Chapter 5

Analytic Hierarchy Process Application in Different Organisational Settings

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Additional information is available at the end of the chapter

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Abstract

Purpose – The purpose of this paper is to apply AHP in two case settings which include (i) evaluation/selection of maintenance policy (ii) sustainability factors of employee suggestion schemes.

Methodology/Approach – The paper adopts a case study approach of selecting most appropriate maintenance policy and prioritizing factors for employee suggestion system. Several steps of the AHP method are used in both case settings to illustrate the application of the AHP method.

Findings – This paper proposes (i) a framework for maintenance policy selection based on the AHP methodology and (ii) a framework to determine the importance of sustainability factors for employee suggestion schemes. The results of the first case setting suggest that total quality maintenance is the most suitable approach for a paper machine. In the second case setting, the findings suggest that five sustainability factors can be modelled according to their importance.

Originality/Value – The paper contributes firstly to the literature by providing a framework for decision-making process regarding the maintenance policy selection. In addition, this paper utilizes an exponentially weighted moving average (EWMA) chart for performing a consistency test and a sensitivity analysis. Secondly, the paper proposes a framework to model the sustainability factors of employee suggestion scheme according to their importance level.

Keywords: Analytical hierarchy process, decision-making, maintenance policy, sensitivity analysis, employee suggestion scheme

1. Introduction

The analytic hierarchy process (AHP) is widely used in multi-criteria decision-making tool for tackling multi-attribute decision-making problems in real situations [1]. It represents a powerful technique for solving complicated and unstructured problems that may have interactions and correlations among different objectives and goals [2]. The AHP helps the decision makers to organise the critical aspects of a problem into a hierarchical structure similar to a family tree [3]. It is based on experts' judgements through pairwise comparisons. Experts are interviewed and pairwise comparison judgements are applied to pairs of homogenous criteria, eventually generating the overall priorities for ranking the alternatives [1].

AHP gained substantial attention as a possible solution to the decision-making problems in different organisational areas, for example, the selection of maintenance policy or factors of employee suggestion schemes which will be more deeply illustrated in the following section. However, this method can also be utilised in many other fields. For example, in the study [4], the fuzzy AHP was employed to prioritise and select a suitable organisational structure. The AHP method has been widely used in the decision-making problems that involve multiple criteria in multiple levels [5] as well. The method helps to decompose their decision problem into hierarchy of factors, each of which can be analysed independently and once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them one to another, two at a time, with respect to their impact on an element above them in the hierarchy [6]. AHP method is used to measure the importance of these factors.

Moreover, this technique allows for the search of relative importance placed on product attributes and attribute levels of the analysed complex goods [7]. To make the pairwise comparisons, we need a scale of numbers that indicate how many times a more important or dominant element over another element was, with respect to the criterion or property, with respect to which they are, compared [8].

In this chapter two case studies are presented: first, empirical case study will be utilised to evaluate and select the most appropriate maintenance approach; the second one, based on expert opinion will present a possibility to formalise the importance levels for the importance of factors of sustainability of employee suggestion schemes.

2. Literature review

2.1. Review of maintenance approaches

Different maintenance approaches (i.e. strategies and concepts, methodology or philosophy) have been developed in the last few decades.

The development of maintenance approaches are discussed by many authors [9–13]. Failure-based maintenance (FBM) prescribes activation of maintenance in the event of failure [10]. No action is taken to detect or to prevent failure [14]. Maintenance is carried out only after a breakdown. This approach is only appropriate in a case where customer demand exceeds supply and profit margins are large. However, increasing global competition, small profit margins, safety awareness and strict environmental regulations are changing the environment that most companies are facing today. In this regard, more emphasis is being placed on developing maintenance concepts [15]. However, it is always possible that a failure is allowed to occur. This depends on the existence of secondary damage, redundancy and the ease to repair. Waeyenbergh and Pintelon [13] suggest that one should determine the economic feasibility in order to evaluate the technical feasibility of FBM for a critical component or a non-critical component.

Preventive maintenance (PM) is comprised of maintenance activities that are undertaken after a specified period of time or amount of equipment used [16]. Therefore, traditional preventive maintenance models are using policies such as age replacement and block replacement [17]. One of the disadvantages of the PM is that PM is only suitable when the standard deviation of the failure population is small [18]. This means that if the distributions have a small standard deviation, they are usually a candidate for PM and in such cases PM is economical. Another shortcoming of PM is the lack of decision support systems and insufficient historical data [14, 19].

Condition-based maintenance (CBM) is a maintenance strategy that monitors the actual condition of the asset to decide what maintenance needs to be done [20]. CBM is defined as the preventive maintenance based on performance and/or parameter monitoring and the subsequent actions. Using a condition monitoring (CM) system, the machine condition is assessed by the current and historical measurements of one or more of relevant CM parameters [21]. Vibration-based maintenance (VBM) is the most frequently used technique under the CBM approach. By an efficient use of VBM policy, which means utilisation of the information provided by vibration monitoring system for planning and performing maintenance actions, the machine can be run until just before failure as defined by the monitored parameter reaching a predetermined unacceptable value [21]. Al-Najjar [22] indicated that the implementation of VBM policy provides possibilities for obtaining early indications of alterations of machine-state.

Al-Najjar [9] proposed a strategy called total quality maintenance (TQMain), which sustains not only machinery but also the essential elements constituting a manufacturing process, such as production/operation, environmental conditions, quality, personnel, and methods. TQMain was defined by Al-Najjar [23] as a means for monitoring and controlling deviations in a process, working conditions, product quality and production cost, and for detecting damage causes and their developing mechanisms and potential failures in order to interfere (when it is possible) to 'stop' or reduce machine deterioration rate before the production process and product characteristics are intolerably affected and to perform the required action to restore the machine/process or a particular part of it to as good as new. Further, Al-Najjar and Alsyouf [24] also presented what characterises TQMain and distinguish it from other maintenance concepts (e.g. reliability-centred maintenance (RCM), total productive maintenance (TPM)). They highlighted that TQMain supports the use of a common database, continuous improvement, implementation of CBM such as VBM, and it is based on intensive use of real-time data acquisition and analysis to detect reasons behind deviations in product quality and machine condition.

Reliability-centred maintenance was first introduced by the aircraft industry of the United States in 1978 [25]. There have also been several improvements to the traditional RCM methodology (e.g. RCM2). Moubray's book [11] is a key reference. RCM can, among other things, improve system availability and reliability, reduce the amount of preventive maintenance, unplanned corrective maintenance and increase safety. These are all important aspects for organisation in order to sustain in a competitive environment [26]. RCM aims to increase the asset's lifetime and create a more efficient and effective maintenance [27]. But, Al-Najjar [22] pointed out that RCM cannot completely exploit the use of condition monitoring (CM) techniques, and the progress of damage cannot be monitored until just before a failure. Further, Pintelon and Parodi [27] described that available statistical data used in RCM are insufficient or inaccurate, and that there is a lack of insight in the equipment degradation process (failure mechanisms) and the physical environment (e.g. corrosive or dusty environment) is overlooked. There have been already attempts to combine RCM and AHP in the maintenance domain—for example, development of a hybrid model for trunk road network maintenance prioritisation. The proposed hybrid model was used to establish failure diagnostic and multi-criteria decision making, respectively [28].

Total productive maintenance (TPM) is a methodology originating from Japan to support its lean manufacturing system, since dependable and effective equipment are essential prerequisite for implementing lean manufacturing initiatives in any organisation [29]. To do so, the overall equipment effectiveness (OEE), which is defined as the product of availability, speed and quality performance, is used to assess the reached level [13]. Nakajima [30], a major contributor of TPM, has defined TPM as an innovative approach to maintenance that optimises equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators. The definition of TPM includes five major elements [31]:

1. overall equipment effectiveness maximisation;
2. a thorough system of preventive maintenance for the equipment's whole life span;
3. implementation by various departments (engineering, production, maintenance, etc.);
4. total employee involvement from top management to the workers on the floor; and
5. motivation management through small group activities and teamwork.

Though the concept of TPM is simple and obvious, there are some reported limitations. First, TPM does not provide clear rules to decide which basic maintenance policy will be used, and second, calculation of the OEE is not really a complete analysis. Cost and profits are not taken into account, and therefore it is not a comprehensive measure [13]. Moreover, TPM also requires changing the organisational culture, what is not easily to accomplish. In this regard, Tsang and Chan [32] indicated that those organisations that will not change their culture will not be successful in implementing TPM. A study regarding application of AHP in the implementation of TPM decision making in manufacturing organisations was performed by Ahuja and Singh [33].

2.2. Review of employee suggestion system factors

The existing research aptly identifies the enablers to the employee suggestion schemes. Buech et al. [34] note that researchers trying to ascertain which factors affect employees to submit suggestions focus on three main streams of research. The first considers work environment, the second focuses on the features of the scheme, weighs the influence of feedback about suggestions against management support of the system as well as rewards for successful suggestions and the third deals with the characteristics of the individuals. Carrier [35] reports that the majority of researchers consider organisational creativity to be fostered through the personal characteristics and motivation of creative individuals while the other group of researchers turned their attention to context and organizational factors. Axtell et al. [36] argue that different sets of variables influence these two stages of employee suggestion system process, i.e. the creative and the implementation phases. So, it is evident that the drivers that trigger the suggestion scheme comprise individual, organisational and contextual variables. Moreover, the innovation process is a complex phenomenon and many variables have roles to play in determining its process [37]. Amabile et al. [38] also contend that the organisational context can impede or support the generation of ideas. Everyone has ideas all the time, not all are creative, nor do they all lead to innovation [39]. Therefore, creativity needs to be nurtured to turn into valuable suggestions. A list of variables emerging from the literature that hint as the indicators are: Top Management Support, Supervisor Encouragement, Coworker Support, Organisational Encouragement, Support for innovation, Communication Evaluation, Awareness, Resources, Rewards, Training, Effective System, Feedback, Implementation of Ideas, Empowerment, Job Factors, Expertise, Self-Efficacy and Individual Characteristics, Teamwork, Employee Participation, Job Control, Organisational Impediments and the Competition, Employee Confidence, Sense of Security, Commitment and Accountability, Improvement in Process, Customer Satisfaction, Product Quality, New Revenue, Cost Saving, Employee Satisfaction.

3. Application of AHP in two organisational settings

First, in an empirical case study for selecting the most appropriate maintenance policy AHP was utilised aiming to evaluate and select the most appropriate maintenance approach. The case study was conducted at a Slovenian paper mill company.

Secondly, an expert opinion study was conducted in the context of UAE organisations using suggestion systems to formalise the importance levels for sustainability of employee suggestion system factors. The illustration of AHP for these two case instances is discussed in the next sections.

3.1. Case study 1: an AHP-based framework for maintenance policy selection

The method proposed for selecting the most appropriate maintenance approach is based on a hierarchical model composed of a set of criterion and sub-criterion. AHP method is demonstrated by the following case study from the paper industry. One of the Slovenian paper mill companies is the subject of the case study in this research. It could be argued that maintenance is highly crucial for this company, since production process in this company is running 24/7. Equipment life, equipment availability and equipment condition is very important in order to ensure smooth running of a paper machine, and provide on-time delivery at low prices. As such, the objective of this case study is to identify the most appropriate maintenance policy concerning the above mentioned objectives.

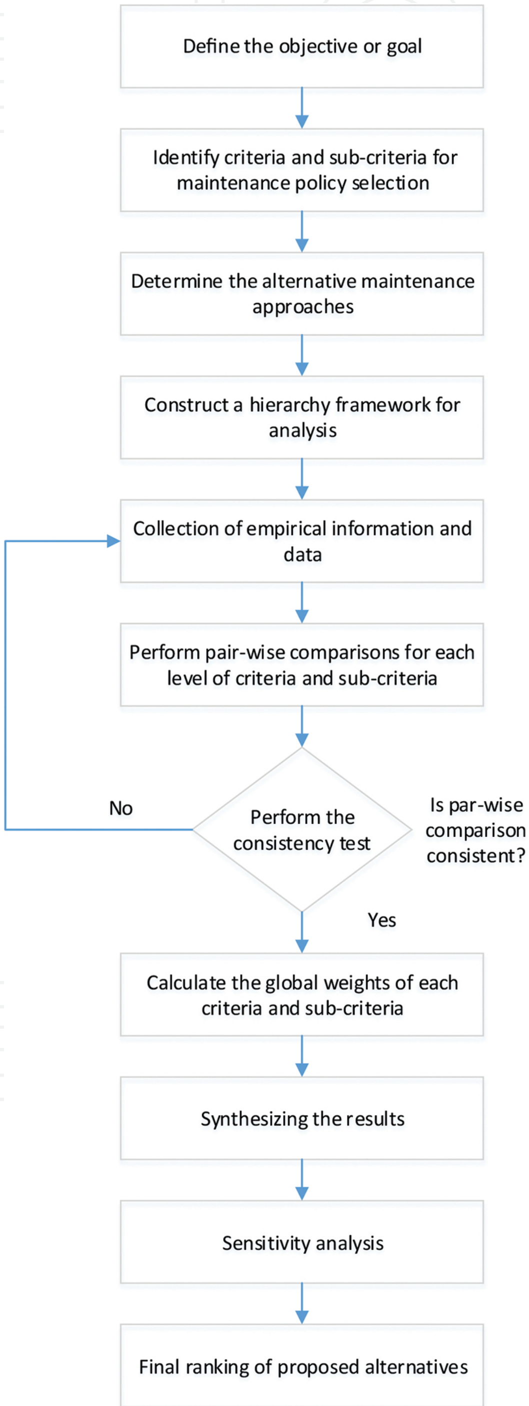

Figure 1. Steps for conducting an AHP study.

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In order to select the most appropriate maintenance policy for the paper machine, this research paper uses the AHP methodology. Based on the guidelines proposed by Saaty [8], an AHP framework was developed for facilitating the study. In this regard, Saaty [8] proposed four steps to make a decision in an organised way:

1. define the problem and determine the kind of knowledge sought,

2. structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives),

3. construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it,

4. use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority and

5. continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

Using these guidelines, an AHP framework was established for facilitating the study. **Figure 1** shows a flow chart involving various steps to conduct the AHP study.

Step 1: *Define the objective or goal*

The objective or goal of this study is to assess and select the most appropriate maintenance approach/policy for a paper machine.

Step 2*: Identify criteria and sub-criteria for maintenance policy selection*

In this step, the objective or goal of maintenance policy selection was decomposed into three criteria (equipment- and process-related measures, financial measures and health, safety and environment measures) and 12 maintenance indicators (sub-criteria) were identified from the literature so as to form a hierarchical abstraction of the problem. A literature search was conducted using the databases such as Emerald, ABI/Inform and ScienceDirect. The search was done in different combinations of keywords such as maintenance performance, maintenance indicators, maintenance costs, maintenance savings and maintenance measurement. Results of the search show different works that have dealt with topics related to these keywords [40–42]. Maintenance indicators are vital for effective support of decision making [42]. Performance measurement provides the required information to the management for effective decision making. As such, management of maintenance performance is critical for long-term economic viability of business and industry [42]. As a result of this literature search, various maintenance performance measures were identified.

Step 3: *Determine the alternative maintenance approaches*

Different maintenance approaches, i.e. strategies and concepts, methodology or philosophy, were used in this study. Briefly, they are the following:

1. failure-based maintenance,

2. preventive maintenance,

3. total productive maintenance,

4. total quality maintenance (using VBM) and

5. reliability-centred maintenance.

A more detailed description of these approaches was presented in the literature review section.

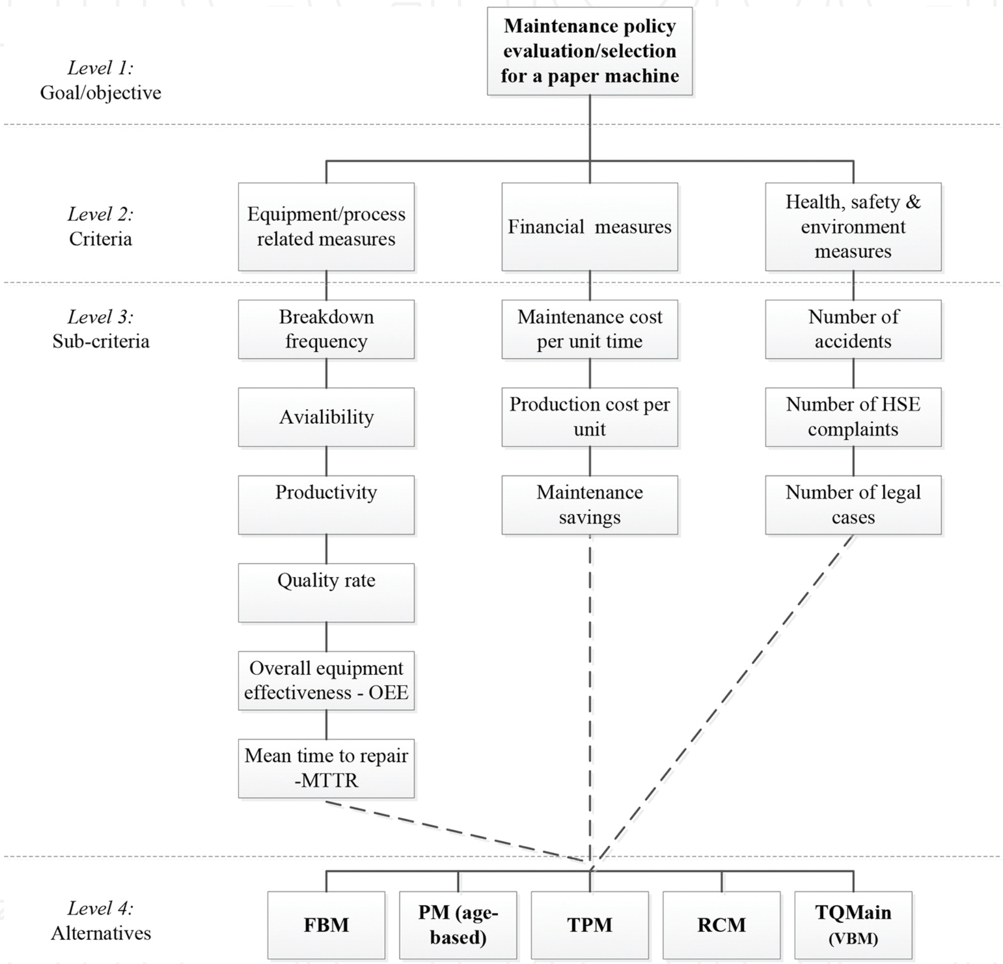

Figure 2. A hierarchy model for maintenance policy evaluation/selection.

Step 4: *Construct a hierarchy framework for analysis*

After the goal of this study had been established, relevant criteria and sub-criteria of maintenance performance measurement were identified via steps 1 and 2. These criteria and sub-criteria were then structured into a hierarchy descending from the overall objective or goal to the various stages and related sub-criteria in successive levels. The top level of the hierarchy represents the defined objective, while the second level of the hierarchy consists of three main maintenance criteria, followed by various sub-criteria (see **Figure 2**). Finally, the fourth level of the hierarchy characterises the alternative maintenance approaches/policies.

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Step 5: *Collection of empirical information and data*

This step is concerned with the collection of empirical information and data through the combined judgements of the individual evaluators from industry and academia. For this purpose, a group of three evaluators were chosen for evaluating the selected criteria and sub-criteria. Two evaluators were chosen from academia having experience in the field of maintenance, and one from industry also experienced in the field of maintenance. They had sufficient knowledge, expertise and understanding of the maintenance approached used in this study.

Step 6*: Perform pairwise comparisons for each level of criteria and sub-criteria*

Once the evaluators were identified and relevant empirical information and data were collected, the next step was to determine the relative importance among the criteria and sub-criteria. Before conducting the pairwise comparison, all team members were given the instruction on how to complete the comparison. Invited evaluators were asked to carefully compare criteria of each hierarchy level by assigning relative scales in a pairwise fashion with respect to the goal of this study. Evaluators' judgements were then combined using the geometric mean approach at each hierarchy level to attain the corresponding consensus. A relational scale of real numbers from 1 to 9 was used in the ranking process (**Table 1**). The purpose of this scale is to determine how many times a more important or dominant element is prioritised over another element with respect to the criterion or property with respect to which they are compared [8].

Scale	Judgement
1	Equal importance
3	Moderate importance of one over the other
5	Essential or strong importance
7	Very strong or demonstrated importance
9	Extreme or absolute importance
2, 4, 6, 8	Intermediate values between the two adjacent judgements

Table 1. Scale of relative preference for pairwise comparison.

Step 7: *Perform the consistency test*

In this step consistency test was performed. A measure of inconsistency is useful in identifying possible errors in expressing judgements as well as actual inconsistencies in the judgements themselves [2]. AHP provides a method called the consistency ratio (CR) which is used to gauge whether a criterion can be used for decision making. In the AHP the pairwise comparisons in a judgment matrix are considered to be consistent if the CR is less than 10% [1]. On the contrary if CR is bigger than 10%, possible cause should be examined. However, the standard consistency test has been critiqued by a number of authors [43–45]. For these reasons, we adopted a quality control approach for the consistency test, proposed by Karapetrovic and Rosenbloom [43]. Authors recommended that quality control of consistency can be performed using the simple Shewhart Xbar-R chart or exponentially weighted moving average (EWMA) chart. In this study, EWMA chart was used. This chart is suitable due to its possibility to identify small shifts in the consistency index (CI). CI can be calculated using the following equation: $CI = \lambda_{max} - n/n - 1$, where '$n$' is the number of criteria or sub-criteria of each level and λ_{max} is the biggest eigenvector in the matrix. In place of dividing each CI by the 'random index', we used an approach to plot the average values for CI (taking into consideration all decision makers) into EWMA chart (**Figure 3**). For this purpose, a free software environment for statistical computing and graphics *R* was applied using the QCC (an *R* package for quality control charting and statistical process control) package. We used a default value of smoothing parameter (λ), which was set at 0.2 in the aforementioned *R* package. **Figure 3** shows that all EWMA values were within the defined control limits. This means that decision makers were consistent.

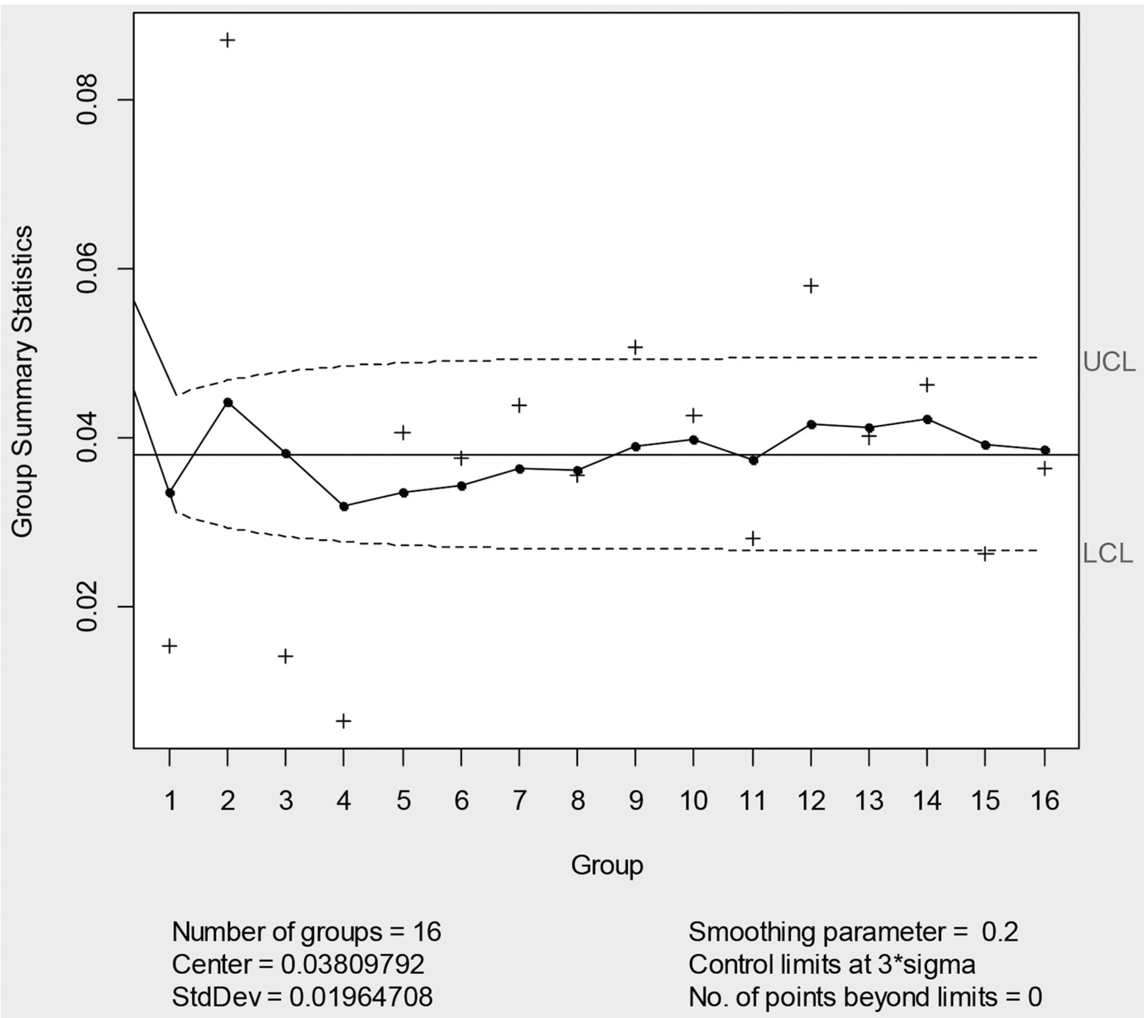

Figure 3. EWMA control chart—average CIs.

Hierarchy level	Criteria	Local weights		Global weights	
		Weights	Ranking	Weights	Ranking
Level 2	*With respect to maintenance performance measures*				
	Equipment/process related measures	0.530	1	0.530	1
	Financial measures	0.270	2	0.270	2
	Health, safety and environment measures	0.199	3	0.199	3
Level 3	*With respect to equipment/process related measures*				
	Breakdown frequency	0.076	5	0.040	9
	Availability	0.181	3	0.096	5
	Productivity	0.183	2	0.097	4
	Quality rate	0.095	4	0.050	7
	Overall equipment effectiveness—OEE	0.422	1	0.224	1
	Mean time to repair—MTTR	0.043	6	0.023	12
	With respect to financial measures				
	Maintenance cost per unit time	0.127	3	0.034	10
	Production cost per unit	0.243	2	0.066	6
	Maintenance savings	0.630	1	0.170	2
	With respect to health, safety a environment measures				
	Number of accidents	0.626	1	0.125	3
	Number of HSE complaints	0.233	2	0.046	8
	Number of legal cases	0.141	3	0.028	11

Table 2. The local and global weights.

Step 8: *Calculate the global weights of each criteria and sub-criteria*

The next step comprises a calculation of local and global weights. While local weights refer to the preceding hierarchical level, the global weights take into account the highest hierarchical level [2]. The local and global weights as well as the corresponding ranks are presented in **Table 2**.

Step 9: *Synthesising the results*

In order to obtain final results, all alternatives were multiplied by the global weight of the single decision criteria. The results are presented in **Table 3**.

In **Table 3**, the global priorities are calculated for each of the alternatives. The highest value (0.498) corresponds to the TQMain, followed by TPM (0.207) and RCM (0.162). As expected the lowest value refers to the FBM.

	Criteria weight	FBM	Weight x FBM	PM	Weight x PM	TPM	Weight x TPM	RCM	Weight x RCM	TQMain (VBM)	Weight x TQMain (VBM)
With respect to equipment/process related measures											
Breakdown frequency	0.040	0.045	0.002	0.084	0.003	0.192	0.008	0.213	0.009	0.467	0.019
Avialibility	0.096	0.041	0.004	0.103	0.010	0.215	0.021	0.136	0.013	0.505	0.048
Productivity	0.097	0.036	0.003	0.087	0.008	0.198	0.019	0.191	0.019	0.487	0.047
Quality rate	0.050	0.039	0.002	0.080	0.004	0.156	0.008	0.214	0.011	0.511	0.026
Overall equipment effectiveness - OEE	0.224	0.034	0.008	0.095	0.021	0.219	0.049	0.148	0.033	0.504	0.113
Mean time to repair - MTTR	0.023	0.046	0.001	0.103	0.002	0.243	0.006	0.112	0.003	0.496	0.011
With respect to financial measures											
Maintenance cost per unit time	0.034	0.040	0.001	0.105	0.004	0.157	0.005	0.223	0.008	0.475	0.016
Production cost per unit	0.066	0.031	0.002	0.091	0.006	0.221	0.014	0.172	0.011	0.485	0.032
Maintenance savings	0.170	0.043	0.007	0.098	0.017	0.235	0.040	0.108	0.018	0.516	0.088
With respect to health, safety & environment measures											
Number of accidents	0.125	0.042	0.005	0.082	0.010	0.177	0.022	0.185	0.023	0.513	0.064
Number of HSE complaints	0.046	0.040	0.002	0.097	0.004	0.207	0.010	0.207	0.010	0.450	0.021
Number of legal cases	0.028	0.043	0.001	0.086	0.002	0.201	0.006	0.201	0.006	0.469	0.013
Total score			**0.039**		**0.093**		**0.207**		**0.162**		**0.498**

Table 3. The summarised matrix.

Step 10: *Sensitivity analysis*

In this step, a sensitivity analysis is held to show the effect of altering different parameters of the model on the choice of the maintenance policy selection. First, the current values of the model are presented. **Figure 4** demonstrates the current importance of each alternative considering all criteria used in this model. As one can see from **Figure 4**, the highest value corresponds to TQMain (49.8%). Additionally, **Figure 4** also shows the values of the weights of all three main criteria from level 2 ($C1$—equipment-/process-related measures, $C2$—financial measures and $C3$—health, safety and environment measures).

Furthermore, a series of sensitivity analysis were performed to investigate the impact of changing the priority of the criteria on the alternatives' ranking. Dynamic sensitivity of expert choice was accomplished to analyse the change in outcome caused by a change in each of the main criterion. The aim of sensitivity analysis is to explore how these changes affect the

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priorities of the selected alternatives. In the following three scenarios are presented. We investigated the impact of changing the priority of three main criteria on overall results. First, the criterion 'equipment-/process-related measures' was increased for approximately 25% (from 53 to 66.2). The results are presented in **Figure 5**. This figure consists of two parts. The results presented on the left side of **Figure 5** are criteria and their corresponding weights, while the right side of the figure illustrates the ranking of the alternative as expressed by importance (in percentage). The results of the sensitivity analysis showed that change (an increase of 25%) in the first criterion has no significant influence on the final ranking of the alternatives. As such, the overall rank of the final outcome remained unchanged.

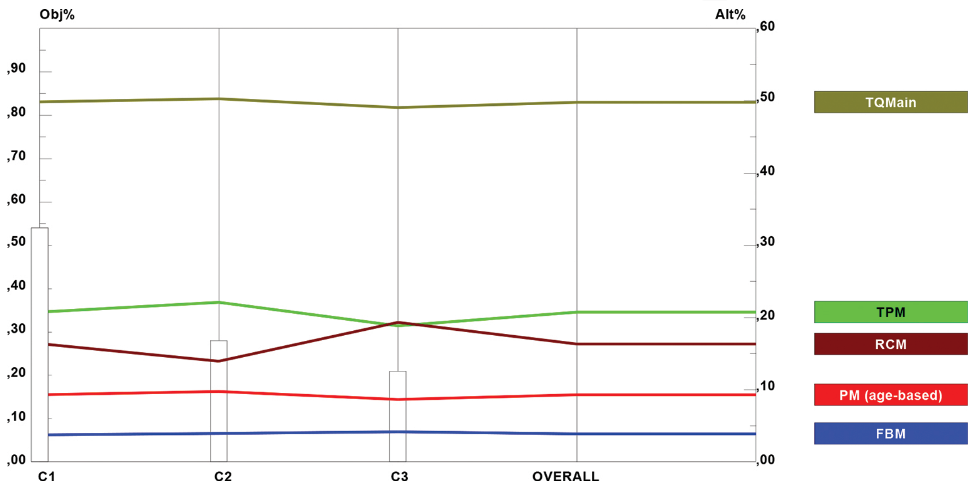

Figure 4. Sensitivity graph—the initial results with respect to the main goal.

Secondly, the criterion 'financial measures' was increased by approximately 25% (from 27 to 33.8) (**Figure 6**). Similarly as in the first case, the change in this criterion also appears to have no substantial impact on the final ranking. As can be seen from **Figure 6**, TQMain remains the best alternative.

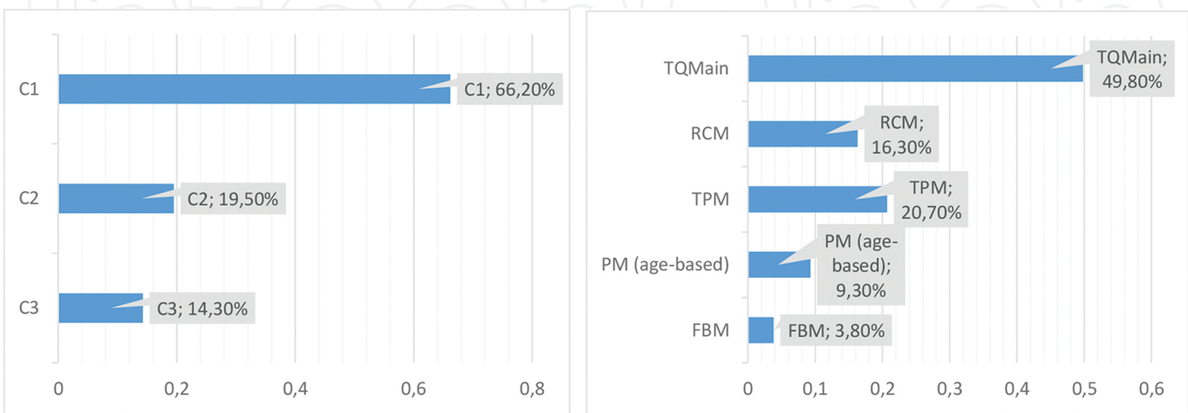

Figure 5. Scenario 1.

Finally, the last criterion 'health, safety and environment measures' was also increased by 25% (from 19.9 to 25.1), and the model was tested for the change of the final ranking. The results show (**Figure 7**) that the criterion 'health, safety and environment measures' has no major impact on the final outcome as well, and therefore TQMain remains the best alternative.

Overall, the results of the sensitivity analysis revealed that the ranks of the alternatives remained stable in all cases. Additionally, a sensitivity analysis was carried out in which main criteria were decreased by 10%. The results displayed that the model is stable also when weights are decreased. This indicates that the proposed model is stable and robust and thus appropriate for decision-making process.

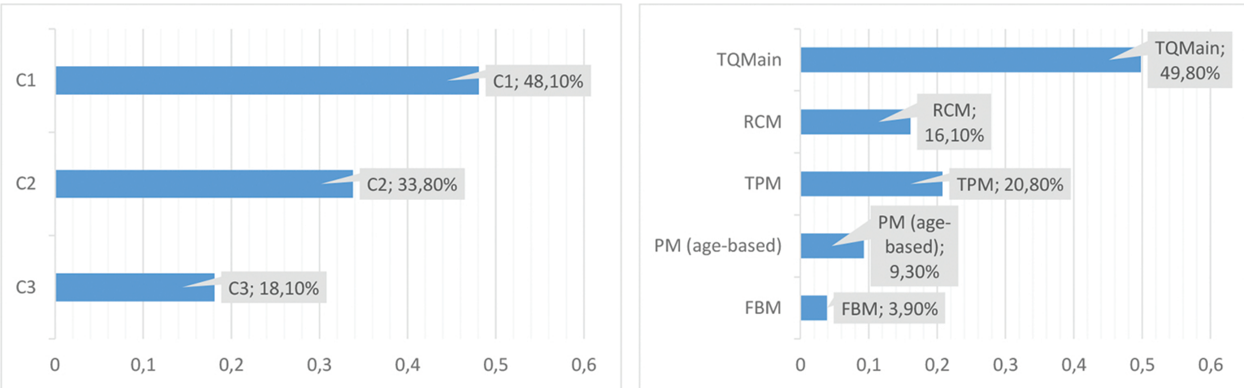

Figure 6. Scenario 2.

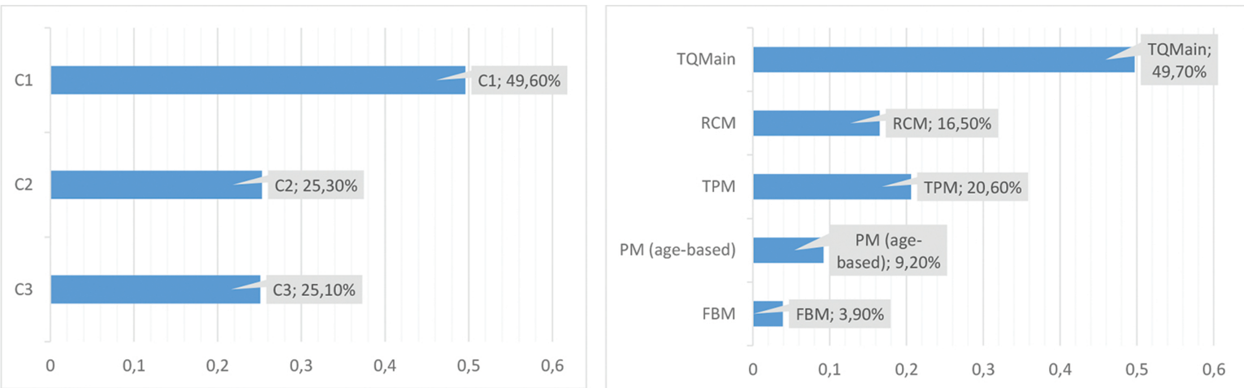

Figure 7. Scenario 3.

Step 11: *Final ranking of proposed alternatives*

Taking into account the results of the 9th step and the results of the sensitivity analysis, the final solution of the AHP method can be determined. Therefore, with respect to the main objective of the proposed model, TQMain was selected as the most appropriate maintenance approach (**Table 4**).

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Approach	Importance	Rank
TQMain	0.498	1
TPM	0.207	2
RCM	0.162	3
PM	0.093	4
FBM	0.039	5

Table 4. Global importance of maintenance approaches.

3.2. Case study 2: prioritisation of factors for sustainability of employee suggestion schemes

Employee suggestion system (ESS) is a tool widely used by the corporations to elicit employees' creative ideas. It should elicit suggestions from employees, classify them and dispatch them to the 'experts' for evaluation. After this, the suggestion might be adopted, in which case the suggestion may well be rewarded. `Experts' are dedicated committees who evaluate the suggestions and propose them for its implementations.

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors equally contribute to the objective
3	Somewhat more important	Experience and judgment slightly favour one over other
5	Much more important	Experience and judgment strongly favour one over other
7	Very much more important	Experience and judgment very strongly favour one over the other. Its importance is demonstrated in practice
9	Absolutely more important	The evidence favouring in ever the other is of the highest possible validity
2, 4, 6, 8	Intermediate-values	When compromise is needed

Employee suggestion systems create win-win situation for employers and employees alike. However, despite the many benefits of the suggestion systems, sustaining them is still a challenge for organisations. Organisations need to assess their suggestion schemes to determine their sustainability and to examine if the right conditions exist for the suggestion schemes to flourish. After all, suggestion systems can contribute to build organisations innovative capability.

The variables identified in the literature review were first subjected to a factor analysis. This enabled the emergence of five factors, namely—Leadership and Work Environment, System Effectiveness, System Capability, Organisational Encouragement and System Barriers. These five factors were considered in an AHP analysis to determine the importance levels. Expert opinion study was conducted to formalise the importance levels for the importance of factors of sustainability of employee suggestion schemes. Once the importance was identified, the initial framework was created to place the indicators in the order of their importance. An AHP expert opinion questionnaire following Saaty's [8] rating scale as reference for the expert to decide the importance of the indicators in the numerical range 1–9 or their reciprocals, i.e. 1/2–1/9 was used.

The steps for conducting the AHP analysis were briefed in the following steps:

The data were collected from three suggestion system implementers. These implementers were contacted through an email requesting their participation in this research study. The implementers had varied experience using suggestion systems, for example, 10–15 years and were active members of IdeasArabia Group. IdeasArabia Group conducts an annual conference on suggestion systems and awards the organisation and individuals for best suggestions. The data were collected in the form of semi-structured interview and after explaining the objective of the study and the application of the AHP method, from two participations. The third participant was then shown the data collected from two participants for the final judgment as to which two users opinion about the importance level of factor indicators was more appropriate for adjusting the importance level of factor indicators for pairwise comparisons or that both opinions were incorrect as per the knowledge of the third practitioner. The third user expressed satisfaction over factor importance level established by the first user and suggested that the same should be adopted in this study.

The steps for conducting the AHP analysis have been briefed in the following steps:

Reciprocal matrix: the first step is to construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it [8]. Pairwise comparisons were carried out for all factors to be considered, usually not more than seven and the matrix is completed [46].

Eigenvector: the next step is the calculation of a list of the relative weights, importance or value of the factors, which are relevant to the problem in question and this list is called an eigenvector. Eigenvector is calculated by multiplying together the entries in each row of the matrix and then taking the *n*th root of that product gives a very good approximation to the correct answer [46].

Consistency index: the consistency index for a matrix is calculated from $(\lambda_{max} - n)/n - 1$.

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51	1.48	1.56	1.57	1.59	

Table 5. Saaty table for calculation of consistency ratio (CR).

Consistency ratio: the final step is to calculate the consistency ratio for this set of judgments using the CI for the corresponding value from large sample of matrices of purely random judgments using **Table 5**, derived from Saaty's book, in which the upper row is the order of the random matrix and the lower is the corresponding index of consistency for random judgments [46]. CR should be less than 0.1 and if the CR is much in excess of 0.1 the judgments are untrustworthy because they are too close for comfort and to randomness and the exercise is valueless or must be repeated [46].

Indicators	Organisational Encouragement	Leadership and Work Environment	System Capability	System Effectiveness	System Barriers
Organisational Encouragement	1	1/2	2	1	2
Leadership and Work Environment	2	1	5	2	3
System Capability	1/2	1/5	1	1/2	1
System Effectiveness	1	1/2	2	1	1
System Barriers	1/2	1/3	1	1	

Table 6. Reciprocal matrix—overall factors.

Variable	Org. Encouragement	Leadership And Work Environment	System Capability	System Effectiveness	System Barriers	Eigen Vector	Consistency Index	Consistency Ratio (CR)
Organizational Encouragement	1	1/2	2	1	2	0.20268124	0.015785444	0.014094147
Leadership and Work Environment	2	1	5	2	3	0.4001638		
System Capability	1/2	1/5	1	1/2	1	0.09691735		
System Effectiveness	1	1/2	2	1	1	0.17644426		
System Barriers	1/2	1/3	1	1	1	0.12379335		

Table 7. AHP calculation for all sustainability factors.

Indicator	Importance rank
Leadership and Work Environment	1
System Capability	2
System Effectiveness	3
Organisational Encouragement	4
System Barriers	5

Table 8. Importance rank for sustainability factors.

The reciprocal matrices created for the AHP data collected through expert opinion study have been shown in **Table 6**. The calculations of the eigenvector, consistency index and consistency ratio are shown in **Table 7**. Importance ranks for factor indicators and for overall sustainability factors are depicted in **Table 8**.

As the consistency ratio resulted in < 0.1, the judgement for overall sustainability factors are perfectly consistent.

4. The overall factor importance

After the study and analysis of the reciprocal matrix and AHP calculations were done, it can be interpreted that:

• Leadership and Work Environment is slightly more important than both—System Effectiveness (2) and System Capability (2), somewhat more important than Organisational Environment (3) and much more important than System Barriers.

• System Capability is equally important to System Effectiveness (1) and slightly more important to both Organisational Encouragement (2) and System Barriers (2). However, it is slightly less important than Leadership and Work Environment (1/2).

• System Effectiveness is equally important to both System Capability (1) and Organisational Environment (1) and slightly more important to System Barriers (2). However, it is slightly less important to Leadership and Work Environment (1/2).

• Organisational Encouragement is equally important to System Barriers (1) and System Effectiveness (1). However, it is less important than System Capability (1/2) and somewhat less important to Leadership and Work Environment (1/3).

• System Barriers is equally important to Organisational Encouragement (1). However, it is slightly less important to both System Capability (1/2) and system Effectiveness (1/2) and much less important to Leadership and Work Environment (1/5).

Table 8 depicts the importance order for five sustainability factors based on the above interpretations. The Leadership and Work Environment is the more important factor when compared to the other four. The indicator System Capability stands at the next importance on rank 2, System Effectiveness at importance rank 3 and Organisational Encouragement at rank 4 and System Barriers at rank 5.

5. Discussion

This chapter discusses application of the AHP method in two different organisational settings based on two case studies.

First, AHP is applicable as an evaluation technique that eases the decision maker's task of choosing the most efficient maintenance policy. Diverse management practices can be implemented by manufacturing organisations in order to improve organisational performance by continuous improvement trough implementation of process changes [47,48]. Maintenance can be seen vital for sustainable performance of a production plant [49]. Sharma et al. [50]

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concluded that development, adoption and practice of new maintenance strategies had become crucial. Selecting a suitable maintenance policy is definitely one of the essential decision-making tasks in improving the cost-effectiveness of the production systems [3,14]. Recent studies [40] indicate that appropriate maintenance can extend the life of an asset and prevent costly breakdowns that may result in lost production. The maintenance function plays a critical role in a company's ability to compete on the basis of cost, quality and delivery performance [51,52]. It appears that aim of the maintenance function is to contribute towards a company's profit, clearly bringing the need for maintenance operations to be in harmony with corporate business objectives [53]. Further, the growing importance of maintenance regarding improving company's profitability and competitiveness [54,55], strengthens the need for selecting a proper maintenance policy [56]. Therefore, using the proposed AHP framework, the criteria for maintenance policy selection can be clearly recognised and the issue can be structured systematically. More importantly, it can effectively support the decision makers in the process of selecting the most appropriate maintenance policy.

Three main criteria for the maintenance policy selection were used in this study and are as follows: equipment- and process-related measures, financial measures as well as health and safety and environment measures. Furthermore, the following sub-criteria are considered to be the most important: OEE, maintenance savings, number of accidents and productivity and availability. The latter can be explained in the context of a production process which in the paper mill is running 24/7. Therefore, used criteria play an important role, especially from the perspective of accomplishing the production goals. Based on the selected criteria as well as on the decision makers' evaluations, the TQMain was selected as the most appropriate maintenance approach. Among others, the TQMain is focused on maintaining and improving continuously the technical and economic effectiveness of the process elements [9], which were indeed important criteria in our study.

To ensure that final solution is stable and robust, we additionally applied sensitivity analysis. With Expert Choice software, AHP enables sensitivity analysis of results which is very important in practical decision making [57].

Secondly, the AHP method was applied to identify the important of each of the factors that would impact the sustainability of the suggestion scheme. This analysis resulted in placing importance ranks among the five factors. These factors are arranged in the order of their importance as below:

1. Leadership and Organisational Environment

2. System Capability

3. Organisational Encouragement

4. System Effectiveness

5. System Barriers

The most important factor is placed at the centre and the least important factor is placed at the bottom of the list. Leadership and Work Environment is the first most important factor, System

Capability is the next important factor followed by System Effectives that is placed at the next level. The Organisational Encouragement is placed at layer four and the last important factor is the System Barriers.

The success of the suggestion scheme is related to the management support, practices, commitment and their leadership [35,58]. Truly, senior management ought to demonstrate their faith in the scheme, promote and support it and encourage all managers to view it as a positive force for continuous improvement [59]. Typically, the management support is seen as crucial to the implementation of ideas. For example, while a person can be creative and generate new ideas on her/his own, the implementation of ideas typically depends upon the approval, support and resources of others, which essentially calls for different forms of management support. If employees make a lot of suggestions, then the opportunity for them to be translated into implementations is greater when there are higher levels of support. Without senior level management support the workers will not be motivated to turn in suggestions [60].

The management support is also very essential for the facilitation of communication mechanism within the organisation. Management, therefore, has a responsibility to satisfy this need for participation and create a culture which is supportive of employee involvement in the decisions that affect his or her work [61]. Thus, the leadership-employee relation is of top most importance that can help the creativity practice to grow in the organisation.

Secondly, the knowledge possessed by individual employees can only lead to a firm, competitive advantage if employees have the incentive and opportunity to share and utilize their individual knowledge in ways that benefit the organisation. Systems that capture the ideas and the capability of such system to evaluate them and provide necessary feedback and reward the employees for the suggestion are other core elements that are necessary once the top management and leadership support is obtained.

Thirdly, organisations need to nurture the system by establishing mechanisms such as team works to improve the employee participation and must ensure that the right expertise and supervision is provided to guide the employees to make their suggestions.

The benefits of the suggestions must be visible. Therefore, it is important that the suggestions result in desired outcomes so these benefits are accrued, and such systems can be sustained. Often there will be organisational impediments that may have a negative impact which are normally the barriers to creativity and this factor has least importance specially because if the systems are the result of the vision of the leadership and resources are allocated to the functioning of the system, organisation impediments have a little scope to cripple the sustainability of the suggestion system.

Each of the factors has a varied influence on the sustainability of the suggestion scheme and hence understanding the importance level identified by the AHP application of each of them would help the organisation to foster the factors accordingly for an improved performance and increase the effectiveness. Using AHP method, it is possible to identify the importance level of critical success factors and success barriers that have emerged in previous studies.

Although the suggestion systems have been around for many decades, identifying the importance level of these factors helps to get a deeper understanding of sustainability of suggestion systems in organisations. Moreover, sustainability is not just a binary state of 'sustaining' or 'not sustaining'. Therefore, it is important to study the impacts of the inhibitors and barriers of suggestion systems on its sustainability.

6. Conclusions

Managers should identify the potential benefits of maintenance policy in terms of productivity, quality and profitability. The latter is essential in order to achieve cost-effective decision making [55]. The proposed framework for the maintenance policy selection appears to enable the structured and systematic way of selecting the most appropriate maintenance policy. By upgrading the traditional AHP method with a EWMA chart for consistency test, our proposed framework for maintenance policy selection represents a valuable tool for decision makers in the field of maintenance.

The second case study showed that AHP method can be successfully applied to arbitrate the importance levels or ranks for the indicators in determining the sustainability of employee suggestion system. By using the proposed importance levels, organisations can assess the suggestion schemes for its sustainability and to recognise if the right conditions exist for the suggestion schemes to flourish.

However, we acknowledge the limitations of using the traditional AHP method. This method is often criticised because of its inability to adequately handle the uncertainty and imprecision associated with the mapping of the decision makers' perception to a crisp number [62]. Nonetheless, Karapetrovic and Rosenbloom [43] suggested that quality control approach can be used with any of the variations of AHP. Future studies could therefore consider different versions of AHP for maintenance policy selection through the lens of a quality management approach.

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