A MODEL TO DIAGNOSE THE DEVIATION IN THE MAINTENANCE PERFORMANCE MEASURES

Basim Al-Najjar

Department of Terotechnology, School of Technology and Design
Växjö University, Luckligs plats 1, 351 95 Växjö, Sweden
Basim.Al-Najjar@vxu.se

Abstract

In order to achieve the strategic goals, the company should utilise an efficient data gathering and analysis system for mapping the technical and economic situation, following up the development and detecting technical and economic deviations at an early stage to plan and perform necessary maintenance actions on time. In many cases, measuring and following up the development of relevant and well selected technical and economic performance measures can be more applicable for mapping the situation and making cost-effective decisions compared with monitoring big mount of data. But, in many cases it demands a reliable technique for interpretation of the behaviour of these performance measures especially if they are not linearly interrelated and if some of them reflect a combination of technical and financial impact.

The problem addressed in this paper is; how is it possible to enhance the ability of detecting significant deviations in the maintenance performance measures at an early stage and tracing their root causes by using data- and knowledge base and inference engine? The major result achieved in this paper is a model developed for interpreting the changes in the maintenance performance measures and tracing their basic causes, which is verified in an example with typical data. The model consists of five modules; what performance measures to chose, how and why an eventual deviation on the performance measures occur, what to do to eliminate and prevent their reoccurrence and mapping of the current situation technically and financially. The main conclusion is that applying the model would enhance the ability of detecting changes in the maintenance performance through identifying the causes for elimination.

In Al-Najjar et al (2004), a model for how to identify the measurable variables, which are needed to develop measures for monitoring maintenance performance behaviour systematically, is introduced and discussed. Also, five maintenance performance measures are proposed and applied. Furthermore, an additional model manual analysis of the trend of maintenance performance measures, for an overall assessment of the company's situation, is presented. In this paper, the idea of manual analysis presented in Al-Najjar et al (2004) is systemised.

Key words: Maintenance performance measures, knowledge base, inference engine, performance measure interpretation

1. INTRODUCTION

In many cases, it is important to apply relevant indicators for monitoring and following up the development of the performance of maintenance and production processes. These indicators can be simple, such as the number of items produced and number of failures, or complex, such as the cost of producing one high quality item and maintenance cost paid for every produced high quality product.

Many authors such as Kennerley and Neely (2003), Al-Najjar et al (2004), highlight the importance of properly identified the performance measures required for following up the work done to achieve company's strategic objectives and survive daily competition. According to Kaplan and Norton (2004), 70 to 90 percent of the companies fail to realize success from their strategies due to lack of relevant data. For companies to be successful and able to accomplish their strategies, it is necessary to implement and control their performance measures in all working levels, such as strategic, operative and tactical daily work, Waeyenberg and Pintelon (2002), Kaplan and Norton (2004) and Al-Najjar et al (2004). Nonaka (1991) argues that it is not just the connection between performance measures and strategy that is important, but also the knowledge required for the organization to achieve their strategic goals. Since this is important there is a need to consistently develop new experience and knowledge in different forma, such as new tools, methods and technologies.

Turban and Aronson (1997), Pintelon and Van Puyvdelde (1997) and Sherwin (2000) argue for the need of investments to secure successful implementation of performance measures and strategies. In general, the major objectives of applying information systems are to gather, analysis and present information and knowledge. Integration of the performance measures with a knowledgebase and an inference engine can provide the manager the required information, knowledge and ability to monitor and interpret the performance measures for making cost effective decisions.

The problem addressed in this paper is; how is it possible to enhance the ability of detecting significant deviations in the maintenance performance measures at an early stage and tracing their root causes by using knowledge base and inference engine? The aim of this paper is to develop a model describing the possibility of using a data- and knowledge-base and inference engine for real-time diagnosis of the behaviour of the performance measures and effectively detecting technical and economic deviations from predetermined values at an early stage. In Section 2, interpretation of maintenance performance measures is discussed. A model describes the utilisation of the data- and knowledgebase together with inference engine for detecting, analysis performance measure deviations and tracing the reasons behind that is developed in Section 3. The model is applied in an illustrative example in Section 4, which is followed by conclusions.

2. INTERPRETATION OF MAINTENANCE PERFORMANCE MEASURES

In this paper the maintenance performance measure is defined as the indicator that provides the information required for mapping and judging the performance level of maintenance technically, financially or combined. Identifying the relevant data required for accurate monitoring of maintenance performance is discussed in Kans (2005) and Al-Najjar et al (2004). Applying few well-selected performance measures for monitoring maintenance makes the procedure of judging its performance and consequently decision-making process much easier compared with the case when using a big amount of data for the same purposes. But, in the same time it demands better techniques to interpret the behaviour of the performance measures and achieve accurate diagnosis of the root causes, Al-Najjar et al (2004). We assume that the measures required for monitoring the performance of maintenance are already selected or developed by applying special techniques, such as top-down analysis method suggested by Al-Najjar et al (2004), Al-Najjar and Kans (2005) and Kans (2005).

Using just one performance measure for detecting changes in any process, such as the case when controlling the quality of a product using specific dimension to judge whether it is accepted or rejected is easy to interpret. But, when the maintenance or production cost is monitored, the increase in any of these two measures may mean many things, such as real increase in the direct maintenance cost, raw material, energy or operating cost.

The increase in the maintenance cost may be beneficial. For example, a chef manager would welcome the increase in maintenance cost if its share in the cost of producing one-item of high quality is reduced, i.e. the number of high quality items has been increased due to more cost-effective maintenance. The same confusion can happen when the production cost increases. This increment is not necessary an undesirable result especially if it is due to the increase in the production time and/or speed and not because of higher maintenance cost per producing one item or due to production losses. The situation will be much more complicated if there exist many performance measures that should be considered for mapping, analysis and evaluation of the production and maintenance processes to make cost-effective decisions.

We can easily trace the root causes lying behind changes in the technical or financial performance measures, such as machine failures and availability, and maintenance cost and production costs, respectively. But, it will not be equally easy to race the root causes when monitoring combined measures mixes technical and financial terms such as direct maintenance cost divided by overall equipment effectiveness, or direct maintenance cost divided by the number of quality items (or tons produced). This is because the increment or reduction in the performance measure value may mean different based on how the measure is developed, i.e. how the information provided by the measure is aggregated. Therefore, interpretation of the changes in the values of the performance measures and tracing the root causes behind them can be a big task, which is not easy to perform manually for achieving cost-effective decisions. This is why systemising this analysis and diagnosing process is important for carrying out a real-time interpretation effectively.

In general, the main objectives of applying relevant performance measures is to detect deviations in the cost and condition of the production and maintenance processes for taking the actions required at an early stage with less labour and cost. Also, the analysis and diagnosis of the deviations in the performance measures will lead to better results if it is associated with identifying the root-causes lie behind changes. Further, recommending what to do for treating the deviations would help avoiding their re-occurrence.

In Al-Najjar et al (2004), a model for identify the variables that are required to develop measures for monitoring maintenance performance behaviour systematically, is introduced and discussed. Also, five maintenance performance measures are proposed and applied. Furthermore, a model for manual analysis of the trend of maintenance performance measures, for an overall assessment of the company's situation, is presented. In this paper, the idea of manual analysis presented in Al-Najjar et al (2004) is systemised.

3 MODEL DEVELOPMENT

In this section, we consider that the model is necessary to detect significant deviations in the maintenance performance when several measures are used for monitoring maintenance and production processes. In order to achieve reliable mapping, analysis and evaluation of the maintenance performance, and to recommend what to do when significant deviations are detected, the model is constructed to perform the following five tasks, i.e. to

1. Identify what to focus on out of all the performance measures being monitored, i.e. performance measures that undergoing significant changes. This step is necessary because, in many cases, there are many monitoring variable (measures) to be considered. Therefore, identifying where to start the investigation and why it is usually not an easy task
2. Analyse the deviations to answer how it is happened, i.e. describing the mechanisms of the initiation and development of the changes
3. Identify the root causes behind these changes, which is required for the prevention of reoccurrence of the same problems
4. Recommend what to do at an early stage to restore the process to as good as new (or as good as before), and finally

5. Assess the measures that are relevant for mapping and evaluating maintenance performance

These five phases of the model performance are carried out by equivalent number of modules. The first module is called "What to analyse", which is responsible of, see also Fig. 1;

1. Arranging a list consists of the values of all the performance measures (x_1,..., x_n) that have been selected for performance monitoring
2. Establishing a list of the reference levels (y_1,.., y_n) for every performance measure introduced in 1 above. These reference levels are important for distinguishing the changes in the values of the performance measures and its severity. The number of the reference levels for each performance measure can be considered three; one at the normal level and one at the action level, i.e. an action should be done as soon as the measure value exceeds that level. The third level (warning level) can be positioned in between these two levels (normal and action levels) for indicating if the measure is undergoing a real change (but still acceptable) and not due to temporarily disturbances, Al-Najjar (1997)
3. The trends of these changes, i.e. changes in time of every performance measure, ease following up their developments. Association of these trends with the reference levels, such as normal, still acceptable/warning and action levels would provide the possibility of detecting significant deviations at an early stage.
4. The inference engine completes the work by reading whether any of these changes exceed the warning level and produce a prioritising list to prioritise the investigations

The second module, which is called How is responsible of investigating the root causes behind the deviations in the performance measures. To complete the work done in the What module, the investigation of the performance measures topping the prioritising list, i.e. those which undergoing significant changes, should be analysed by the inference engine in the How module. Previous technical experience, knowledge and analysis results of the possible reasons and the problem developing mechanisms that may cause deviations in the performance measures can be utilised when building the inference engine for identifying where and how to investigate. The reasons behind the changes in the prioritised measures can be several. Therefore, the inference engine investigates all these possible reasons individually and in combination with other reasons to detect possible interactions, see Fig. 1.

The third module (Why) is responsible of summarise the work done by How module by identifying the most probable reasons behind the deviations in the prioritised performance measures. The output of the Why module eases the task of recommending what to do, i.e. to suggest either to just handle the current situation, or to eliminate the roots causes or both, which is the task of the fourth module. The fifth module is responsible of mapping maintenance and production processes technically and financially, which is necessary for evaluating the maintenance performance.

The data- and knowledgebase that are involved in this model ought to include all the relevant data required by the inference engine to perform this task. It includes the knowledge and the previous experience concerning detecting, analysis and the results of handling previous problems. The data- and knowledgebase is necessary for improving the model continuously and cost-effectively. The model provides a possibility to assess not just technical or financial performance measures but also combined measures such as those expressed in the module performance measures assessment, i.e. the fifth module

4 APPLYING EXAMPLE

In this section, the model is described by an example treating one measure for monitoring the performance of maintenance through using the direct maintenance cost (DMC) divided by the high quality production (HQP) measured in tons or items, which is denoted by DMC/HQP. The performance measure DMC/HQP reflects the maintenance contribution in the production of each item or ton assuming that the quality control system is working properly. In other words, it means how much the company pays for maintaining the production system per each item or ton. Also, it describes the reliability of the production process.

When the list of the performance measures and trends of their behaviour are described, the inference engine will be able to prioritise the measures of the most critical values, i.e. the measures whose values exceeded a predetermined level. Let, for instance, one of these levels being the warning level. Assume that DMC/HQP exceeded the warning level. In general, the levels of the performance measures can be decided based on the company's policy.

When a measure exceeds a warning level it is always better to investigate the root causes and the developing mechanisms behind this significant change. Also, it is necessary to investigate interactions of these causes, if it possible, for identifying and cost-effectively eliminating them for restoring the process to its previous condition.

In this example, we considered the following factors are the most probable causes behind the increment of DMC/HQP, see also Fig.2:

1. Less accepted production; lower production quality due to inefficient or lack of maintenance.
2. Higher production rate; high production speed leads to faster deterioration in the machine condition, more stoppages, longer stoppage time and consequently more direct maintenance cost
3. Longer production time; it means also faster deterioration and shorter life length of the machinery, and consequently more direct maintenance cost
4. Quality of maintenance actions; it influences the maintenance impact on the machines and production process. The bad maintenance quality results in more frequent stoppages, less production and higher direct maintenance cost

In order to identify the basic causes behind maintenance performance deviation, the inference engine would analyse technical and financial past data of the machine and process. Identifying the interactions between the root causes those mentioned above are important to clarify the situation better. When the root causes are identified, the recommendation for what to do in order to eliminate the problem and prevent its reoccurrence is the next step to be accomplished by the inference engine.

Reporting what happened together with the assessment of the measures of the maintenance performance eases for decision maker to achieve a cost-effective maintenance action.

CONCLUSIONS

Monitoring and following up the development in production and maintenance processes automatically through applying special performance measures demands using special rules to implement a data- and knowledgebase and inference engine to accomplish a cost effective maintenance decision. Applying the model developed in Section 3 offers opportunity to diagnose and interpret the behaviour of the performance measures monitored. In general, the performance measures can be many in complex production processes. Using this model, detecting significant deviations in the performance measures can be done effectively does matter how many they are. Identification of the root causes behind these deviations enables the user to take the cost-effective actions required at an early stage.

It was obvious from the applied example how important are the past data from the working areas related to the performance measure in question. The applied example shows the possibility of monitoring even more complicated performance measures such as direct maintenance cost/high quality production, i.e. combined technical and financial measures, if the required data are available.

The knowledge available that can be utilised for identifying and analysis production and maintenance problems is enormous. This knowledge is not easy to utilise effectively without better data quality and coverage from the working areas relevant to the problems under consideration. A knowledge and data based analysis system using the technology of data- and knowledgebase and inference engine opens for the companies a possibility of applying real-time cost-effective maintenance decisions. At the same time it demands that the company should store specific data and knowledge required for applying and enhancing the model involved. This leads to decisions of less uncertainty, which in turn leads to lower level of risk and cost diminishing. Further, this also leads to more effective and efficient use of the companies' resources for both short and long term towards higher profitability and better competitiveness.

REFENCES

Al-Najjar, B, Hanson, M.O, Sunnegårdh, P., (2004). Benchmarking of Maintenance Performance: A Case Study in two manufacturers of furniture

Al-Najjar, B (1997), Condition Based Maintenance: Selection and Improvement of a cost-effective vibration based policy in rolling element bearings. Doctoral thesis, ISSN 0280-722X, ISNR LUTMDN/TMIO-1006-SE, ISBN 91-628-2545-X, Lund University, Inst of Industrial Engineering, Sweden.

Al-Najjar, B. and Kans, M (2005). A Model to Identify Relevant Data for Accurate Problem Tracing and Localisation, and Cost-effective Decisions: A Case Study. To be published

Kans, M. (2005). On the identification and utilisation of relevant data applying cost-effective maintenance. Report, no 14 (Tekn. Lic.), School of Technology and Design, Växjö University, Sweden

Kaplan, R.S and Norton. D.P (2004), "Strategy Maps - converting intangible assets into tangible outcomes", Harvard Business School Press, Boston, Massachusetts, ISBN 1-50139-134-2, USA

Kennerley M and Neely A (2003) "Measuring performance in a changing business environment", International journal of Operations & Production Management, Vol.23, No. 2, pp. 213-229

Nonaka, I (1991) "Harvard Business Review on Knowledge management", Harvard Business School Press

Pintelon, L,& Van Puyvdelde, F, (1997) " Maintenance Performance Reporting Systems: Some Experiences", Central for Industrial Management, Leuve, Belgium and Glaverbel, Mol, Belgium, Journal of Quality in Maintenance Engineering. Vol 3 No 1, 1997, pp, 4-15.

Turban, E, & Aronson, J, (1997), "Decision Support Systems and Intelligent Systems", 5th edition, Prentice Hall PTR Upper Saddle River, NJ, USA.

Sherwin, D (2000), "A Review of Overall Models for Maintenance Management", Journal of Quality in Management, Vol. 6 No. 3. 2000. pp. 138-164.

Waeyenbergh, G, Pintelon, L (2002), "A Framework for Maintenance Concept Development", International Journal of Production Economics, pp.299-313

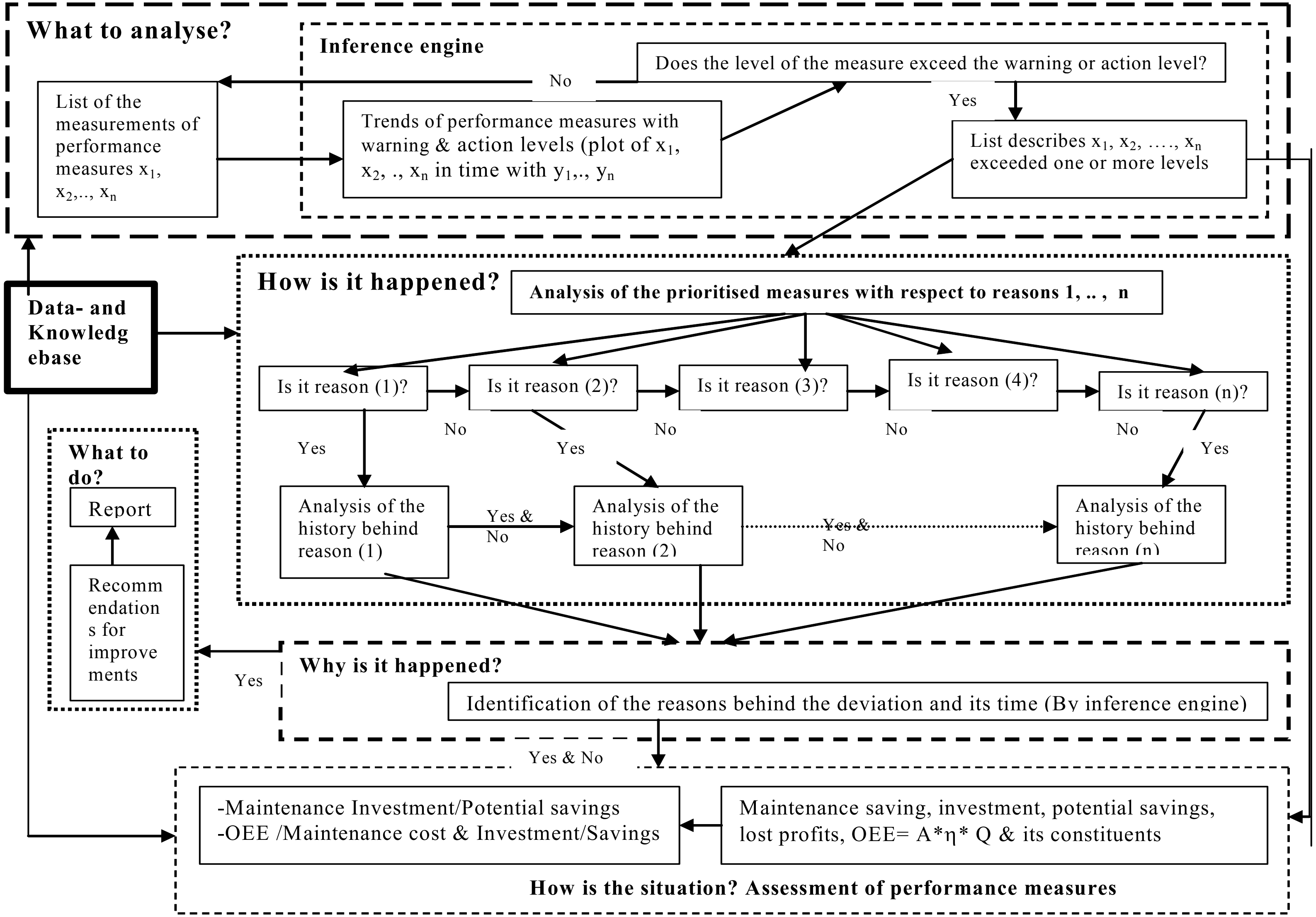

Fig. 1. A model for diagnosis of maintenance performance measure

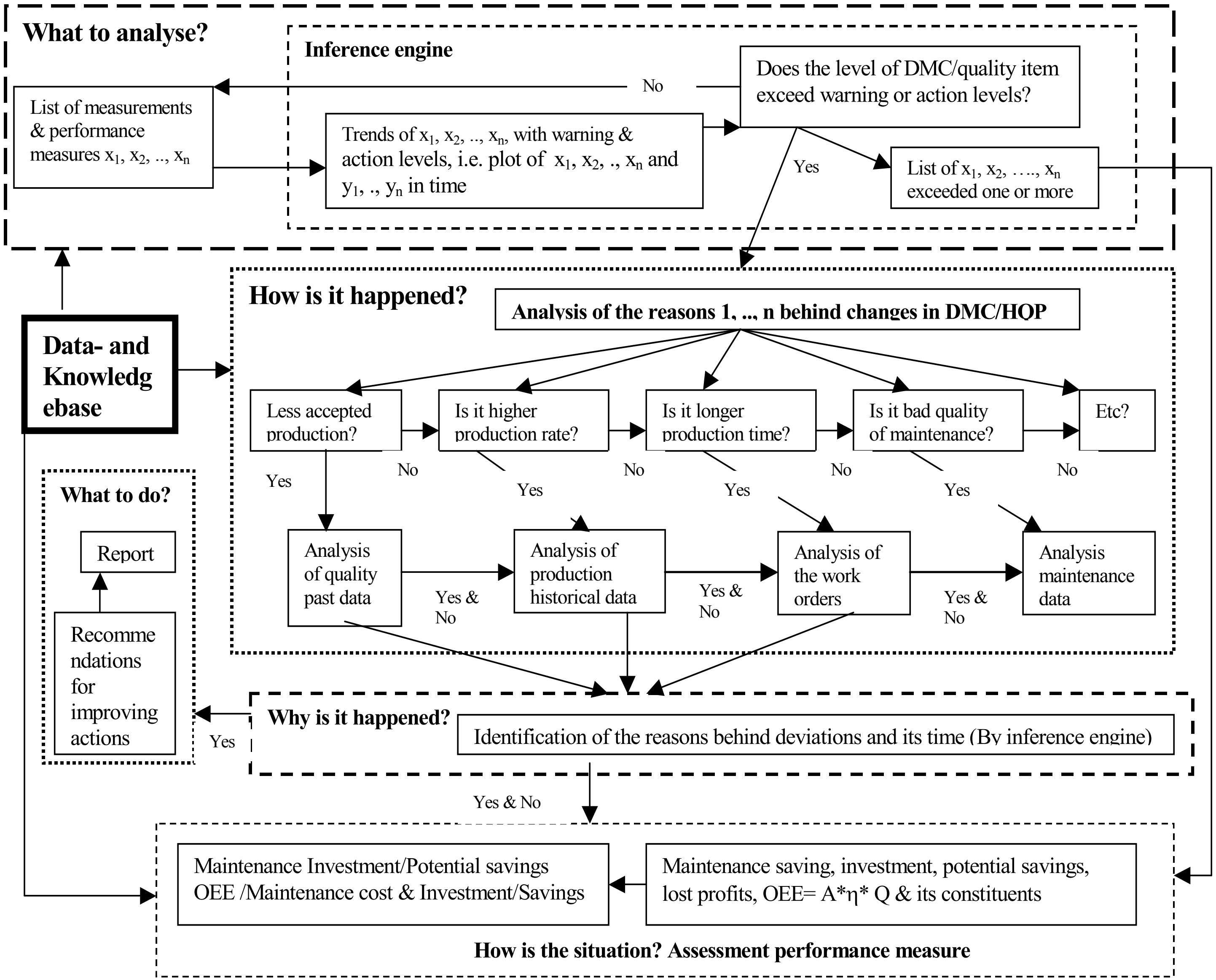

Fig. 2. Application of the model for diagnosis of maintenance performance measure when using maintenance direct cost divided by quality production