Sustainable Maintenance Model for Infrastructure in Egypt

S. Hasan, I. Beshara

Abstract**—**Infrastructure maintenance is a great challenge facing sustainable development of infrastructure assets due to the high cost of passive implementation of a sustainable maintenance plan. An assessment model of sustainable maintenance for highway infrastructure projects in Egypt is developed in this paper. It helps in improving the implementation of sustainable maintenance criteria. Thus, this paper has applied the analytical hierarchy processes (AHP) to rank and explore the weight of 26 assessment indicators using three hierarchy levels containing the main sustainable categories and subcategories with related indicators. Overall combined weight of each indicator for sustainable maintenance evaluation has been calculated to sum up to a sustainable maintenance performance index (SMI). The results show that the factor "Preventive maintenance cost" has the highest relative contribution factor among others (13.5%), while two factors of environmental performance have the least weights (0.7%). The developed model aims to provide decision makers with information about current maintenance performance and support them in the decision-making process regarding future directions of maintenance activities. It can be used as an assessment performance tool during the operation and maintenance stage. The developed indicators can be considered during designing the maintenance plan. Practices for successful implementation of the model are also presented.

Keywords**—**Analytical Hierarchy Process, AHP, assessment performance model, KPIs for sustainable maintenance, sustainable maintenance index.

I. Introduction

INFRASTRUCTURE projects have a great contribution to economic and social growth. However, its remarkable environmental, social, and economic impacts play a significant role in achieving sustainable development. Sustainable maintenance is defined as the process of continuous improvement of maintenance processes, considering the environmental, social, and economic aspects; to increase the efficiency and safety of operations, resources and employed staff, as well as decreasing the operation cost [1]. Sustainability is the new necessary paradigm which involves the integration of the economic, environmental and social perspective at both operational and strategic levels. The operational level includes tools, techniques and methodologies to enable sustainability in design, while the strategic level refers to organizational issues such as strategy, structure and culture of a company.

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II. Background

There are researches that have addressed sustainable infrastructure maintenance. Reference [2] revealed that a sustainable maintenance approach infrastructure could be achieved using the following benchmarked parameters: Applying maintenance concepts, integrating approach in infrastructural design and construction, empowering workers, clear communication of maintenance policy to all stakeholders, incorporating eco-friendly construction material, formulation of quality assurance team, site work environment, improvement of environmental standard, provision of incentives (financial and non-financial), teaching of maintenance personnel/crew, provision of budget for routine maintenance, effective communication of information, delegation of responsibility, work schedule should be flexible, and financial allocation while [3] has introduced five categories for sustainable maintenance for critical infrastructure. The study revealed that sustainability maintenance is an ongoing process throughout the service life of infrastructure to maintain its negative impacts within the desired limits and ideally enhance its sustainability performance. The categories are: Minimizing adverse impacts of the infrastructure on people through maintenance, keeping the maintenance operations sustainable, sustainable material allocation throughout the maintenance process, environmental protection and restoration in maintenance operations, and sustainable leadership and management of infrastructures maintenance. Dimensions of sustainable maintenance have been discussed in [4]; the study stated that the social dimension is an important aspect to be added to the sustainable maintenance categories to analyze the maintenance and service efficiency. In addition, the study assured the importance of a balance between those three dimensions, economic, environmental and social, for achieving effective sustainable maintenance. The social dimension of sustainable maintenance is very complex and contains many elements. The elements include safety and health of employees, working hours (number of hours an employee works per week), payments, financial resources spent on training and investments in new equipment and software supporting people in their work.

Many models for assessment of sustainable maintenance have been developed. The principles of the system dynamics approach in evaluating the sustainability performance of highway infrastructure projects through invşestigating the dynamic factors affecting the performance of indicators during the construction and operation stage has been explored [5]. The dynamic approach captures a holistic view of the evaluation system being assessed; integrating collectively three dimensions of sustainable development principles. The approach can support analysis of the impact of dynamic interactions between various factors on the sustainability performance, which allows project decision-makers to identify how a particular level of project sustainability performance is obtained. A rating system for green bridges that consists of five classes to judge their status with respect to sustainability through exploring a list of important criteria that affect the sustainability of bridge projects has been introduced [6]. The degree of importance and weights of these criteria are determined using Simos' procedure. A framework for measuring sustainable maintenance performance (SMP) for Malaysian automotive companies has been developed, It enables clear alignment between maintenance function and corporate objectives by defining objectives and key performance measures at each organizational level; corporate, tactical and functional. The framework of SMP measurement systems for automotive companies proposed 78 measures; these measures are broken down into three levels; 15 measures at the corporate level, 20 measures at the tactical level and 43 measures at the functional level [7]. Reference [8] identified and categorized the most often used sustainable Key Performance Indicators (KPIs) and analysis methods of their evaluation in the metallurgical industry. The comparative study of KPIs in the metallurgical industry allowed identifying the most important categories and indicators in the economic, environmental, and social sustainability dimensions. It also proved that the AHP method is a suitable tool for the aggregate evaluation of sustainability. A model and procedure for assessing maintenance from the perspective of sustainable manufacturing requirements through integrating three sustainability dimensions (economic, social and environmental) with balance scorecard perspectives as a basis to develop the model of maintenance sustainability performance assessment have been developed [4]. For the model developed, the assessment procedure based on the paradigm of aggregate assessment to integrate the sustainability-related aspects into the conventional maintenance management has been applied. The model incorporates fuzzy integrals with fuzzy measure methodologies. Fuzzy multiple criteria to evaluate sustainable maintenance in the rubber industry were introduced. Interpretive Structural Modeling (ISM) method was used to determine the interrelationships of KPIs identified for sustainable maintenance evaluation. The Fuzzy Analytic Network Process (FANP) method was applied to arrange the importance weight to each indicator of KPIs in the evaluation model [9].

The AHP is a method that converts subjective opinions to qualitative values, as its use reflects the experiences of practitioners and key decision-makers and ensures the consistency of the decision. The strength of AHP is its ability to quantify and compare subjective/qualitative variables functions, where it operates through a series of pairwise comparisons that compare the factors affecting the decision making based on the preferences of respondents, and ensures the consistency of the calculated weights [10], [11]. AHP has been applied for developing assessment models for different types of infrastructure. A condition assessment for underground water mains using AHP has been developed [12]. It was used to generate the relative weights of each factor representing the relative importance of this factor among other factors that affect the water main condition. Reference [13] applied both AHP and ANP (Analytic Network Process) for developing a model working as a support tool to make strategic decisions in the field of railway transportation in Italy. That model helps to select the most promising alternative among different infrastructural projects. An organization performance assessment model to assist in identifying the potential improvement areas has been developed [11]. This model was based on integration between AHP and linear regression model.

Based on the literature review, a research gap was identified in the performance assessment of sustainable maintenance in highway infrastructure projects in Egypt; the following limitations were derived:

- Lack of integrating the sustainable maintenance dimensions.
- Combining balance between three pillars of sustainable maintenance (economic, social, and environmental).
- Lack of a benchmarking assessment model of sustainable maintenance.

Considering this research gap, this paper presents a model and procedures for assessing maintenance from the perspective of sustainable requirements for highway infrastructure projects in Egypt using the AHP method for the aggregate evaluation of sustainability. The goal of sustainable maintenance assessment is to provide decision makers with information about current maintenance practices and support them in the decision-making process regarding future directions of maintenance activities.

III. Methodology

In order to develop a model that assess the maintenance sustainability, the following research methodology has been followed and is represented in Fig. 1.

– Identification of KPIs of sustainable maintenance in infrastructure projects, covering the three dimensions of sustainability, through literature review and interview with industry experts;
– Collecting data using a questionnaire survey to investigate the importance of selected indicators, and identifying the challenges and requirements for implementing sustainable maintenance in Egypt;
– Data analysis by initial calculation of a Relative Importance Index (RII);
– Conducting AHP for weighting and ranking the assessment indicators of sustainable maintenance;
– Consistency test for developed weights; and,
– Developing a model for assessing the performance of sustainable maintenance of highway infrastructure projects.

IV. Data Collection

A. Identification of KPIs of Sustainable Maintenance

Based on the literature review, the common KPIs of sustainable maintenance evaluation have been summarized and categorized through three levels. Level 1 has incorporated the three main categories of sustainable maintenance: environmental, economic, and social. Each of them has sub categories in level 2. Furthermore, the subcategories have been divided into 26 indicators, as shown in Table I. Then, the identified KPIs have been investigated by interviewing industry experts to specify whether all selected KPIs are compatible with highway infrastructure projects and to determine the importance of the identified KPIs in evaluating sustainable maintenance.

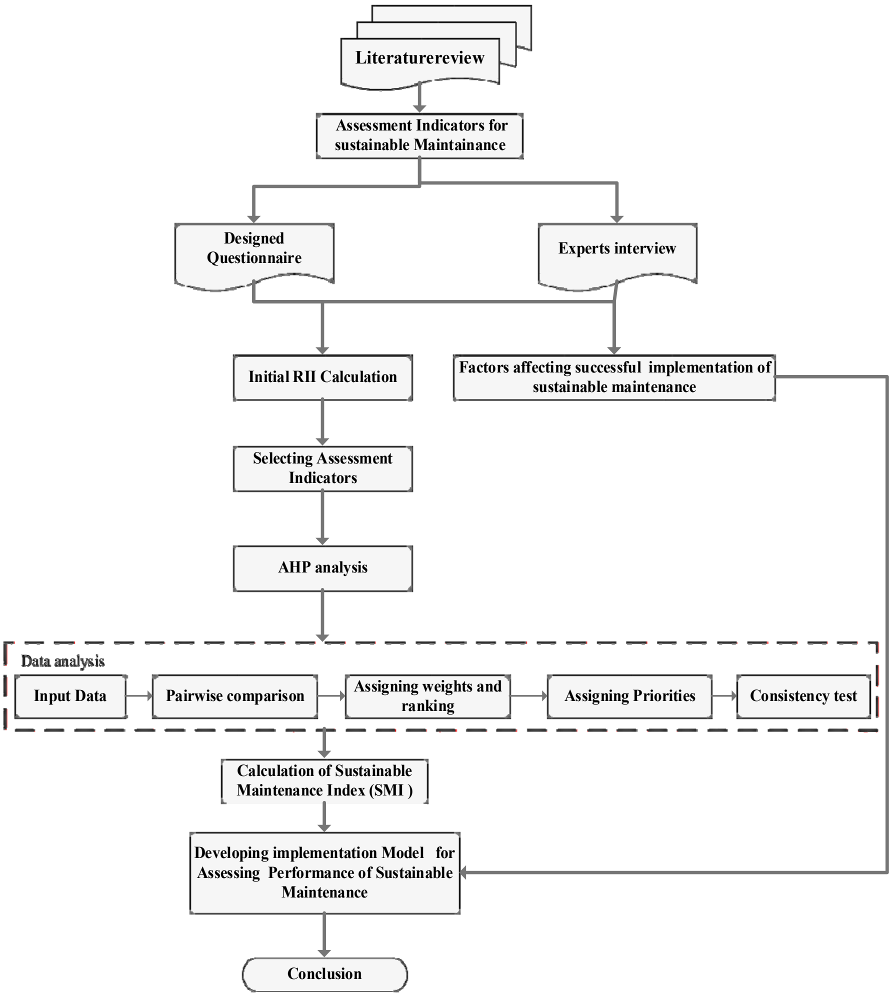

Fig. 1 Research methodology

B. Questionnaire Survey

A questionnaire was designed in order to investigate the following items: 1) Exploring the assessment weight on the three levels for categories, subcategories, and the 26 indicators, which have been selected based on the literature and experts' interviews, and 2) Identifying the challenges of applying sustainable maintenance in highway infrastructure projects in Egypt. The first section discusses the weight of importance of the listed KPIs to assess the sustainable performance in infrastructure. The second section investigates the preferences of pairwise comparison for the three level hierarchy of the selected indicators. The last section investigates the main problems facing maintenance management for infrastructure roads and bridges in Egypt. The designed questionnaire has been oriented to 30 industry experts in the maintenance of infrastructure highways classified as consultant engineers, construction supervision engineers, and owner representative engineers. The survey was conducted over five months from October 2019 to February 2020, with 21 of the questionnaires returned with full answers, representing a 70% response rate. Using Microsoft Excel, the preliminary statistical analysis has been conducted.

V. Data Analysis

Data analysis has been conducted to calculate the following: 1) Initial RII, 2) overall combined weights of indicators using AHP model, and 3) factors affecting successful implementation of sustainable maintenance in highway infrastructure projects.

TABLE I
LITERATURE REVIEW SURVEY OF KPIS FOR SUSTAINABLE MAINTENANCE ASSESSMENT

	Perspectives	Measures/KPI	References
Economic Performance	Cost Effective	Preventive maintenance cost	[4], [7], [9]
		Corrective maintenance cost	[4], [7], [9]
		Environmental costs	[4], [8]
	Quality	Performance rate	[4], [5], [7]
		Quality rate	[4], [7]-[9]
		Closure rate	[7], [9]
	Productivity	Maintenance program achievement	[6], [7]
		Quality for maintenance task (Rework)	[5], [7]
		Response time for maintenance	[7]
		Mean time to repair	[7]
Environmental Performance	Resources Saving	Reused/recycled components (materials, water, …)	[4], [6]-[8]
		Total of water consumption	[4], [7]-[9]
		Total of energy consumption	[4], [7]-[9]
		Renewable energy consumption	[4], [6]-[8]
	Environmental Impact and Compliance	Air pollution (greenhouse Gas (GHG) emissions, dust emissions, …)	[4], [7], [8]
		Noise level	[4], [5], [6]
		Land pollution	[4], [5], [7], [9]
		Environmental management systems (EMS)	[4], [8]
Social Performance	Learning and Growth	R&D investments	[4], [8]
		Training hours per employee	[7]-[9]
		Trainee satisfaction	[7], [8]
		Number of innovative sustainable solutions	[7]
	Employee Satisfaction	Injury rate/accidents	[4], [5], [7]-[9]
		Employee satisfaction rate	[4], [7]-[9]
	Stakeholders Satisfaction	Stakeholders satisfaction rate	[4], [7], [8]
		Clear responsibilities and communication	[4], [8]

A. Initial RII

This initial data analysis was conducted to test the importance of the selected indicators to proceed later for further model analysis using AHP. This study has supposed that if the RII is lower than 0.5, the indicator will be deleted; otherwise the study will involve the indicator for further analysis using AHP. According to the designed questionnaire, a four-point ascending Likert scale ranging from 1 to 4 was used to rank the responses of importance level of the KPIs, where, “1” refers to strongly not important, and “4” refers to strongly important. RII has been used to rank the relative importance according to (1) [14]:

$$RII = \frac{W}{A \times N} = \frac{\sum_{i=1}^{4} \boldsymbol{indicator\ frequency \times i}}{A \times N} \quad (1)$$

where: W = Total weight of indicator, I = Indicator weight of each frequency, A = Highest weight = 4, N = Total number of respondents = 21.

Table II shows the results of the RII calculations, where it ranged from 0.53 to 0.92. The indicators are then categorized in three importance categories according to RII, where: High important (RII ≥ 0.8), medium (0.8 > RII ≥ 0.6), and low important (RII < 0.6).

TABLE II
THE RII VALUES OF KPIS

	Perspectives	KPIs	Standard deviation	RII	R
Economic	Cost Effective	Preventive maintenance cost	0.47	**0.92**	H
		Corrective maintenance cost	0.00	0.75	M
		Environmental costs	0.94	**0.58**	L
	Quality	Performance rate	0.82	0.75	M
		Quality rate	0.00	0.75	M
		Closure rate	0.82	0.75	M
	Productivity	Maintenance program achievement	0.47	0.67	M
		Quality for maintenance task (rework)	0.47	**0.92**	H
		Response time for maintenance	0.00	0.75	M
		Mean time to repair	0.47	0.67	M
Environmental	Resources Saving	Reused/recycled components (materials, water, …)	0.94	0.83	H
		Total of water consumption	1.25	**0.58**	L
		Total of energy consumption	0.82	0.75	M
		Renewable energy consumption	0.94	0.67	M
	Environmental Impact and Compliance	Air pollution (Greenhouse gas (GHG) emissions, dust emissions, …)	0.94	0.67	M
		Noise level	0.47	**0.58**	L
		Land pollution	0.47	**0.58**	L
		EMS	0.94	**0.58**	L
Social	Learning and Growth	R&D investments	0.47	**0.92**	H
		Training hours per employee	0.47	**0.92**	H
		Trainee satisfaction	0.82	0.75	M
		Number of innovative sustainable solutions	0.47	0.67	M
	Employee Satisfaction	Injury rate/ accidents	0.82	0.75	M
		Employee satisfaction rate	0.82	0.75	M
	Stakeholders Satisfaction	Stakeholders satisfaction rate	0.82	0.75	M
		Clear responsibilities and communication	0.47	0.83	H

It can be noticed that "Preventive cost" and "Quality for maintenance task (rework cost)" are regarded as the highest important KPIs of economic performance, which are most related to the maintenance cost. Also, the same importance is given to another two indicators related to social performance, which are "R&D investments" and "Training hours per employee"; which is a very promising result as it highlights the importance of research and development and training. Four indicators that are related to environmental performance are ranked and categorized as lower importance (with RII = 0.58 < 0.6); "Total of water consumption", "Noise level", "Land pollution", and "Environmental management systems (EMS)".

However, most of the other indicators ranked as medium important (with RII = 0.75, and 0.67).

It can be noticed that all calculated RII are higher than 0.5, therefore the selected 26 indicators will move to further analysis using AHP. However, the calculated RII has been used as a first screening for the selected indicators, but it did not consider the weight of upper related main categories as hierarchy, thus the next analysis using AHP will take into account the important weight for the three hierarchy levels.

VI. AHP Model Development of Sustainable Maintenance Assessment

AHP is based on three main principles as the basis for decision making: Developing hierarchies; assigning priorities using pair-wise comparison matrices; and, ensuring logical consistency within criteria [15]. Appling these principles would help developing the AHP model through the following four steps: 1) Identifying the purpose of the model or the problem, 2) selecting the indicators/criteria that affect the purpose achievement or problem solving, 3) setting the relative weights of the indicators and sub-categories in each category using pairwise comparisons between each pair of criteria within the same hierarchy, then finally, 4) checking the consistency.

A hierarchy was constructed as shown in Fig. 2, and relative priorities were obtained by means of experts preferences to identify pair-wise comparison matrices of the main categories (level 1), their subcategories (level 2), and their related indicators (level 3) that were used to obtain the indicators' relative weights, or their importance among the others. The results of the calculated relative weights for each level have been displayed in Table III, where it shows that there is a consistency with the calculated RII shown in Table II.

The results show that the category of economic performance is the most important (0.578), then social performance (0.263), while small weight is given to the environmental performance (0.159). It reflects the human behavior that is interested with the direct and instant impact, while neglecting the indirect or long-term effect. However, it is a good sign that the social performance category is in the focus area in current planning.

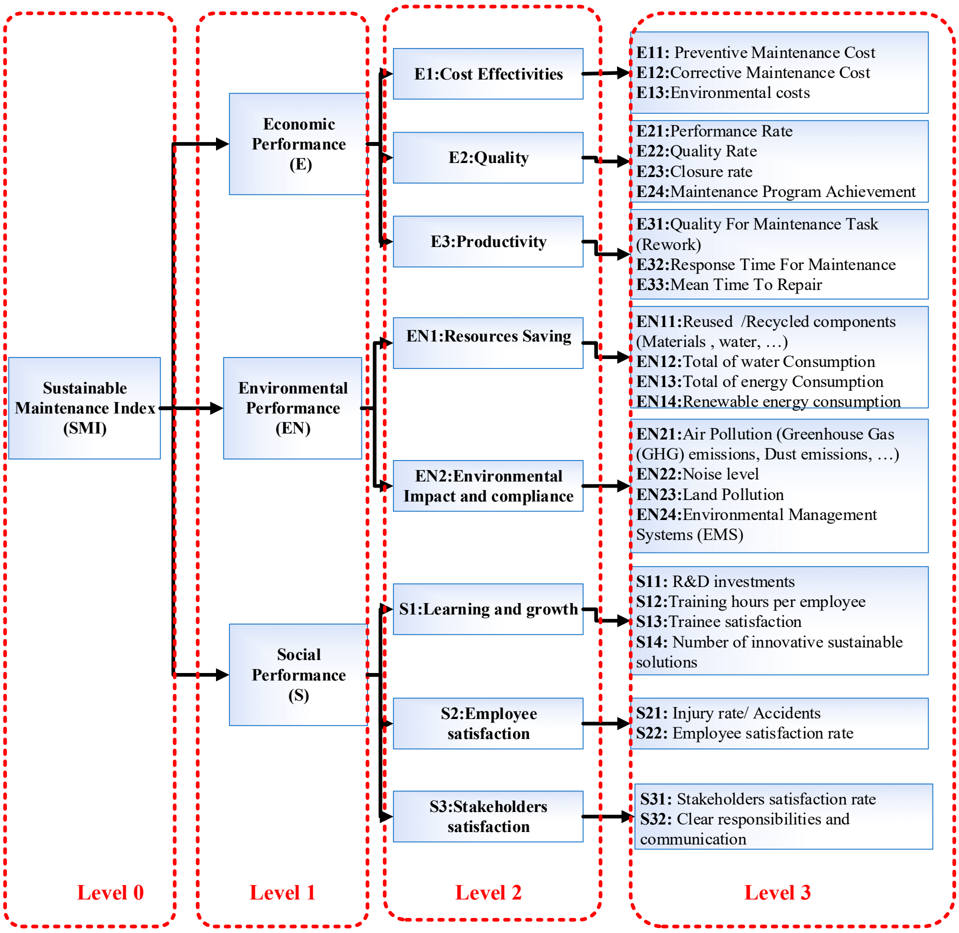

Fig. 2 Hierarchy of the AHP model

On the second level, the results shows that the factors related to cost are the most important in the economic dimension, factors relating to resources saving are the most important in the environmental dimension and the factors related to learning and growth are the most important in the social dimension; E1: Cost effective (0.444), EN1: Resources saving (0.571), S1: Learning and growth (0.515). These results reveal the awareness of people working in highway infrastructure about sustainability, as it relies on saving resources, learning and cost saving even if they cannot apply it due to implementation barriers of sustainable maintenance.

On the third level there are eight indicators that are classified as the highest important indicators; E11: Preventive maintenance cost (0.523), E21: Performance rate (0.376), E31: Quality for maintenance task (0.446), EN11: Reused/recycled components (0.39), EN24: EMS (0.436), S11: R&D investments (0.325), S22: Employee satisfaction rate (0.571), S32: Clear responsibilities and communication (0.571). The calculated relative weights for highest important indicators range from 0.325 to 0.571.

The final step is to combine the calculated indicators' weights to estimate the Sustainable Maintenance Index (SMI). The resulted combined indicators' weights (Wi) are also displayed in Table III. It is represented in percentage values to sum up to 100% as the total score for the SMI of the infrastructure project. Applying (2) for each indicator to calculate the combined indicators' weights into one model, the resulted value represents the datum score for measuring the performance of each indicator. For implementation, the calculated Wi % represents the perfect performance for each indicator, so the sum of the actual performance for all indicators will reflect the value of the SMI according to (3). This technique has been applied for assessing the condition of healthcare facilities [16].

$$\text{Overall combine d Weights of indicator } Wi\ \% = W_{X\ (category)} \times W_{Y\ (subcategory)} \times W_{Z\ (indicator)} \quad (2)$$

$$\text{Sustainable Maintenance Index (SMI)} = \sum Wi \quad (3)$$

The results reveal that saving resources by reuse/recycle, having a clear EMS, clear responsibilities and good communication, research and development and employee satisfaction are the way to sustainability, with of course developing a maintenance plan focusing on a preventive approach and assuring high performance and high quality.

TABLE III
CALCULATED OVERALL COMBINED WEIGHTS OF INDICATORS USING AHP MODEL

Main Category level (1) W_x	Subcategory (Level 2) W_y	Assessment Indicators (level 3) W_z	(1) W_x	(2) W_y	(3) W_z	(4)* W_i% = (1)× (2)× (3)
Economic Performance (E)	E1: Cost Effective	E11: Preventive Maintenance Cost	0.578	0.444	0.523	13.5%
		E12:Corrective Maintenance Cost			0.312	8.0%
		E13:Environmental costs			0.165	4.2%
	E2: Quality	E21:Performance Rate		0.222	0.376	4.8%
		E22:Quality Rate			0.236	3.0%
		E23:Closure rate			0.115	1.5%
		E24:Maintenance Program Achievement			0.273	3.5%
	E3: Productivity	E31:Quality For Maintenance Task (Rework)		0.333	0.446	8.6%
		E32:Response Time For Maintenance			0.322	6.2%
		E33:Mean Time To Repair			0.232	4.5%
Environmental Performance (EN)	EN1: Resources Saving	EN11:Reused/Recycled components (Materials, water, …)	0.159	0.571	0.390	3.5%
		EN12:Total of water Consumption			0.082	0.7%
		EN13:Total of energy Consumption			0.215	2.0%
		EN14:Renewable energy consumption			0.313	2.8%
	EN2:Environmental Impact and Compliance	EN21:Air Pollution (Greenhouse Gas (GHG) emissions, Dust emissions, …)		0.429	0.247	1.7%
		EN22:Noise level			0.106	0.7%
		EN23:Land Pollution			0.211	1.4%
		EN24:Environmental Management Systems (EMS)			0.436	3.0%
Social Performance (S)	S1:Learning and growth	S11: R&D investments	0.263	0.515	0.325	4.4%
		S12:Training hours per employee			0.321	4.3%
		S13:Trainee satisfaction			0.217	2.9%
		S14: Number of innovative sustainable solutions			0.136	1.8%
	S2:Employee satisfaction	S21: Injury rate/ Accidents		0.147	0.429	1.7%
		S22: Employee satisfaction rate			0.571	2.2%
	S3:Stakeholders satisfaction	S31: Stakeholders satisfaction rate		0.337	0.429	3.8%
		S32: Clear responsibilities and communication			0.571	5.1%
		Total Score				100%

A. Consistency Analysis

In order to reduce the effect of subjectivity of individuals' preferences for pairwise comparison, the consistency test aims to avoid some inconsistencies in the final matrix of judgments by verifying the reliability and consistency of expert survey results. Therefore, AHP calculates the consistency ratio (CR) comparing the consistency index (CI) of the matrix of respondents' judgments versus the consistency index of a random-like matrix (RI). Since the value of CR is less than 0.10, it can be assumed that the judgments matrix is reasonably consistent. Otherwise, the weights are returned to the practitioners for reassessment. The weights are accepted if the matrix is consistent, and the process of decision making using AHP can be continued [17]. This is applied using (4) and (5):

$$CI = (\lambda_{max} - n) / (n-1) \tag{4}$$

where λ_{max} denotes the maximum eigenvector and n represents the matrix dimensions.

$$CR = CI / RI \tag{5}$$

where, RI denotes the random index related to the matrix size.

Consistency test has been conducted for the pairwise matrices in the three levels that contained 12 matrices, where it was found that the values of calculated CR are less than 0.1; CR for the matrix of main category level is 0.007, the values of CR for the matrices of subcategory in level 2 is ranged between zero and 0.016, while the values of CR for the matrices of assessment indicators in level 3 ranged between 0.001 and 0.056. Therefore, it was assumed that the respondents, judgments matrix is reasonably consistent, and the process of the AHP model is to be continued.

VII. Barriers Affecting the Successful Implementation of Sustainable Maintenance in Infrastructure Projects

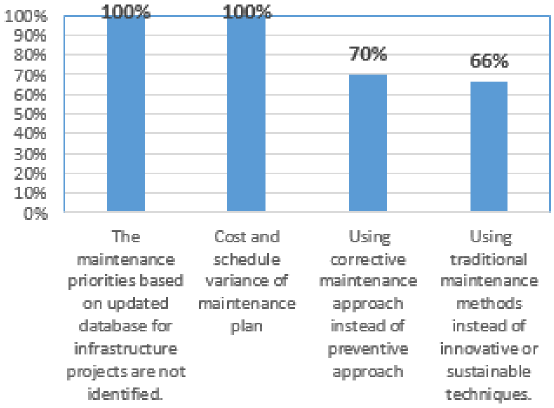

Fig. 3 The Main Barriers Affecting the Successful Implementation of Sustainable Maintenance in Infrastructure Projects

The main factors that hinder the implementation of sustainable maintenance are also discussed in this study. Based on the questionnaire analysis, Fig. 3 shows the four main obstacles as following:

1. The unavailability of updated database for infrastructure projects that shows maintenance priorities.
2. Cost and schedule variance of maintenance plan.
3. Using corrective maintenance approach instead of preventive approach.
4. Using traditional maintenance methods instead of innovative or sustainable techniques.

It can be noticed that the cost and maintenance priorities are the main barriers where the respondents agreed that these two barriers hinder the appropriate implementation. Then, the two other barriers that lead directly to cost variance as cost overhead, such as applying corrective action instead of proactive action (70%), and resistance to applying innovative maintenance methods (66%).

VIII. Development of Implementation Model and Successful Implementation Practices

The assessment model of sustainable maintenance will help maintenance managers to transfer the strategy into action and offer an objective measures for an actual level of SMP. For implementation, first, in the early planning for maintenance, each company will make its maintenance plan during the design stage with the developed indicators considered in the maintenance plan. Second, we assign the actual performance Wi % for each indicator then compare it with the calculated Wi % in this study, since it represents the best performance for each indicator. Third, we calculate the value of SMI by summing up the values of the actual performance of all indicators ($\sum Wi$). Finally, according to the value of the SMI, decision makers can make future directions of maintenance activities. The implementation model is shown in Fig. 4.

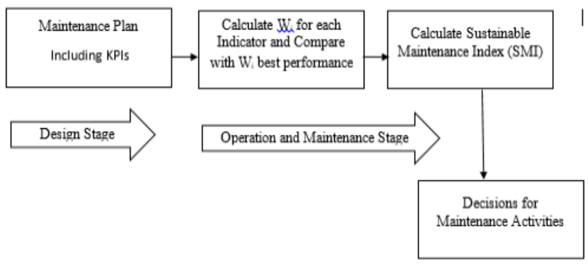

Fig. 4 Implementation Model

The current study suggested main practices to help in the successful implementation of sustainable maintenance:

1. Early consideration of the indicators of maintenance assessment during the planning phase.
2. Applying planned periodic maintenance (applying proactive maintenance).
3. Cost and time control for maintenance implementation.
4. Training courses related to planning and maintenance.
5. Increase R&D investment.
6. Database analysis.
7. Top management commitment.

IX. Conclusion

The main objective of this study was to develop an assessment model for the performance of sustainable maintenance taking into account the three dimensions of economic, social, and environmental. AHP was used to rank and explore the weight of 26 assessment indicators using three hierarchy levels containing the main sustainable categories and subcategories with related indicators. AHP allowed to consider objectively the experiences of practitioners and key decision makers for preparing a benchmarking assessment model. The developed model calculates the SMI by summing up the actual performance weight of each indicator then comparing it with the developed benchmarking overall combined weights. Recommended practices of successful implementation of the assessment model based on challenges analysis are also presented. The main conclusions can be summarized as follows:

1. Using the AHP method, the economic dimension is the most important, then the social, and then the environmental dimensions.
2. The factors related to cost are the most important in the economic dimension, the factors relating to resources saving are the most important in the environmental dimension and the factors related to learning and growth are the most important in the social dimension; E1: Cost effective (0.444), EN1: Resources saving (0.571), and S1: Learning and growth (0.515).
3. Resources saving by reuse/recycle, having a clear EMS, clear responsibilities and good communication, research and development and employee satisfaction are the way to sustainability, with of course developing a maintenance plan focusing on a preventive approach and assuring high performance and high quality.
4. The factor "Preventive maintenance cost" has the highest relative contribution factor among others, Wi = 13.5%.
5. Two factors of environmental performance (water consumption and noise level) have the least W_i (0.7%).
6. The developed model aims to provide decision makers with information about current maintenance performance and support them in the decision-making process regarding future directions of maintenance activities.
7. It can be used as an assessment performance tool during the operation and maintenance stage, and as a benchmark for assessment of sustainable maintenance.

However, future studies could employ a large sample size of interviews to further validate these findings. Finally, mechanisms for managing knowledge to promote sustainability in other infrastructure projects should be explored further. Policy makers and government bodies should reinforce the need for a guidance and incentive mechanism to encourage adoption of more sustainable solutions. The government should invest in innovative research to discover more innovative solutions and models for achieving sustainable maintenance in infrastructure projects.

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