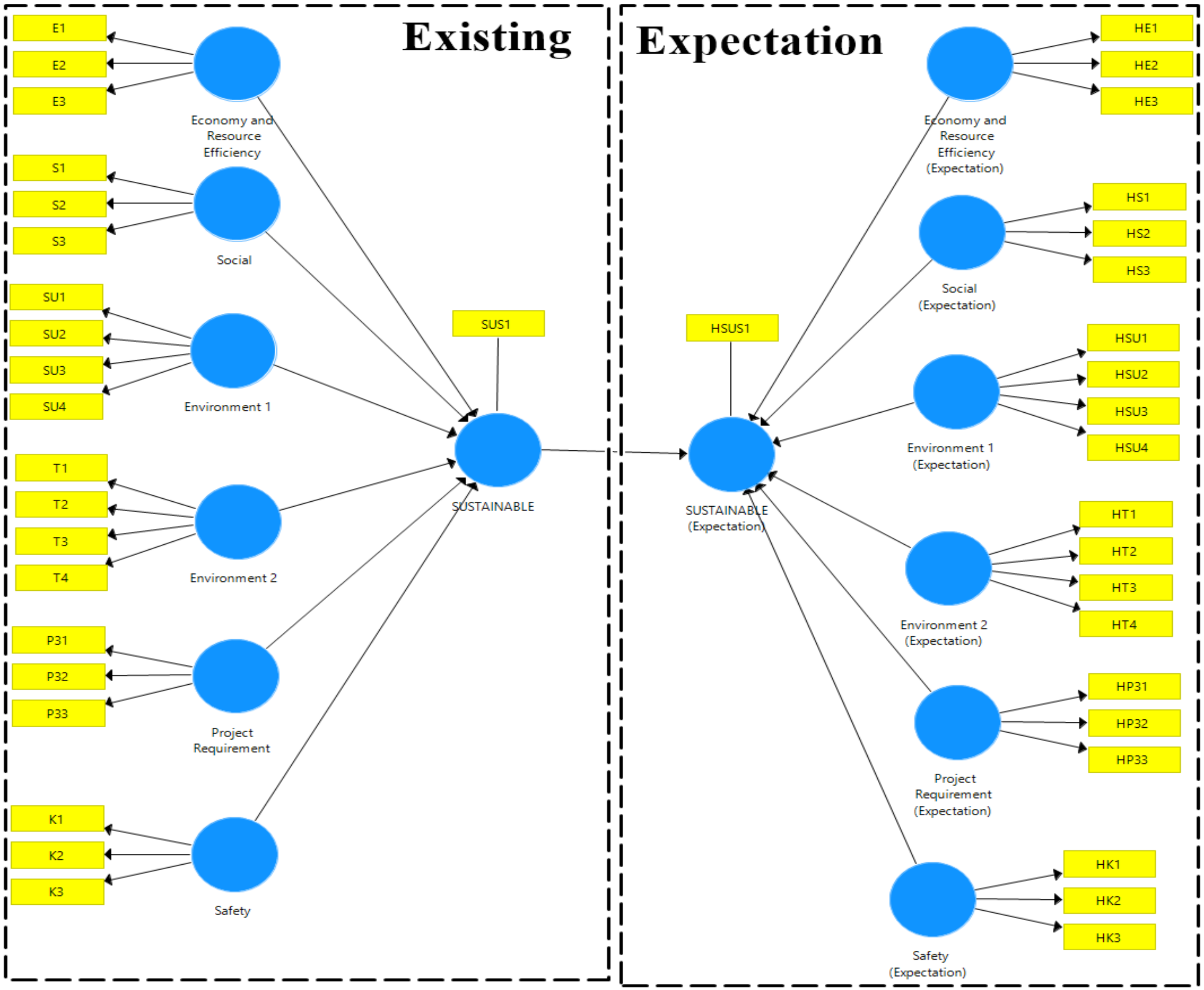

Figure 1. Research model diagram

4. Result and Discussion

The respondents were categorized according to the two job types and these include 49 respondents in GEs and 40 in CEs with some of the characteristics analyzed discovered to include gender, age, education level, and work experience as indicated in Table 2.

4.1. Existing Condition

A large number of GEs strongly disagreed that T4 (recycled road material) is a sustainable road infrastructure indicator but they strongly agreed with E3 (road durability). Meanwhile, most of the CEs strongly disagreed K2 (road lighting) is an indicator but strongly agreed with SU1 (tree replacement) as shown in Table 3.

Table 2. Respondent demographics

		(GE) (Number of people)	(CE) (Number of people)
Gender	Male	35	28
	Female	14	12
Age	<25 years	0	12
	25–35 years	22	18
	36–45 years	8	7
	46–55 years	13	2
	>55 years	6	1
Education level	Bachelor	19	26
	Postgraduate	28	12
	Doctor	2	2
Work experience	<5 years	1	25
	5–10 years	24	5
	11–15 years	6	4
	16–20 years	0	5
	>20 years	18	1

Table 3. Respondents' responses to road infrastructure existing conditions

No	Code	GE (%)					CE (%)				
		SA	A	LA	D	SD	SA	A	LA	D	SD
1	E1	10.2%	53.1%	26.5%	10.2%	0.0%	22.5%	25.0%	22.5%	30.0%	0.0%
2	E2	10.2%	40.8%	38.8%	10.2%	0.0%	7.5%	22.5%	20.0%	27.5%	22.5%
3	E3	28.6%	49.0%	22.4%	0.0%	0.0%	22.5%	30.0%	27.5%	20.0%	0.0%
4	S1	4.1%	32.7%	28.6%	22.4%	12.2%	30.0%	17.5%	25.0%	10.0%	17.5%
5	S2	8.2%	28.6%	42.9%	18.4%	2.0%	15.0%	20.0%	17.5%	25.0%	22.5%
6	S3	12.2%	32.7%	34.7%	20.4%	0.0%	27.5%	20.0%	32.5%	20.0%	0.0%
7	SU1	2.0%	26.5%	36.7%	30.6%	4.1%	37.5%	20.0%	22.5%	20.0%	0.0%
8	SU2	0.0%	38.8%	42.9%	16.3%	2.0%	25.0%	30.0%	30.0%	15.0%	0.0%
9	SU3	2.0%	24.5%	59.2%	14.3%	0.0%	10.0%	22.5%	22.5%	25.0%	20.0%
10	SU4	0.0%	12.2%	42.9%	40.8%	4.1%	25.0%	32.5%	22.5%	15.0%	5.0%
11	T1	0.0%	32.7%	42.9%	24.5%	0.0%	10.0%	17.5%	17.5%	30.0%	25.0%
12	T2	0.0%	26.5%	38.8%	30.6%	4.1%	20.0%	22.5%	10.0%	20.0%	27.5%
13	T3	2.0%	40.8%	12.2%	42.9%	2.0%	27.5%	10.0%	20.0%	27.5%	15.0%
14	T4	0.0%	4.1%	49.0%	44.9%	2.0%	20.0%	27.5%	20.0%	22.5%	10.0%
15	P31	10.2%	49.0%	32.7%	6.1%	2.0%	22.5%	30.0%	25.0%	22.5%	0.0%
16	P32	14.3%	57.1%	28.6%	0.0%	0.0%	32.5%	17.5%	22.5%	27.5%	0.0%
17	P33	2.0%	42.9%	44.9%	10.2%	0.0%	25.0%	32.5%	27.5%	15.0%	0.0%
18	K1	0.0%	40.8%	36.7%	22.4%	0.0%	30.0%	25.0%	12.5%	32.5%	0.0%
19	K2	6.1%	44.9%	32.7%	14.3%	2.0%	17.5%	10.0%	20.0%	32.5%	20.0%
20	K3	2.0%	20.4%	38.8%	38.8%	0.0%	17.5%	25.0%	15.0%	20.0%	22.5%

SA: Strongly Agree, A: Agree, LA: Low Agree, D: Disagree, SD: Strongly disagree

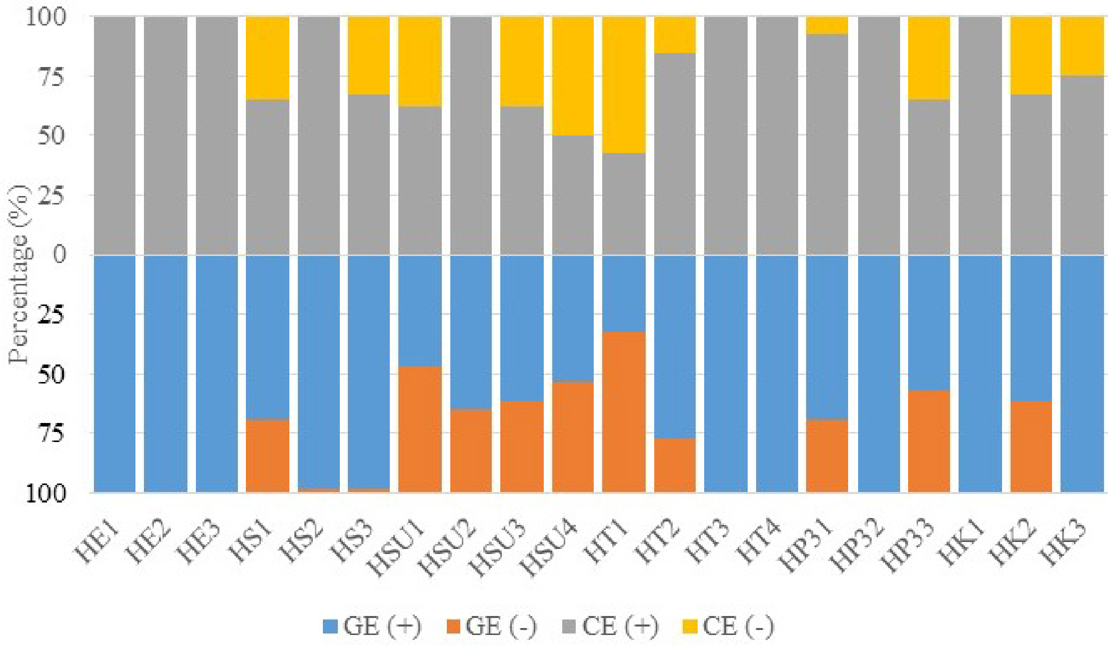

Figure 2. Value of responses to road infrastructure expectation condition

Table 4. AVE value and reliability value in the GE model

Variable	EXISTING		EXPECTATION	
	AVE value	**Composite Reliability**	**AVE value**	**Composite Reliability**
Economy and Resource Efficiency (E) / (HE)	1.000	1.000	1.000	1.000
Social (S) / (HS)	1.000	1.000	0.666	0.797
Environment 1 (SU) / (HSU)	1.000	1.000	0.561	0.718
Environment 2 (T) / (HT)	1.000	1.000	0.576	0.731
Project Requirement (P3) / (HP3)	0.711	0.831	1.000	1.000
Safety (K) / (HK)	0.705	0.826	1.000	1.000

4.2. Expected Condition

The respondents provided both positive and negative responses in this section. This was observed from the highly negative response of the GEs to HSU1 (tree replacement) and CEs for HT1 (permeable area) as indicated in Figure 2. Meanwhile, positive responses were provided on “Economy” and “Resources Efficiency” by the GES while the CEs provided negative responses on these variables. The two groups also responded contradictorily to the “Environment 1” with the CEs observed to indicate positive responses while the GEs tended to disagree with its use as an indicator for sustainability. However, both groups provided a negative response to “Social”, “Safety” and “Environment 2” variables and 96% of GEs also responded negatively to “Recycled Road Material” while they both responded positively to “Project Requirement”.

4.3. Model Analysis with Partial Least Square – Structural Equation Modeling (PLS-SEM)

The PLS-SEM analysis has two sub-models which are the measurement and structural models with 40 manifest, 12 latent, and 2 mediator variables used to measure sustainability.

4.3.1. GE respondents

The correlation of the convergent validity correlated with the principal indicates the manifest variable of a construct has a high influence. This is usually observed from the loading factor value being greater than 0.70 or higher than 0.60 during the development phase. This means a manifest variable which does not have a loading factor value > 0.60 is required to be eliminated from the model and a recalculation was conducted using the PLS algorithm up to the moment all the loading factor values surpass 0.60. The loading factors from the second run after those that did not meet the requirement have been eliminated are presented in Figure 3.

The discriminant validity value in AVE for each variable was observed to have met the requirement as indicated by the value which is > 0.50. This means the requirement of discriminant validity was satisfied and the variables are qualified to be used for further tests as shown in Table 4.

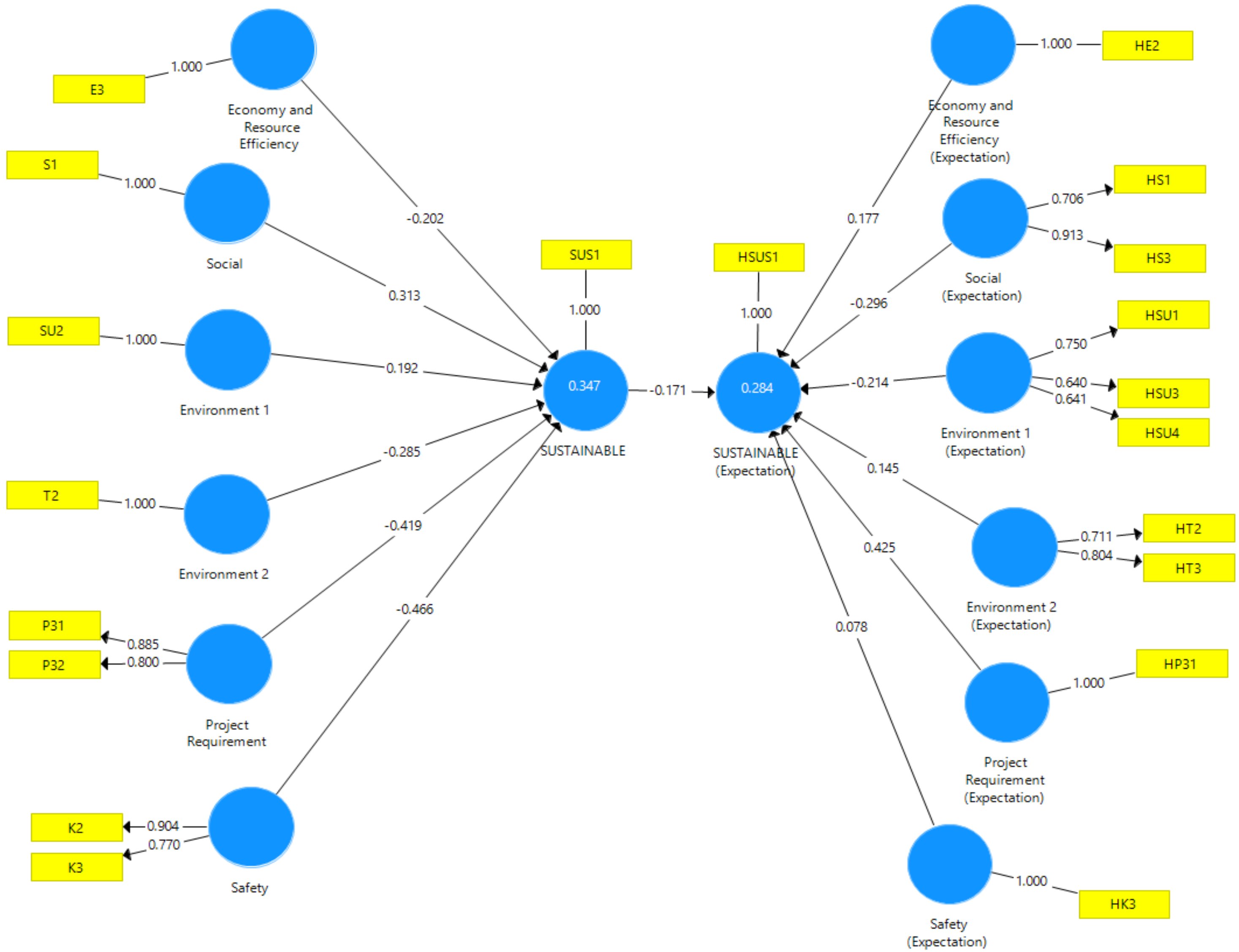

Figure 3. Model flow diagram of the second run (GE)

Table 5. Inter variable coefficients of the GE model against existing conditions and expectations

Existing						Expectation					
Code	**Variable**	***t* statistics**	**Code**	**Indicator**	**Loading Factor**	**Code**	**Variable**	***t* statistics**	**Code**	**Indicator**	**Loading Factor**
K → Sustainable	Safety	2.766	K2	Street lighting	0.904	HP3 → Sustainable (Expectation)	Project Requirement	3.411	HP31	Environmental review process	1.000
			K3	Road guard rail	0.770	HS → Sustainable (Expectation)	Social	1.601	HS3	Urban landscape	0.913
S → Sustainable	Social	2.362	S1	Pedestrian access, bicycle path, and designated lane for public transport	1.000				HS1	Pedestrian access, bicycle path, and designated lane for public transport	0.706
P3 → Sustainable	Project Requirement	2.269	P31	Environmental review process	0.885	HSU → Sustainable (Expectation)	Environment 1	1.212	HSU1	Tree replacement	0.750
			P32	Low impact road construction	0.800				HSU4	Cool Pavement	0.641
T → Sustainable	Environment 2	1.978	T2	Zero run off	1.000				HSU3	Warm Mix Asphalt (WMA)	0.640
E → Sustainable	Economy and Resource Efficiency	1.449	E3	High durability road	1.000	HE → Sustainable (Expectation)	Economy and Resource Efficiency	1.157	HE2	Cost analysis to reach economic efficiency	1.000
SU → Sustainable	Environment 1	1.057	SU2	Energy efficiency	1.000	HT → Sustainable (Expectation)	Environment 2	0.982	HT3	Reusing road waste	0.804
									HT2	Zero run off	0.711
						HK → Sustainable (Expectation)	Safety	0.437	HK3	Road guard rail	1.000

In addition to the validity, the latent variables were also tested for reliability to prove the accuracy and consistency of the measuring instruments. In PLS-SEM, Composite Reliability with a value greater than 0.70 was used for this purpose and the results showed that all the variables met the requirements and were considered reliable to be used in the model.

The next stage after the convergent validity, discriminant validity, and composite reliability was providing results for the structural model through the analysis of the correlation for all estimated paths. The strength of the structural model predictions was, therefore, determined using the R-Square values of the endogenous variables and t-statistics.

An R-square value of 0.347 was obtained for the sustainable variable and this means only 34.7% of its variability can be explained by the variability of the six latent variables while the remaining 65.3% is explained by other variables apart from the ones studied in this research. Moreover, the R-square value of the effect of sustainable (expected) on the six latent variables was 0.284 and this means only 28.4% of its variability can be explained by the variability of the six latent variables while the remaining 71.6% is explained by other variables apart from the ones studied in this research.

The most influential variables among the 20 manifest variables tested for the existing and expected conditions were determined using the loading factor values of each manifest and latent variable. The t-test values showed that each latent variable has a greater influence compared to the manifest as indicated in Table 5. The GEs were observed to have viewed “Safety” as the most influential sustainable variable and street lighting was discovered to be the indicator with the highest influence as indicated by its high loading factor compared to the others in the safety variable. Moreover, the GEs also considered "Project Requirement" as the most influential variable for the expected infrastructural development while the environmental review process was selected as the indicator with the highest influence as indicated by its high loading factor when compared with the others in the project requirement variable as indicated in Table 5.

4.3.2. CE respondents

Figure 4 shows the loading factor values obtained from the second run after the removal of those that did not meet the requirement from the model.

Table 6 shows the discriminant validity fulfilled the requirements as indicated by the AVE value for each variable which is greater than 0.50 and this means the variables are eligible for further tests. Moreover, each variable was also observed to have fulfilled the requirement for the composite reliability as indicated by the values greater than 0.70 and this also means all the variables are considered reliable to be used in the model.

Table 6. AVE and reliability values in the CE model

Variable	EXISTING		EXPECTATION	
	AVE Value	***Composite Reliability***	**AVE Value**	***Composite Reliability***
Economy and Resource Efficiency (E) / (HE)	1.000	1.000	0.658	0.793
Social (S) / (HS)	1.000	1.000	0.666	0.797
Environment 1 (SU) / (HSU)	1.000	1.000	1.000	1.000
Environment 2 (T) / (HT)	0.636	0.776	0.567	0.720
Project Requirement (P3) / (HP3)	1.000	1.000	1.000	1.000
Safety (K) / (HK)	1.000	1.000	1.000	1.000

The model designed for the influence of sustainability on the six latent variables provided an R-square value of 0.290 and this indicates only 29% of its moderator variability was explained by the variability of the six latent variables while the remaining 71% is explained by other variables not studied. Meanwhile, the model for the effect of expected sustainability produced 0.336 and this means 33.6% of its moderator variability can be explained by the variability of the six latent variables while the remaining 66.4% is explained by other variables not used in this research.

The t-test value and loading factor for the moderator variable (sustainable) presented in Table 7 show “Project Requirement” as the variable with the highest influence for the existing condition of the infrastructure based on the perception of the contractors. “Environmental Review Process” was found to be the most influential indicator due to its high loading factor value when compared to the others in the project requirement variable. Meanwhile, “Social” was found to be the most influential variable for the expected sustainability by these contractors, and “Pedestrian, bicycle, and public transportation access” was discovered to be the most influential indicator based on its loading factor value which is higher than those obtained for the others in the “social” variable.

Figure 4. Model flow diagram for the second run (CE)

Table 7. Inter-variable coefficients of the CE model against existing and expected conditions

Existing					
Code	**Variable**	***t* statistics**	**Code**	**Indicator**	**Loading Factor**
P3 → Sustainable	Project Requirement	2.494	P31	Environmental review process	1.000
SU → Sustainable	Environment 1	1.450	SU3	Warm Mix Asphalt (WMA)	1.000
S → Sustainable	Social	1.186	S3	Urban landscape	1.000
T → Sustainable	Environment 2	0.907	T2	Zero run off	0.864
			T3	Reusing road waste	0.725
K → Sustainable	Safety	0.605	K3	Road guard rail	1.000
E → Sustainable	Economy and Resource Efficiency	0.337	E3	High durability road	1.000

Expectation					
Code	**Variable**	***t* statistics**	**Code**	**Indicator**	**Loading Factor**
HS → Sustainable (Expectation)	Social	2.321	HS1	Pedestrian access, bicycle path, and designated lane for public transport	1.000
HT → Sustainable (Expectation)	Environment 2	1.942	HT1	Permeable road area	0.845
			HT2	Zero run off	0.647
HK → Sustainable (Expectation)	Safety	0.761	HK3	Road guard rail	1.000
HSU → Sustainable (Expectation)	Environment 1	0.648	HSU1	Tree replacement	1.000
HE → Sustainable (Expectation)	Economy and Resource Efficiency	0.637	HE2	Cost analysis to reach economic efficiency	0.852
			HE3	High durability road	0.768
HP3 → Sustainable (Expectation)	Project Requirement	0.499	HP32	Low impact road construction	1.000

5. Conclusions

The objective of this study was to evaluate the factors influencing existing and expected road infrastructure in Indonesia with a focus on the sustainable aspects based on the perceptions of government employees (GEs) and contractors (CEs).

The results from the questionnaire distributed showed the GEs provided the highest positive response to the E3 factor (high road durability) regarding the existing condition while the highest negative rating was given to the T4 indicator (recycled road material). Meanwhile, the highest positive rating for the expected condition was given to the HE1 indicator (contractor guarantee) while the most negative value was for the HSU4 indicator (cool pavement).

The CEs showed the most positive response for the existing condition was with the SU1 indicator (tree replacements) while the highest negative response was for the K2 indicator (street lighting). Meanwhile, they believe the highest positive indicators for the expected condition were HE3 (high durability road) and HP32 (low impact road construction) indicators while the most negative was HT1 (permeable road area).

The GEs also believed the most influential variable for the existing condition of road infrastructure was “Safety” and street lighting was perceived to be the indicator with the highest influence as indicated by its high loading factor value of 0.904 when compared with the others in the “Safety” variable. Meanwhile, “Project requirements” was perceived by these GEs to be the variable with the highest influence to enhance the quality of expected road infrastructure while the environmental review process was believed to be the most influential indicator as shown by its high loading factor value of 1,000 when compared with the others used in developing the “Project Requirement” variable.

The CEs viewed “Project Requirement” as the most influential variable for the existing infrastructure while the environmental review process was believed to be the most influential indicator as shown by its high loading factor value of 1,000 when compared with the others used in developing this variable. Meanwhile, “Social” was perceived by these CEs to be the variable with the highest influence to enhance the quality of expected road infrastructure while “pedestrian, bicycle, and public transport access” was found to be an indicator with the highest influence as indicated by its high loading factor value of 1,000 when compared with the others used in developing the “Social” variable.

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