Jurnal Teknologi

Full paper

Strategic Road Performance Model: An Approach to Sustainable Facilities Management

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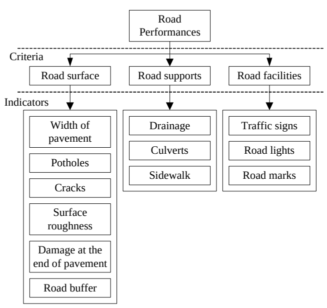
Article history

Received : 15 August 2014
Received in revised form :
15 October 2014
Accepted :15 November 2014

Graphical abstract



Abstract

The concept of sustainability has been seen as a part, or even a core component of facilities management. In a broader context, sustainable facilities management has a very important position for its contribution to sustainable development. Nowadays, the road infrastructure performance management system also emphasizes on the importance of sustainability to optimize the function of the roads in supporting the mobilization and transportation of people and goods. The use of performance indicators has been recommended to achieve sustainability in the road management. This study is aimed at developing a Strategic Road Performance Model (SRPM) for Padang City of Indonesia which has been stipulated as a national disaster zone. A benchmark study conducted to identify as many as twenty performance indicators belongs to the three criteria used in previous studies. The three rounds of the Delphi method are done to obtain road performance indicators. A number of twelve indicators are generated from the third round of that Delphi method. Analytical Hierarchy Process (AHP) is then performed to prioritize the indicators. Finally, this study generates the Strategic Road Performance Model (SRPM) based on performance indicators.

Keywords: Indicators; road performance; strategic road performance model; facilities management

1.0 INTRODUCTION

Facilities management (FM) has developed as a new management discipline in many countries during the 1980s and 1990s [1-3]. Awang *et al*. suggests that the FM sector has gained increasing interest in public sectors around the world [4]. FM is known for its contribution to organizational success [5-13]. According to Rimbalova and Vilcekova, FM is a dynamic field that is related to the general public [14]. As a new discipline, FM is also often associated with the built environment [15, 16].

One of the important aspects of FM is sustainability. Shah states that the concept of sustainability has been seen as a part, or even a core component of FM [17]. Recently, the concept of sustainable facilities management (SFM) has been emerging as the integration of sustainability aspects and FM. Abbas found that sustainability is an important issue for organizations in managing facilities [18]. Nielsen and Galamba explain that SFM is seen as a concept that is very important because of its significant contribution to sustainable development [19]. It is supported by Hodges explaining that the integration of sustainability and FM can become an instrument that brings substantial benefits to a succession of sustainable development [20].

The linkage between FM and organizational performance has been seen of the reciprocal function. Ameratunga states that in fact there is no standard performance measurement construction in FM [21]. Associated with the statement, McDougall and Hinks suggests that the FM approach to performance measurement has historically tended to focus on financial measures in almost all the business, which then extends to customer satisfaction and quality [22]. It is based on the recognition that the financial approach is inadequate to show the effectiveness of the work. Hinks and McNay previously have presented a framework of management for the FM performance assessment using key performance indicators identified by the Delphi method to assess the performance of the FM [23].

The concept of SFM has been studied in a variety of forms of facilities management. One of the infrastructure facilities studied very seriously related to the performance and function in achieving SFM is the question of roads. Performance and maintenance are the two keywords that are often encountered in various studies to achieve SFM in the field of road infrastructures. Kamil *et al*. have developed the performance indicators to realize of green infrastructure in case of natural disaster zones in West Sumatra, Indonesia [24]. Previously, Kamil *et al*. had developed a model of the database and Web-GIS application to monitor the performance of roads [25] as well as formulated strategies and policies for road maintenance system in achieving SFM [26, 27].

This study is aimed at developing a Strategic Road Performance Model (SRPM) for Padang City of Indonesia which has been stipulated as a national disaster zone. The development of the model is based on performance indicators, where the identification and prioritization of performance indicators are done by using a combination of the Delphi method and Analytical Hierarchy Process (AHP). The resulting model is expected to be an approach to SFM in road infrastructures.

■2.0 RESEARCH METHODOLOGY

A benchmark study conducted to identify performance indicators has been used in previous studies. The results are shown in Table 1.

Table 1 Performance indicators used in previous studies

Indicators	Researchers
Width of pavement	Haryanti [28]
Potholes	Haryanti [28], Tamin *et al*. [29], Zietlow [30], Kashiwagi *et al*. [31], Transportation Research Board [32], Stankevich *et al*. [33], Queiroz [34]
Cracks	Haryanti [28], Zietlow [30], Kashiwagi *et al*. [31], Stankevich *et al*. [33], Queiroz [34], Berkland and Bell [35], Panthi [36]
Surface roughness	Haryanti [28], Tamin *et al*. [29], Zietlow [30], Kashiwagi *et al*. [31], Transportation Research Board [32], Queiroz [34], Panthi [36]
Unflat	Haryanti [28], Tamin *et al*. [29], Panthi [36]
Damage at the end of pavement	Haryanti [28], Stankevich *et al*. [33], Berkland and Bell [35]
Road buffer	Haryanti [28], Zietlow [30], Queiroz [34]
Drainage	Haryanti [28], Tamin *et al*. [29], Zietlow [30], Stankevich *et al*. [33], Queiroz [34]
Culverts	Haryanti [28], Tamin *et al*. [29], Stankevich *et al*. [33]
Traffic signs	Haryanti [28], Tamin *et al*. [29], Zietlow [30], Stankevich *et al*. [33], Berkland and Bell [35]
Guardrail	Haryanti [28], Tamin *et al*. [29], Transportation Research Board [32], Stankevich *et al*. [33], Berkland and Bell [35]
Speed of road users	Tamin *et al*. [29]
The height of plant/grass	Zietlow [30], Transportation Research Board [32], Stankevich *et al*. [33], Queiroz [34], Berkland and Bell [35]
Trees covering the road	Berkland and Bell [35]
Foreign elements in main roads	Zietlow [30], Stankevich *et al*. [33], Queiroz [34]
Pile of snow	Transportation Research Board [32]
Billboard	Stankevich *et al*. [33]
Road marks	Haryanti [28], Stankevich *et al*. [33], Berkland and Bell [35]
Road groove	Zietlow [30], Kashiwagi *et al*. [31], Transportation Research Board [32], Queiroz [34]
Thickness of asphalt	Zietlow [30]

A total of three rounds of Delphi are conducted to identify indicators. The indicators are grouped into three criteria according to Kamil *et al*., i.e. road surface, road support and road facilities [24]. The expert respondents involved are in amount of five people representing government, consultants, contractors and academicians. Respondents were asked to determine the appropriate indicators to road conditions of Padang City by using a questionnaire. In the first-round of Deplhi, a reduction of eight indicators from twenty indicators is presented in the questionnaire. But also, there is an addition of three indicators according to the respondents in accordance with road conditions of Padang City. So the first round of Delphi produces fifteen indicators. However, at this stage there has not yet reached a consensus among respondents.

The second-round of Delphi aims at classifying the indicators into a valid group and determines the performance parameters of these indicators. At this stage, there is a reduction of three indicators, so that produced twelve indicators in accordance with the conditions of the Padang City based on opinion of the respondents. In this second round, consensus has not been achieved so that there should be a third-round of Delphi. The consensus among the respondents has been reached at the third round, where there are twelve agreed indicators. Thus, the performance indicators identified for the roads in the Padang City numbered twelve indicators.

Prioritization of indicator then is performed by using Analytical Hierarchy Process (AHP). This prioritization aims at determining the weight of each indicator as a basis for treatment level of the road management. At this stage, a survey using a questionnaire is also conducted. A total of four expert respondents are involved in the survey. The result of the analysis is the priority of indicators is modeled in Strategic Road Performance Model (SRPM).

■3.0 RESULTS AND DISCUSSION

3.1 Performance Indicators for Road Management System

From the three rounds of Delphi, 12 performance indicators were generated for roads in the Padang City were incorporated into the three criteria, as shown in Figure 1.

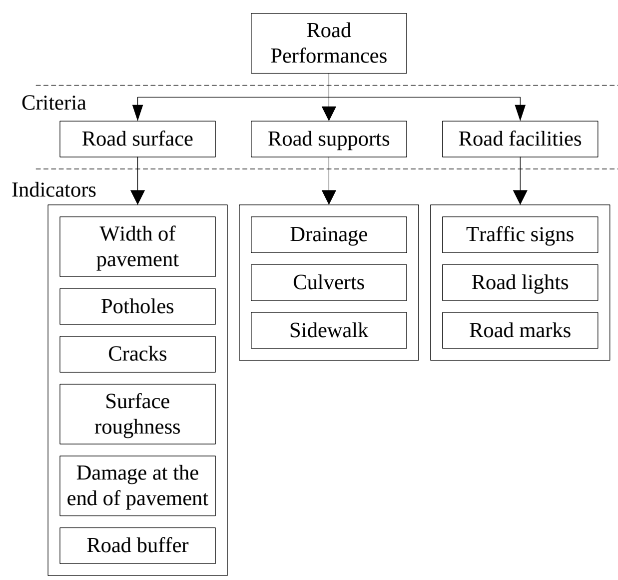


Figure 1 Performance indicators for road management systems

Figure 1 shows that all performance indicators for road management system are directly related to the technical aspects of the physical conditions of the road. Tamin *et al*. have proposed that potholes and traffic signs can be used as specified performance indicators for unpaved national road's performance-based contracts in Indonesia [29]. This is supported by Kasiwhagi *et al*. stating that the potholes, cracks and roughness are typical performance measures used in performance-based contracts [31]. Furthermore, Stankevich *et al*. suggests that potholes, cracks and roughness should be viewed as performance indicator that must be eliminated to achieve routine performance-based maintenance contracts [33]. Queiroz adds that potholing and cracking are an indicator that is used to model the road deterioration, so it needs to be managed well [34]. In other frameworks, Panthi uses cracks and roughness as the two performance criteria to estimate the cost of road maintenance [36].

Pavement has been studied as one of the aspects in measuring and assessing performance based road contracts [33, 35]. Tamin *et al*. suggests that the drainage and culverts become a necessity that must be managed optimally to realize a reliable road infrastructure [29]. According to them, specific issues related to performance-based contracts financing in Java are caused partly by the availability of a minimum drainage. Stankevich *et al*. informed that the management has given good drainages in improving the quality of the road on State Highway 5 to New Plymouth, New Zealand [33].

3.2 Prioritization of Performance Indicators

Analytical Hierarchy Process (AHP) is used to prioritize performance indicators. This prioritization aims at determining the weight of each indicator as a basis for treatment level of the road management. A survey using questionnaires was conducted to ask the expert respondents to state preferences for indicators and their relationship. AHP is implemented with the following steps: (1) create a matrix of pair wise comparisons for each criterion and indicator; (2) calculate the weight of the criteria and indicators; and (3) calculate the Consistency Ratio (CR). Based on pair wise comparisons and CR weight calculation, the combined weighting can only be done for the assessment of the two respondents who had a CR rate above 10%, they are the respondents from the government and consultant. The results of the combined weighting of the both respondents for criteria are shown in Table 2 and the result of the assessment of indicator weights is shown in Table 3.

Table 2 Combined weighting of respondents for criteria

Criteria	Weight		Combined Weighting
	Respondent 1	Respondent 2	
Road surface	0.49	0.60	0.54
Road supports	0.31	0.20	0.25
Road facilities	0.20	0.20	0.20
Total	**1.00**	**1.00**	**0.99**

Table 3 Result of the assessment of indicator weights

Criteria	Weight of Criteria	Indicators	Weight of Indicators	Main Weight of Indicators	Maximum Assessment	Values
Road Surface	0.54	Width of pavement	0.17	0.0931	100	9.31
		Potholes	0.18	0.0997	100	9.97
		Cracks	0.16	0.0891	100	8.91
		Surface roughness	0.10	0.0517	100	5.17
		Damage at the end of pavement	0.22	0.1173	100	11.73
		Road buffer	0.14	0.0783	100	7.83
Road Supports	0.25	Drainage	0.41	0.1034	100	10.34
		Culverts	0.41	0.1034	100	10.34
		Sidewalk	0.17	0.0422	100	4.22
Road Facilities	0.20	Road signs	0.33	0.0651	100	6.51
		Road marks	0.27	0.0531	100	5.31
		Road lights	0.33	0.0651	100	6.51
Total Value of Road Performance						96.14

Based on Table 2, the criterion of the road surface has the greatest combined-weight values. This is because there are six indicators incorporated in the criteria that influence the value of the sum of the weights. Table 3 shows that the indicators of drainage and culverts have the greatest weights that have the same value, while the indicator of surface roughness has the smallest weight. The main weight of indicators is the multiplication of the weights of indicators and weights of criteria. The main weight of indicators is then multiplied by the maximum assessment to obtain the value of each indicator. Based on the value of the indicator in Table 3, then the priority indicators are shown in Table 4.

Table 4 shows that the indicator of damage at the end of the pavement has the greatest value based on weighting and maximum assessment. This is understandable because the pavement is an important treatment to the physical road. Several previous studies have shown that the type and model of pavement greatly affect the quality of the roads that will have an impact on the life of roads, the smoothness of traffic and possible accidents. Ullas *et al*. suggested that damage to the pavement is a complex problem involving not only structural fatigue but also many functional difficulties of pavement [37]. The damage occurred as a form of interaction between traffic, climate, materials and time. Availability of adequate drainage and culverts as physical support facilities clearly determine the level of reliability of the roads. According to Rokade *et al*., pavement system incorporated with good drainage can be expected to provide a longer design life of the pavement section [38].

Table 4 Priority of indicators

Indicators	Values
Damage at the end of pavement	11.73
Drainage	10.34
Culverts	10.34
Potholes	9.97
Width of pavement	9.31
Cracks	8.91
Road buffer	7.83
Road signs	6.51
Road lights	6.51
Road marks	5.31
Surface roughness	5.17
Sidewalk	4.22

3.3 Performance Indicators for Strategic Road Performance Model (SRPM)

By using selection and priorities rules, 12 performance indicators for road management systems were identified. These 12 indicators are: (a) Damage at the end of pavement; (b) Drainage; (c) Culverts; (d) Potholes; (e) Width of pavement; (f) Cracks; (g) Road buffer; (h) Road signs; (i) Road lights; (j) Road marks; (k) Surface roughness; and (l) Sidewalk.

SRPM proposed in this study is fully modeled based on performance indicators. The concept of sustainability is expected applied in the facilities management can be achieved by managing and maintaining the performance indicators. The technical aspects embedded in each performance indicator require serious treatment and should be a top priority. Abigo *et al*. stated that in order to achieve sustainable development in facilities management, sustainability must be embedded in the second phase of the strategic, the tactical and operational phase of the facilities management [39]. Moving to a broader context in the field of road infrastructure, Tekie stated that the management system must be sustainable, affordable and appropriate to the needs of decision-making and financial resources as well as manpower resources [40]. Schwaab and Thielmann added that the sustainable roads need to provide economic efficiency, ecological stability, and social justice without exception [41].

■4.0 CONCLUSION

This study has identified and prioritized twelve performance indicators for road management system which is then modeled in Strategic Road Performance Model (SRPM). Through a benchmark study on previous researches, followed by three rounds of Delphi, performance indicators are identified and then prioritized by Analytical Hierarchy Process (AHP). Model SRPM can be written as follows:

SRPM = f(Damage at the end of pavement; Drainage; Culverts; Potholes; Width of pavement; Cracks; Road buffer; Road signs; Road lights; Road marks; Surface roughness; Sidewalk).

Acknowledgement

The authors would like to thank the Directorate General of Higher Education, Ministry of Education and Culture of Republic of Indonesia for the financial support and research grant.

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