HYBRID PALM OIL MILLS MAINTENANCE SYSTEM

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ABSTRACT

This paper proposes a technique that enhances snapshot model for cause of failure and decision analysis in order to easily assist maintenance engineers during identification and definition of the actual maintenance problem. The technique is a hybrid of failure mode, effect and criticality analysis, information technology and decision analysis into the snapshot model. A tool that automates the hybrid of snapshot modelling for cause of failure and decision analysis is also developed. This tool aims to ensure maintenance engineers can conduct snapshot modelling with little or without the help of operation research experts to facilitate in the cause of failure and decision analysis process.

KEYWORDS: Hybrid system, maintenance, snapshot modelling

1.0 INTRODUCTION

The cause of failure analysis is the process of identifying, defining, and diagnosing the maintenance problem. The main purpose of cause of failure analysis is to avoid tackling the wrong problem. Generally this analysis involves (Liu, 1997):

a) Identifying the existence and location of the problem: Which are recognising the symptoms, seriousness of the problem from the aspect of cost, downtime as well as the size, and the areas of the fault in the plant's machines where the problems are most developed.
b) Determining the problem's causes: The analysis of the problem's causes can be at structural or functional level. Consequently depending on the level of causal analysis, different solution strategies may be generated.
c) Generating and determining possible solution strategies. Having identified problem and its nature, location, causes and consequences, then possible solution strategies could be developed or generated.

However, the data specified above are difficult to be found in any organisation and also very tedious to be collected on a dynamic basis if maintenance management information system is supposed to be used. For this reason the usages of a survey form for collecting such type of data on periodic basis is suggested. At each failure or maintenance intervention, the engineer registers the data related to the snapshot model in survey form. Once finished, OR analyst collects back the survey form and starts the analysis process. The results of the analysis, will be reported back to the maintenance engineers which reveal the true status of the plant under the study.

Despite the usefulness of the snapshot model as one of the important tools for cause of failure and decision analysis, the implementation of the model in large scale is doubtful. This is mostly due to, the scarcity and the reliability of the data related to snapshot model, the problem of analysing the data, and the problem of interpreting the results of the analysis to the users (maintenance engineers).

2.0 THE PROPOSED HYBRID SYSTEM

The proposed approach of automating and augmenting snapshot model aimed to complement such type of modelling. Enriched the various techniques that have proven appropriate and possible in combining with snapshot model could give a more effective, ease of use and practically applied to the real world maintenance problems.

2.1 Elements of Enhancement

The enhancement require the utilisation of the emerging information technology (IT) and failure mode, effect and criticality analysis (FMECA). In theory, IT and FMECA can be utilised to produce an enhanced snapshot model. Once the data collection done, the analysis process needs further techniques to be enriched. The technique called decision analysis is introduced. The decision analysis will use analytic hierarchy process (AHP) method and decision making grid (DMG) by utilising fuzzy logic rule base (FLRB) method. Figure 1 shows the conceptual merger of above mentioned techniques into the current snapshot model.

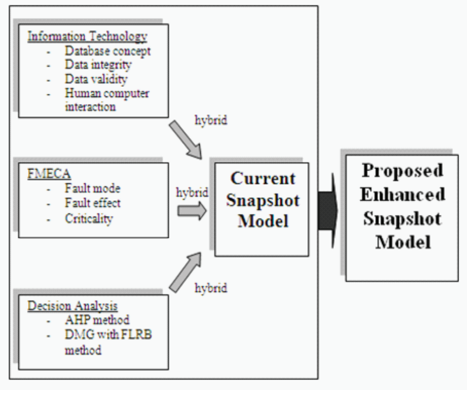

FIGURE 1
The Conceptual Hybrid of FMECA, IT and Decision Analysis into Snapshot Model

2.2 Information Technology

The computer technology can increase the involvement of maintenance engineers in the development of the snapshot model by allowing the replacement of the survey form with a more general computer form that contains feature of checking the validity and consistency of the data and can be applied for different machines. It can also permit maintenance engineers to carry out the snapshot analysis with little assistance of or without OR analysts.

2.3 Failure Mode, Effect and Criticality Analysis

The failure mode and effect analysis that could combined with the snapshot analysis include:

- Major fault areas and their modes. This analysis will analyse all number of failures for each component according to their mode.
- Failure mode and their cause analysis. This analysis provides guidelines and directions to which is need to be done for specific failure mode.
- Failure modes and their cost analysis. This analysis identifies the consequences of each failure mode in term of the cost.
- Failure modes and their downtime. This analysis will lead to identify the failure mode, which frequently disrupt the operation of the machines.
- Failure modes and means of prevention analysis. This analysis identifies the viable means of preventing each type of failure mode.

Criticality analysis (CA) is a procedure by which each potential failure mode is ranked according to the combined influence of severity and probability of occurrence. The procedure for obtaining the criticality analysis is as follows (Kececioglu, 1991):

- The number of failure for each mode will be calculated from the collected data.
- The total number for all the failure of the machine will be calculated.
- The failure mode frequency ratio (FMFR) will be calculated by dividing the number of failure for each mode by the total number of failure for the machines.
- Obtain the estimated probability of stopping, Ps, of the machine if the failure in a given mode should occur.
- Obtain the component unreliability Q by subtracting the component's predicted reliability from 1 or 100 (if calculated in %).
- Calculated the Criticality CR = (FMFR) x (Ps) x (Q).

By using the above steps, criticality ranking will be conducted for the components of any machine under the study.

2.4 Decision Analysis

Decision analysis is particularly a techniques which is part of the framework to achieve world class maintenance (Labib, 1998). Among the established method to implement decision analysis are AHP and DMG based on FLRB method. The AHP is a decision support tool, which can lead the decision makers to model a complex problem in a hierarchical structure showing the relationship of the goal, objective (criteria), sub-objectives and alternatives (Saaty, 1977). Figure 2 show the workflow of AHP process.

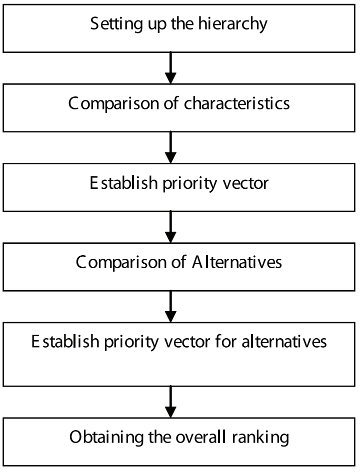

FIGURE 2
Analytic Hierarchy Process (AHP) Workflow

There are four major steps to calculate AHP which are:

1) Setting up the hierarchy: The first step in AHP is to develop hierarchy by breaking the problem down into components. This level is also known as design phase. The three major level of hierarchy are the goal, objectives and alternatives.
2) Comparison of characteristics and establish priority vector: Characteristics refer to the objectives or criteria that located in the second level of the hierarchy. In this phase, it is known as evaluation phase. Decision maker needs to perform comparison between each objective in a one-to-one (N x N) matrix form. Pair wise comparison is used to determine the relative importance of each alternative in term of each criterion. The pair wise comparison expresses the qualitative answer of a decision maker into some numbers, which is easy to manipulate in the calculation and solve the problem of inconsistency unit of measurement for each criterion. Table 1 showed the proposed scale where the scale member set is {9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9}.

By referring to the above standard scale, a matrix of characteristic (objectives) can be constructed. For consistency, it is necessary to set $a_{ji} = 1/a_{ij}$ (this state the obvious fact that if objective 1 is slightly more important than objective 3, than the objective 3 is slightly less important than objective 1).

TABLE 1
Scale of Relative Importance

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgement slightly favour one activity over another
5	Essential or strong importance	Experience and judgement strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgement	When compromised is needed
Reciprocal of above nonzero	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	

Hence the concept of putting values in a matrix conform the following rules:

a) The equal attribute in the matrix is put as 1 (diagonal).
b) The decision maker only needs to fill the upper right triangle of the matrix.
c) For the lower left triangle of the matrix, the value should be the inverse of the corresponding cell in upper right.

3) Comparison of alternatives and establish priority vector for alternatives: The previous steps are determined the weight of each objectives, so the next step is to determine how well each alternative score on each objective. The process of calculation is almost similar with the previous step where a pair wise comparison matrix for each objective is constructed by referring to the scale.
4) Obtaining the overall ranking: The final step is to obtain a vector of overall scores for each alternative, which can accomplish by multiplying the weight calculated by each alternative associated to each of the criteria. The first ranked alternative will have the highest weight (highest priority).

One foundation of the AHP is the observation that the human decision-making is not always consistent. Consistency suffers when the criteria being compared are subjectively in nature. The AHP provides a standard by which the degree of consistency can be measured. If inconsistency exceeds an established threshold, then participants can re-examine their judgements. In the AHP, the pair wise comparisons in a judgement matrix are considered to be adequately consistent if the corresponding consistency ratio (CR) is less than 10%. First, the columns in the judgement matrix A, multiply with the resulting vector priority, w, and the averaging the ratio of each element to yield an approximation of the maximum eigenvalue, denoted by λ_{max} (an eigenvalue of a square matrix A is a scalar c such that Aw = cw holds for some nonzero vector w).

Then the consistency index (CI) value is calculated by using formula CI = $(\lambda_{max} - n)/(n-1)$. Next, the consistency ratio (CR) is computed by dividing the CI value by the random index (RI). The CR is the average CI of sets of judgements (from a 1 to 9 scale) for randomly generated reciprocal matrices. The consistency index is shown in Table 2.

For a perfectly consistent decision maker, each ratio in Step 2 equal to n. This implies that a perfectly consistent decision maker has CI = 0. The values of RI in Table 2 give the average value of CI if the entries in, for example A were chosen at random (subject to the constraints that a_{ii}s must equal 1, and $a_{ij} = 1/a_{ji}$). If the ratio of CI to RI is sufficiently small, then the decision maker's comparison is probably consistent enough to be useful. If CI/RI<0.10, then the degree of consistency is satisfactory, whereas if CI/RI > 0.10, serious inconsistencies exist and AHP may not yield any meaningful results (Saaty, 1990).

The features to enhance the snapshot model are:

1) First level-Criteria evaluation: This steps need the decision maker prioritises his/her preferences on different criteria such as fault mode, effect, major fault, fault cause and consequences.

TABLE 2
Random Index/Random Consistency Index for Different Value of n

Order of Matrix (n)	Randomly Generated Index of Consistency
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

2) Second level-Sub criteria evaluation: This steps need the decision maker prioritises his/her preferences on different sub criteria such as number of fault, machine downtime, cost and criticality.
3) Third level-Alternatives selection: The machines are ranked according to their weights. Weights are obtained through running an AHP algorithm in an absolute mode and hence a consistency ratio of value zero is assured.

The above mentioned three level of AHP method is a complimentary of three type of analysis provided by snapshot model which are major fault analysis, cause of fault analysis and consequences of fault analysis. Once the FMECA features called fault mode, effect and criticality analysis embedded to snapshot model, they also will be added features to decision analysis process.

The three steps of the fuzzy controller are Fuzzification, Rule evaluation (Inference) and Defuzzification (Sharma et.al., 2007). Each of these steps is described below:

1) First step-fuzzification: The first step in the fuzzy controller is the fuzzification process. The membership function, universe of discourse U, is the classifications that are considered in the problem. It is assumed that both frequency and downtime can be classified into `High', `Medium' and `Low'.
2) Second step-rule evaluation: The rule evaluation step can also be explained as an input-output system. In this step, inputs are expert rules, and fuzzy inputs obtained from the first step (that is values of m), while outputs are fuzzy values of maintenance actions to be carried out. Given two variables of frequency and downtime with each having three subsets of Low, Medium, and High, then one needs at least nine (3x3) rules to describe the model (system). These rules are in the form of IF . . . THEN . . . statements. Examples of maintenance prescriptions are as follows:

    a) Operate To Failure (OTF)
    b) Fixed Time Maintenance (FTM)
    c) Skill Levels Upgrade (SLU)
    d) Condition Base Monitoring (CBM)
    e) Design Out Maintenance (DOM)

A summary of the application of each action, based on the values of Frequency (Fr) and Downtime (Dt), is given in Table 3. An example of a rule can be `IF downtime is low and frequency is high, THEN improve operators skill. This rule can be written as follows:

IF frequency is HIGH and downtime is LOW THEN S. L. U (Rule 7)
Rule 7 is shown in the third row, and first column in Table 3. The summary of rules is presented in Table 3.

TABLE 3
Summary of Rules for Maintenance Actions

	Dt (low)	Dt (medium)	Dt (high)
Fr (low)	OTF	FTM	CBM
Fr (medium)	FTM	FTM	FTM
Fr (high)	SLU	FTM	DOM

Once rules are constructed, and given the values of the fuzzy inputs for (mfl, mfm, mfh, mdl, mdm, mdh) one can apply the minimum and maximum (AND & OR Zadeh) inference computations.

3) Third step-defuzzification: This is the final step in the fuzzy controller. This process is based on the idea of deriving a crisp value from a fuzzy function. The defuzzification can be performed by deriving the centre of gravity of the area under the curve of the function. Given the cost function of each maintenance action, one can arrange the maintenance actions, the fuzzy output, and the cost scale function. The feedback mechanism offered by the rules grid or DMG of fuzzy logic, as shown in Table 3, in addition to the feedback already offered in AHP in the form of consistency ratio, provides an effective performance.

The above-mentioned FLRB method will be used as an enhancement of snapshot model features called prevention action analysis.

3.0 THE CASE STUDY AND RESULT

This case study demonstrates the application of the above-mentioned techniques and its effect on maintenance performance. This company is used as a pilot study in order to test whether the system meets the user expectation and preference. A number of experts were interviewed and proposed during the design and develop the targeted system.

3.1 Company Background

The company is a palm oil mills (POM), which the main job is extracting the Fresh Fruit Bunches (FFB) to Crude Palm Oil (CPO). In this particular company there are about 50 major machines or plants. Since the aim of this tool is to assist maintenance engineers establish an appropriate maintenance action, the case study related to an old POM, which are operated more than ten years and use a conventional method of cause of failure and decision analysis techniques.

3.2 The Result

Most of the maintenance information found at POM at the time of the study commenced is originated from the unstructured daily and lubricant report. The unstructured daily report only has the date of the report, time of the report and the description of works. The lubricant report just gives the machine that need a top up or change the lubricant oil, the quantity of oil needed and a description of work or problem occurs that might cause the need to top up or change the lubricant oil.

The snapshot model will be built based on the data collected from POM concerning the most problematic machine namely, Screw Press. Example of the result using the hybrid cause of failure and decision analysis techniques are shown in Table 4, 5 and 6.

TABLE 4
The Combined Major Fault Area with the Number of Fault, Criticality, Cost and Downtime Analysis for the Period from 1.8.05 to 30.9.05

	TOTAL FAULT	**TOTAL CRITICALITY (/100)**	**TOTAL COST (xRM100)**	**TOTAL DOWNTIME**
COMPONENT NAME/ AREA OF FAULT	88	40.68	139.16	107
316 COUPL BOLT & NUT	20	4.6	26.1	30
29420E BEARING	19	4.75	62.88	21.5
120 X 150 X 14 OIL SEAL	15	4.05	13.5	7.5
29320E SKF BEARING	10	4.8	9	5
100 X 130 X 14 OIL SEAL	7	3.99	6.3	3.5
22224E BEARING	7	4.76	6.3	3.5
22220E BEARING	6	4.74	5.4	3

TABLE 5
Final Result based on the AHP Method in the Decision Analysis Technique to Select the Most Critical Components for the Period from 1.8.05 to 30.9.05

No	Code	Name	Weight	Rank
1	S9086	29420E BEARING	23.94%	1
2	W2078	316 COUPL BOLT & NUT	20.44%	2
3	S4020	120 X 150 X 14 OIL SEAL	19.28%	3
4	S9085	29320E SKF BEARING	17.46%	4
5	S9079	22224E BEARING	6.74%	5
6	S4019	100 X 130 X 14 OIL SEAL	6.21%	6
7	S9073	22220E BEARING	5.93%	7

TABLE 6
Final Result based on the FLRB Method in the Decision Analysis Technique to Select Prevention Action for the Period from 1.8.05 to 30.9.05

No	Code	Name	Policy Code	Description
1	S9086	29420E BEARING	Preventive Maintenance	Easy Maintenance
2	W2078	316 COUPL BOLT & NUT	Preventive Maintenance	Easy Maintenance
3	S4020	120 X 150 X 14 OIL SEAL	Operate to Failure	Easy Maintenance
4	S9085	29320E SKF BEARING	Operate to Failure	Easy Maintenance
5	S9079	22224E BEARING	Operate to Failure	Easy Maintenance
6	S4019	100 X 130 X 14 OIL SEAL	Operate to Failure	Easy Maintenance
7	S9073	22220E BEARING	Operate to Failure	Easy Maintenance

4.0 CONCLUSION

It is recognised the importance of the snapshot model as a tool for cause of failure and decision analysis. The recent development in the computer technology in terms of speed and capacity coupled with the successful research in the human computer interaction play considerable role in the development of a successful tool that capable of constructing snapshot model. From the result, it shows that the use of hybrid maintenance cause of failure and decision analysis could significantly improve the decision context by adding the features of snapshot model. In term of efficiency of decision-making process, the result shows that the reduction of time to reach decision among the decision makers. The hybrid cause of failure and decision analysis techniques could not deny the use of human judgments during the survey that have been conducted. Further enhancement could be done by embedding the techniques with the computerised maintenance management system (CMMS). The quality of data also could be the major issues and it could be done by using the automated data capturing techniques such as using condition monitoring method.

5.0 ACKNOWLEDGEMENT

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