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A Study to Develop Critical Success Factors of Roads Maintenance Management System for Sustainable Facility Management

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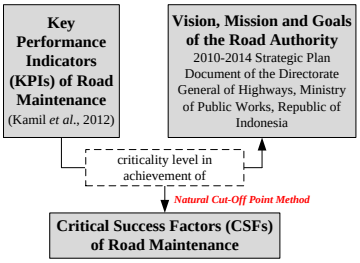
Graphical abstract



Abstract

The issues of sustainability in road maintenance management have been widely discussed in recent years. In some countries the maintenance of roads were based on selected indicators or commonly known as key performance indicators. In some countries such as Indonesia the allocation of budget and road maintenance planning were based on the age of these roads. The budget for and the planning of roads based on age have resulted in poor road conditions in Indonesia. The main objective of this study is to develop a sustainable road maintenance and management model (SRMM model) for the city of Padang, West Sumatrea that are in consonant with the vision, mission and goals of road authority towards meeting sustainable road maintenance management program. Using data obtained from selected roads in that city, after reviews of literature to identify key factors that contributed to the sustainable maintenance and management of roads, an opinion survey was conducted. Eleven experts in the field of road infrastructure and facilities management were selected as respondents. These experts were asked to identify the key factors that contributed to the quality of road maintenance management. Using the cut-off point approach, ten KPIs listed from the reviews are connected with the vision, mission and goals of the Directorate General of Highways, Ministry of Public Works Republic of Indonesia as the road authority. Respondents were asked to provide an assessment of the criticality level of the KPIs to the vision, mission and goals. Based on the calculation results, ten CSFs were identified to develop the (SRMM) model. The use of SRMM model based on statistically selected CSFs by the road authority is anticipated to help develop a reliable and sustainable road maintenance management system in Padang.

Keywords: KPIs; CSFs; road maintenance; sustainable facility management

1.0 INTRODUCTION

Tucker *et al.,* and Sarpin and Yang suggests that facilities management (FM) can be regarded as a new management discipline that has been discussed and driven since the 80s [1, 2]. Organisations such as the International Facility Management Association (IFMA) and The British Institute of Facility Management (BIFM) have been promoting the facility management program for several years. In essence, the focus of facilities management is the function of the facilities and their contribution to organizational success [3-6]. According Awang *et al.,* over the past few years, there has been an increasing interest towards facilities management in various public organizations worldwide [7].

The issues of sustainable management of facilities have been discussed significantly in recent years. Further, Tucker *et al.,* explained that the scope of facilities management are vast [1]. In the context of maintenance management, Sarpin and Yang found that integrating sustainability concept in facility management practices such in the maintenance and management of roads can provide great benefits in addressing related issues [2]. It is supported by Hodges and Rimbalova and Vilcekova [8, 9]. Meanwhile, Nielsen and Galamba and Hakkinen and Nuutinen explains that access to literatures on sustainable facility management (SFM), are available, although most are related to the theme of sustainable development not management[10, 11].

Amongst the facilities that contribute significantly to the economic and social well being of a nation is road. According to Ahmed, maintenance is an important post-work activity after road infrastructure development is completed [12]. However, failure to maintain the roads efficiently has resulted in the roads being left in poor conditions. In some countries such as Indonesia, there is a need to strategized the timing of maintenance activities with the timing of funds allocated by the authority since funds for maintenance are allocated periodically, based on the age of the facilities not on the needs. Thompson and Visser regarded it as the

main issue since the maintenance schedule is not related to the strategy of releasing the economic benefits through cost saving but rather using age of facilities as a guide to prepare the maintenance strategy for facilities such as roads [13].

Several previous studies present different methods to assess the road maintenance strategies. Kamil *et al*., formulated third road maintenance strategies by using the maintenance awareness model [14]. Meanwhile, Kamil *et al*., also develop a model for road maintenance policy through the integration of fuzzy logic and Analytical Hierarchy Process (Fuzzy-AHP) where the model developed were based on perceived importance [15]. Others, using the key performance indicators (KPIs) to develop the maintenance schedule [16-19].

Using CSFs, this study aims at developing a sustainable road maintenance management model. The approach adopted involves the process of identifying a list of KPIs from reviews and linked to the vision, mission and goals of the organization. In this case, the organization is the Directorate General of Highways, Ministry of Public Works Republic of Indonesia as road authority. It is expected that the use of CSFs would be a useful tool in maintaining and managing the performance of roads.

2.0 RESEARCH METHODOLOGY

The case studies selected for the purpose of this research is the road network within the City of Padang, West Sumatera. Ten major roads in that city were identified to serve as the object of research and are assumed to be representative of all roads in the City of Padang and West Sumatera Province.

A review was conducted to obtain data representing KPIs identified from reviews as input to the determination of CSFs. The next step is to identify the vision, mission and goals of Directorate General of Highways, Ministry of Public Works Republic of Indonesia as the road authority. The vision, mission and goals was based on that listed in the 2010-2014 Strategic Plan Document of the Directorate General of Highways, Ministry of Public Works Republic of Indonesia. Then a focus group (FGD) comprises of experts in the field of road infrastructure was formed and discussion amongst these FGD members was conducted to select the relevant KPIs. The FGD members were purposefully selected based on their experience of more than three years in the field of road infrastructure and expertise.

The first FGD discussion was held on July 25, 2011 in the City of Padang. A research questionnaire was designed and the FGD members attending the meeting were asked to provide an assessment of the criticality level of the KPIs to the achievement of the vision, mission and goals of road authority. The critical level is measured with a modified Likert scale and used previously by Khandelwal and Ferguson [20]. The value used is Critical (C), Important (I), Required (N) and Required (UN). The data is then processed using natural cut-off point method to identify the CSFs.

Research framework is shown in Figure 1.

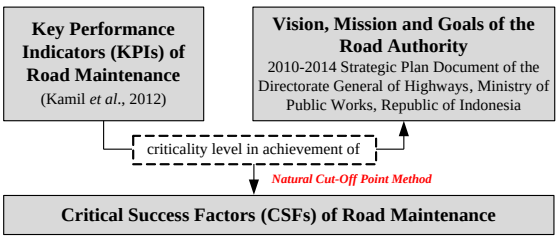


Figure 1 Research framework

Based on Figure 1, it is seen that the KPIs become a major input in determining the CSFs. Through its relationship with the vision, mission and objectives as indicated by the road authority over the level of criticality assessment, weight and score of each KPI is computed using natural cut-off point. The result is CSFs are determined by the cut-off point.

3.0 RESULT AND DISCUSSION

3.1 KPIs for Road Maintenance System

From that FGD meeting, fifteen KPIs were selected which is perceived as representing factors the road maintenance system in the City of Padang. These fifteen KPI for road maintenance system in the City of Padang, are: i) Average traffic speed - The average speed is that which is associated with the impact caused by the rider. Kloeden *et al*., shows that the decrease in speed by drivers is very important to make the system more secure trip, ii) Availability of call center - Act as an interface between the authority and the road users such as listening to their questions, complaints and responding to their correspondence [21]. iii) Implementation of maximum capacity limit - Determination of the maximum capacity limit for the road needs to be done considering the number of vehicles that exceed the capacity were identified as having an impact on road conditions. iv) Measurement of road life, v) Measurement of surface roughness, plot and textures of road - Roughness, grain and texture as the physical condition of the road are related to each other. According to Johnsson and Odelius, road roughness and texture impact on noise and vibration [22]. Measurement method proposed by Yero, where measurements can be carried out based on the depth of the texture and roughness index to determine the condition of the road [23]. vi) Satisfaction toward road transportation - Public satisfaction with the road as one mode of transportation is a condition that will eventually arise if the roads are well-maintained and in good condition, vii) Good condition of roads, viii) Travel smoothness, ix) Safety of road repair, x) Noise due to road users, xi) Routine and periodic maintenance - Routine and periodic maintenance normally associated with efforts pavement, xii) Availability of road supporting facilities - Facilities can be either road culverts, traffic lights, street median and road signs. Yun *et al*., asserts that road facilities are much related to the safety of the rider; it is part of the necessity to managed roads systematically [24]. According to Aigbe *et al*., the deteriorating condition of roads and non-functioning of most of these facilities is a testament to the low level of road improvements by government agencies (road authority), xiii) Single accidents, xiv) Pestilent accidents, and xv) Number of accidents - Atubi and Nury *et al*., found that traffic accidents and deaths that occurred is a serious problem throughout the world [25-27].

3.2 Determination of CSFs

Assessing the data obtained from respondents was analyzed using natural cut-off point method to identify the CSFs. CSFs calculation is shown in Table 1.

Table 1 The calculation of cut-off point to determine CSFs

Indicators	Frequence of Critical Levels				Weight of Critical Level				Total Weight of Critical Level	Total Respondent	Average
	C	I	N	UN	C (4)	I (3)	N (2)	UN (1)			
Average traffic speed	8	60	27	4	32	180	54	4	270	11	24,55
Availability of call center for questions, correspondence, and public complaints	3	20	54	22	12	60	108	22	202	11	18,36
Implementation of maximum capacitylimit	40	41	6	12	160	123	12	12	307	11	27,91
Measurement of road life	25	35	26	13	100	105	52	13	270	11	24,55
Measurement of surface roughness, plot and textures of road	13	46	29	11	52	138	58	11	259	11	23,55
Satisfaction toward road transportation	10	49	30	10	40	147	60	10	257	11	23,36
Good condition of road	26	57	15	1	104	171	30	1	306	11	27,82
Travel smoothness	23	63	12	1	92	189	24	1	306	11	7,82
Safety of road repair	20	49	27	3	80	147	54	3	284	11	25,82
Noise due to road users	7	38	36	18	28	114	72	18	232	11	21,09
Routine and periodic maintenance	32	52	14	1	128	156	28	1	313	11	28,45
Availability of road supporting facilities	10	61	25	3	40	183	50	3	276	11	25,09
Single accidents	7	34	43	15	28	102	86	15	231	11	21,00
Pestilent accidents	12	49	28	10	48	147	56	10	261	11	23,73
Number of accidents	8	53	28	10	32	159	56	10	257	11	23,36

The discussion on the output (see Table 1) to identify the responses from selected respondents on the factors that are considered important in developing a sustainable road maintenance and management model (SRMM model) is presented hereby. The study found that the respondents were of the opinion, implementation of the maximum capacity limit is critical (C) towards achieving the vision, mission and goals of the Indonesia Road Authority (frequency score 40). Availability of call center for questions, correspondence and public complaints were judged to be not critical (3 critical votes or assessment frequencies). Availability of road support facilities (road furniture), good road conditions (good condition of the road, travel smoothness and routine and periodic maintenance) are judge as essential. Full result is presented in Table 1.

The assessment of importance is further enhanced by assigning quantity score for each scale. A score of 4 were assigned for critical scale, for importance, the score is 3 and for required and non-required the weight is 2 and 1 respectively. To calculate the weighted scored by each indicator the observed score is multiplied by the weigh being assigned. The average scores for each indicator or variable is based on the total weighted score divided by the number of respondents. The highest average score is 28,45 and the lowest score is 18,36, the cut of points for the distribution can be calculated as follows:

$$\begin{aligned} \text{cut-off point} &= (\text{average highest score} + \text{average lowest score}) / 2 \\ &= (28{,}45 + 18{,}36) / 2 \\ &= 23{,}41 \end{aligned}$$

According to Tam and Tummala, the selection rule to identify relevant indicators for the SRMM Model using cut-off point method is that only variables (or indicators) with its average weight above the cut-off point average or mean (23,41) will be considered as relevant indicators. Those whose average weighted score fall below the means, will be considered as irrelevant [28].

3.3 CSFs for SRMM Model

Using this selection rule, ten indicators with the average value above the cut-off point defined as CSFs for the SRMM Model were identified. These ten CSFs are: a) Average traffic speed; b) Implementation of maximum capacitylimit; c) Measurement of road life; d) Measurement of surface roughness, plot and textures of road; e) Good condition of roads; f) Travel smoothness; g) Safety of road repair; h) Routine and periodic maintenance; i) Availability of road supporting facilities; and j) Pestilent accidents.

Routine and periodic maintenance variable obtained the highest average value, namely 28,45. This indicates that the budget allocation for both types of maintenance is indeed a crucial sustainable maintenance and management of roads. The road requires maintenance at any time, either regularly or periodically. The physical condition of the road over time is affected by various factors, such as loading by vehicles, weather, accidents and others. Road authorities are required to work optimally in maintaining roads and monitored their conditions at all times. Although the routine and periodic maintenance is very dependent on financing, these activities however are of public interest.

Implementation of maximum capacity limit obtain an average value of 27,91. It shows that the implementation of the maximum capacity limit rules for road needs to be enforced with efficacy Although in some streets have been placed weighbridge, but still these roads encountered vehicles (especially trucks of goods) which tonnage exceeding the maximum limit allowed. The suggestion is that authorities need to work in an integrated way with the nexus and the police to address this.

Measurement of road life can be done using various methods and life cycle costing methods is the recommended one. Various cost elements have been identified to measure the age of the road based on the recommendation suggested in a previous research by Kamil *et al*., and Kamil *et al*., [29, 30]. Monitoring and obtaining data that indicates surface roughness, plot and the textures of the road is found to be important, since this variable obtained a score of 23,55. Measurement of surface roughness, grain and texture of the road needs to be done to ensure that the roads are in a physical condition that is expected by the user. Road authorities need to

monitor the physical path periodically. This action will be associated when routine and periodic maintenance is performed. Previous study by Kamil *et al*., using the Delphi method even make the road surface as one of a group of indicators to measure the performance of road infrastructure [31]. this indicates that the finding of the current study as per the importance of monitoring the physical conditions of roads is consistent with the outcome of earlier research and thus must be considered and taken seriously when allocating the budget.

Maintenance activities are basically aimed at maintaining the physical condition of road in order such roads in good condition. Good conditions of road will have an impact on the good road performance. This condition must be monitored at all times. Previous study by Kamil *et al*., has designed a model for monitoring performance of road based on database and Geo Information Systems (GIS) [32]. These models can provide information as to the performance of road. Implications of the good condition of the road is that it eases smooth travel. Safety of road repairment obtain an average value of 25,82. Here we can see that security become indispensable to the maintenance phase. The goal of the road authority to keep roads facilitates safe and smooth travel is an important variable to be considered when preparing budget allocation.

Availability of road (furniture or supporting facilities that obtained an average value of 25,09 shows that is an important variable in the SRMM Model. Road supporting facilities such as road culverts, traffic lights, road median, road signs and other very necessary to ensure the safety of drivers when crossing the road. Drainage is also a very important road facility. This finding is supported by a previous research by Kamil *et al*., [33].

Pestilent accidents obtain an average value of 23,73 which is the lowest average value for CSFs. Despite being last in the hierarchy of acceptable CSFs based on the magnitude of the average value in this study, this variable need to be noted by the road authorities and road users themselves since in pestilent accidents is the result of poor condition of the road.

■4.0 CONCLUSION

This research, using selected roads in the City of Padang, West Sumatera had identified ten CSFs in promoting a sustainable road maintenance and management system. Through an assessment of critical level of the KPIs to the achievement of the vision, mission and goals of the Directorate General of Highways, Ministry of Public Works Republic of Indonesia as the road authority, the CSFs were identified using the natural cut-off point method. The SRMM Model can thus be written as follows:

SRMM = f (Average traffic speed; Implementation of maximum capacitylimit; Measurement of road life; Measurement of surface roughness, plot and textures of road; Good condition of roads; Travel smoothness; Safety of road repair; Routine and periodic maintenance; Availability of road supporting facilities; and Pestilent accidents).

These ten CSFs provide the guideline in preparing the budget and strategy that can be considered in sustainable maintaining and managing of roads in the City of Padang.

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