

# Maintenance Audits Using Balanced Scorecard and Maturity Model

There is increasing interest in the use of maintenance performance measurement (MPM) and the possibility of using the maintenance audits for benchmarking metrics. This article proposes a methodology for simple measurement, one that accepts the indicators used on a scorecard with four perspectives and is hierarchized according to organizational level. The maintenance audit will evaluate the degree of fulfillment of objectives and the degree of satisfaction obtained from each of those perspectives. It will provide a clear picture of the current status of maintenance organization and the success of implemented policies taking into account the maintenance maturity model, i.e., the logical evolution of maintenance function in the company.

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ferent national adaptations and translations propose a set of more than 70 indicators [2]. These two standards are not mandatory and they consider different (incompatible) metric characteristics in their qualitative (surveys) and quantitative (indicators) aspects. As will be shown, to correctly measure the maintenance function, the two should be combined.

Depending on its goals, a maintenance audit can be either qualitative or quantitative. Classic examples of audits with a strong qualitative component are those concerned with safety, Sorensen [3]. A classic quantitative

audit is a nuclear power plant maintenance performance audit, which is similar to RCM analysis, Martorell et al. [4]. Each type has its own strengths and weaknesses.

The proper measurement of maintenance performance requires an association between coherent and compatible objectives and indicators. This article proposes a method for grouping maintenance performance indicators using the hierarchized Balanced Scorecard (BSC) and considering different organizational levels. While the contributions of authors like Wireman [5], and the recommendations of the EFNMS and the North

The criteria for maintenance audits differ from other types of audits; the absence of standardized procedures as well as little literature on the topic means also that research and development have lagged behind the burgeoning interest. A classic maintenance audit standard, COVENIM 2500-93 [1] from Venezuela (1993), uses surveys to gather data. The most recent standard is EN 15341; its dif-

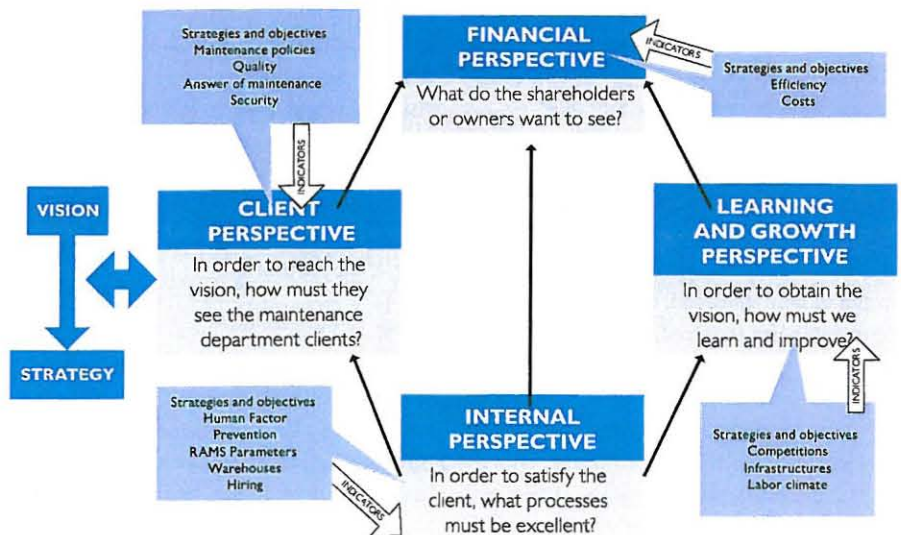


FIGURE 1. The BSC of maintenance.

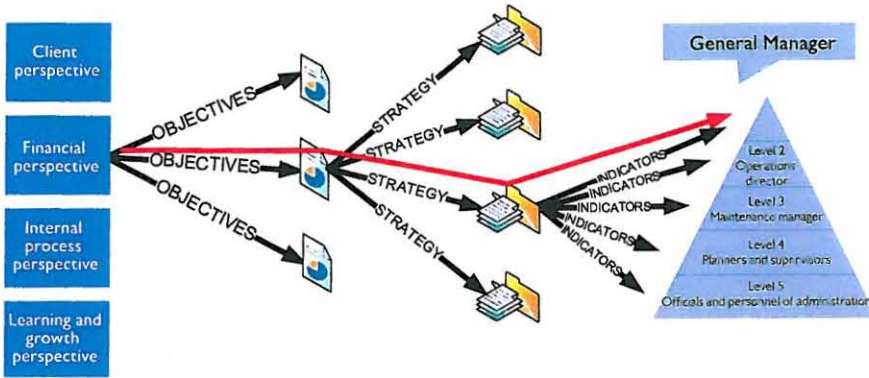


FIGURE 2. Projection of indicators.

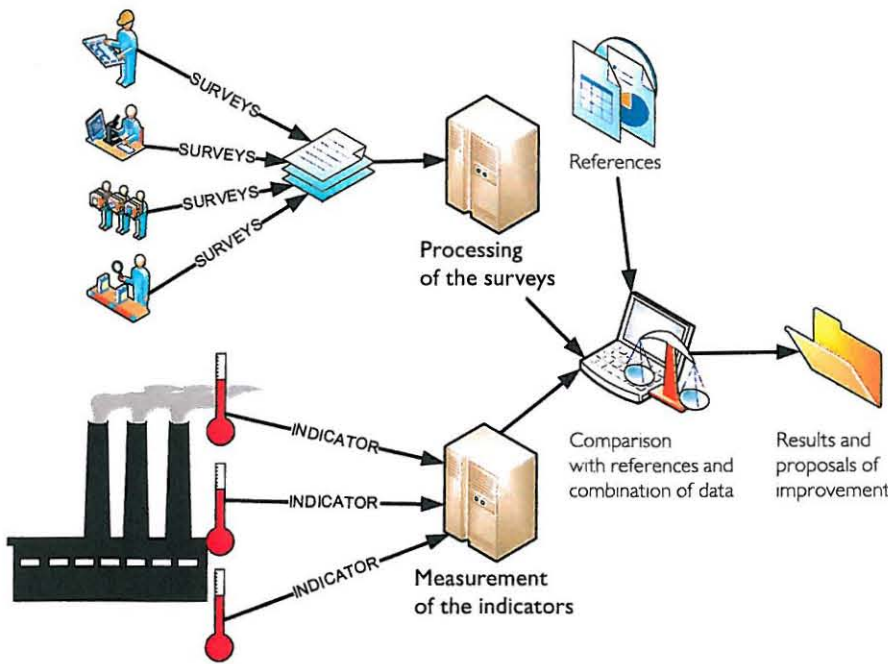


FIGURE 3. Model of qualitative and quantitative audit.

American SMRP to the field of the maintenance metrics are useful, they propose an excessive number of indicators and do not provide a clear approach. Present methods can use too many indicators, read the data too optimistically, and fail to clearly articulate or even understand objectives and purpose of the measurement. This absence of vision, added to poorly communicated corporate objectives, constitutes the main deficiency in traditional systems.

The present proposal uses the framework of the Balanced Scorecard (BSC), Kaplan & Norton [6], and classifying indicators accordingly. Following the BSC guidelines, it uses the four general perspectives: client's perspective, financial perspective, perspective of internal processes, and perspective of learning and growth. The article sets these

indicators within the organization's hierarchy, by using a break down process. The use of a hierarchized BSC is a logical integrating tool for MPM and allows the maintenance department to achieve the goals set by the top management layer.

A maintenance audit is an apparently simple concept but is, in fact, extremely complex. Given the lack of standardization and the number of divergent opinions, it is seldom performed.

The present article will suggest a methodology of simple measurement, using the framework of the BSC with its four perspectives. The goal is to audit the degree of the fulfilment of objectives and the degree of satisfaction obtained from each of the four perspectives. This will provide a clear picture of the department's situation and indicate the

best time to begin improvements; see Wardhehoff [7].

### The maintenance scorecard

Typically, scorecards indicate the level reached in the attainment of objectives, usually upper management's financial objectives. They have remained unchanged, even though the management of organizations has considerably modified its strategic vision in recent years. Various criteria of management, as in the EFQM Excellence Model, are often isolated and independent of each other; for example, an organisation's technical and economic aspects are separated. Each follows different directives and operates at different functional and hierarchic levels, creating the false impression that objectives can be separated. In some departments, like maintenance, operating and economic indicators are clearly divided, the former following the directives of the head of maintenance and the latter following the company's overall direction.

On the Maintenance Scorecard (MSC), maintenance-based BSC is reorganized; objectives are integrated in a logical way. The MSC helps to transform good intentions into actions directly applicable to employees' daily work, while bearing in mind the four strategic business perspectives mentioned above: financial, client, internal processes and learning-growth. In the case of maintenance, however, the head of maintenance often knows only a few production objectives. For the most part, no one tells him/her exactly what the organization expects, leaving him/her to figure it out on his/her own.

The structure of the MSC, represented in FIGURE 1, indicates the modus operandi used to translate the organization's mission into concrete objectives; strategies to achieve them can be generated by using the four perspectives. The objectives are derived from the general company objectives but are specific to the maintenance. For this to work, the whole maintenance hierarchy must know the objectives of the upper management.

Based on this knowledge, maintenance managers must consider their own departments and improve their activity. This comprises the "knowledge pool" of the organization. More specifically, the indicators become control indices with predetermined frequencies, allowing managers to see if the



results are in line with the specified objectives. If not, then suitable corrective measures must be taken.

The maintenance indicators should be grouped into one of the four perspectives mentioned in FIGURE 1; their objectives should be also included. The indicators measure the degree of success of the diverse strategies and the extent to which the objectives have been attained.

### The maintenance audit

The presented audit model consists of two aspects, one qualitative and one quantitative, Zahra Mohaghegh et al. [8]. The quantitative part measures numerical indicators included in the scorecard, located in the four different BSC perspectives and hierarchized at different levels. The qualitative aspect constitutes a set of surveys carried out at different hierarchical levels.

In the model, the indicators and the surveys are combined, thereby validating the quantitative indicators with the qualitative perceptions of the surveys. They are collated with the references associated with each measurement to reveal deviations and isolate possible problems.

Some indicators will contribute measures in conventional units, like monetary units, temporary units or number of actions, products etc. Others will be ratios of certain magnitudes, representing a percentage of different costs or types of maintenance, or representing indices of efficiency or inefficiency whose ideal value is zero.

It is important to know the present state of the maintenance and to be able to compare different aspects on the same scale. This is more important than knowing the value itself of indicators, as an absolute value lacks interest; the trend gives much more value. Therefore, it is best to be especially careful in the first audit, as it will be a benchmarking and reference point in subsequent audits.

#### PROCESS OF APPLICATION OF THE AUDIT

An audit involves more than a predetermined questionnaire or the measurements of numerical indicators. A number of complementary stages are required to obtain a result that is useful to decision making; see FIGURE 4.

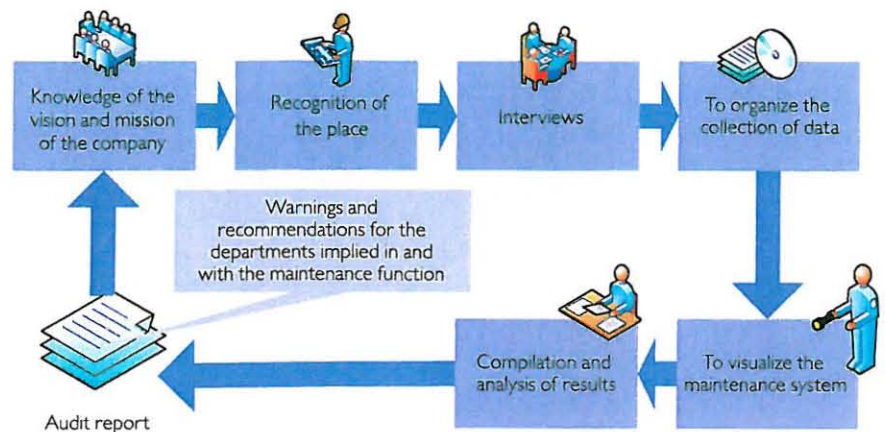


FIGURE 4. Scheme of audit and previous stages.

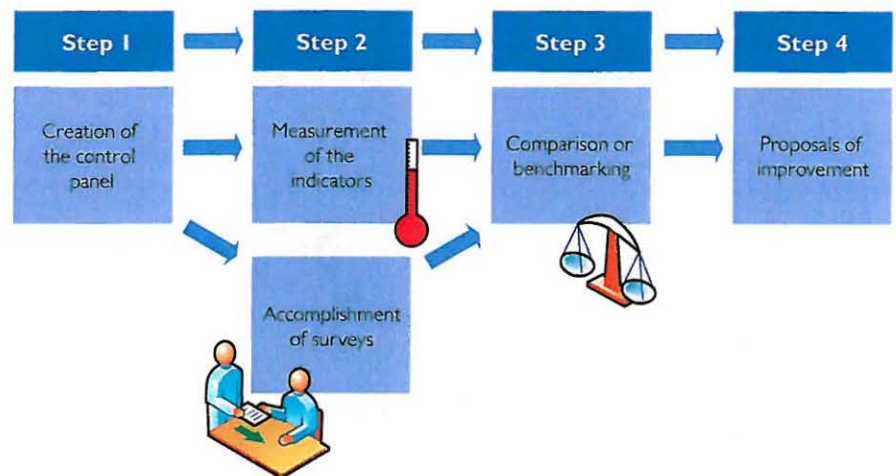


FIGURE 5. Steps to follow in the accomplishment of the audit.

The developed methodology combines the scorecard, the strategy of the company and what is requested of the maintenance department, as observed in FIGURE 5. That is to say, the measurements and the scorecard will reflect what the company expects from the maintenance department.

The benefit of this method is its rapidity; the audit team only needs to know the business objectives that involve the maintenance department.

Objectives can be classified into two types: effective yield and organizational efficiency. The improvement derived from the recommendations should not be considered, as the proposal of improvements constitutes the last step of the process. It is external and subsequent to the audit.

To perform a maintenance audit in an organization for the first time using the de-

scribed methodology, the following phases are suggested.

#### Phase 1: Creation of the scorecard

First, a scorecard with clear indicators and repeatable measures must be created. The measures selected must be performed in similar conditions and should not be affected by the audit process. Among all hierarchized indicators, those considered both representative and independent will be selected.

This first step filters the necessary and independent indicators (the only ones that will be considered) from all those included on the scorecard. Considering daily performance controls can lead to the addition of many more indices, but the audit must be done quickly, making it impossible to consider all measures.

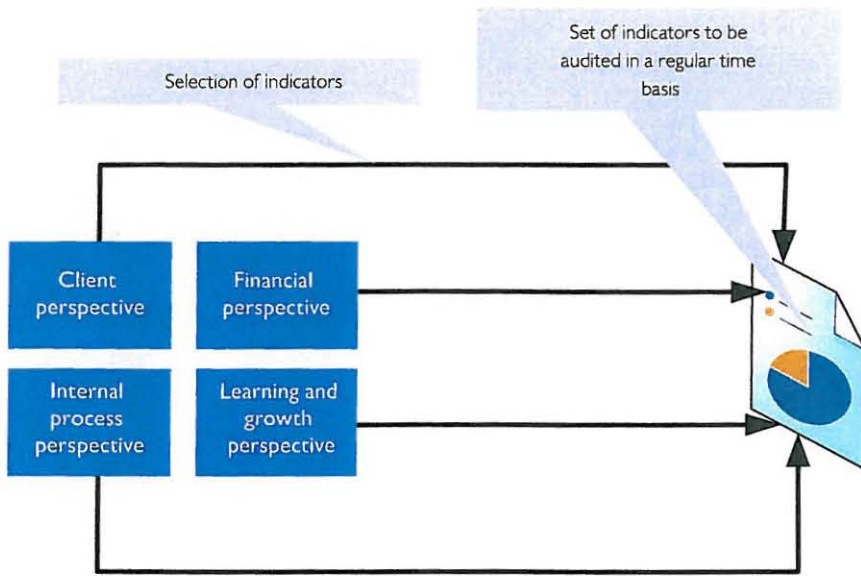


FIGURE 6. Extraction of parameters of the integral scorecard.

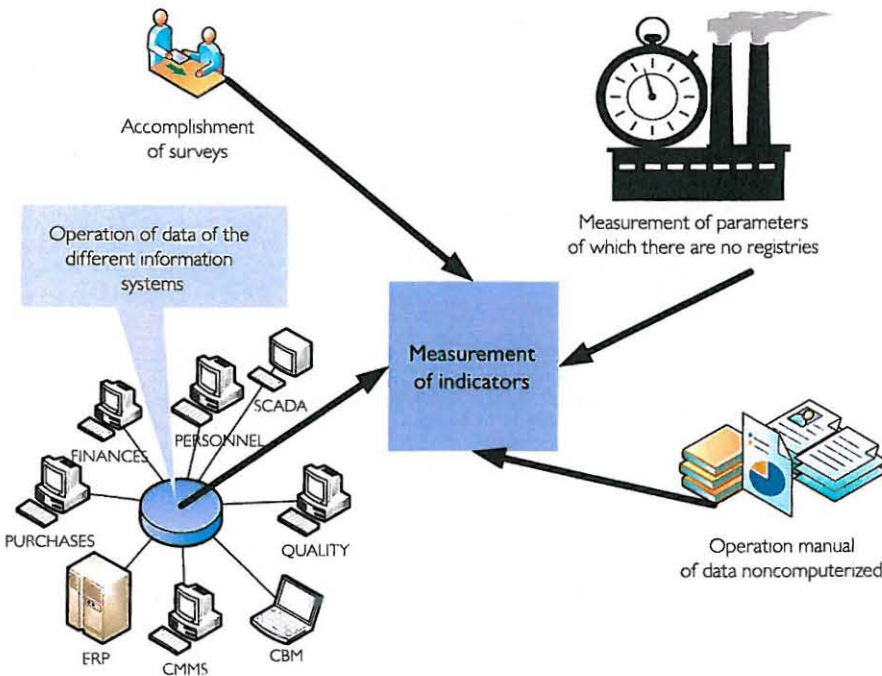


FIGURE 7. Sources of intelligence to consider in the measurement of the indicators.

**Phase 2: Measurement of the indicators and accomplishment of the surveys**

This process must be systematic; it must also be performed quickly without consuming too many resources. In addition, the audit must be agile and trustworthy. Some authors recognize the need to work with standard and generic measures, but are conscious of the possible inapplicability of these meas-

ures to an organization's objectives. Other authors like Wani et al. [9] propose the use of nonstandard indicators, arguing that if indicators are custom-designed, they will best suit the audit's needs; on the other hand, it will be more difficult to perform comparisons or benchmarking.

The weak point of the surveys, meanwhile, is their human factor. Nevertheless it

is useful to have individual perceptions and to be able to compare them to the measured numerical figures.

There are four possible sources for information in the measurement of indicators, as shown in FIGURE 7. The required data are usually not integrated into one system, and their dispersion in different applications and computer systems is often chaotic. Thus, the data collection process is time consuming, and auditors have to check the quality of the data and assure that all records are properly updated.

**Phase 3: Comparison or benchmarking**

When the measures have been obtained, they are collated with the set reference points. The deviation of the measurements from the reference points will indicate the positive or negative result of the audit. These reference points can have several origins: benchmarking, the experience of technicians and the previous performance of assets, the recommendations of the manufacturer or the experience of the auditor who, according to Lemos [10], must set proper thresholds for the organization.

**Phase 4: Proposals of improvement**

The most important result of the audit will be the deviations from the reference values. Based on these deviations, some improvements should be proposed and scheduled to be corrected before the next audit.

**PROGRAMMING AND PLANNING OF THE AUDIT PROCESS**

The first step is the preparation of the scorecard, but the use of many surveys and indicators demands a structured measurement process with a tight schedule. Obviously, the auditor wants to be able to visualize the four perspectives of the BSC during the progress of the audit, and understand why the audit is considering specific indicators. Therefore, it is necessary to create a clear and transparent methodology that makes the measurements possible.

To plan a logical sequence in the measurement of those parameters and to secure partial results throughout the process, Wireman [3] and Campbell [11] look at the evolution of the maturity of the maintenance in an organization on the basis of levels. Wireman's definition of the necessary steps to follow



takes a pyramid shape, shown in FIGURE 8. This maintenance evolution pyramid can be used to organize the audit in a chronological way with the intention of identifying the level of where the organization is in the pyramid. It can also be used to determine if the correct actions have been taken to assure maintenance evolution based on solid and well defined steps.

As the figure shows, the indicators associated with the four BSC perspectives can be transferred to the pyramid, so that a new set of indicators for each level of the pyramid is created.

When the indicators are relocated in the maintenance evolution pyramid, the measurement process can start, beginning at the bottom of the pyramid and using the benchmarks associated with each level as a basis for comparison. The audit can be stopped at any point if the organization's real level of maturity turns out to be different than is mapped on the pyramid.

This methodology creates a structured measurement process that allows partial results throughout the audit. The different stages in the evolution of the maintenance are audited, leading to useful recommendations. If the benchmarked levels are surpassed, only small nonconformities will appear. More serious recommendations derive from the benchmarking discrepancies in the indicators on non mature levels. Success or non success in one level will be explained by the indicators on lower levels.

It is important to emphasize (see FIGURE 9) that in cases of high levels of immaturity, the audit's value is considerably reduced because the obtained figures are not relevant. In this case, it is time to re-transfer the indicators to the BSC and to consider what needs to be developed on the scorecard.

The complete process can be seen in FIGURE 10. The audit begins at the base of the pyramid; the indicators associated with different levels are evaluated and compared with the corresponding benchmarks to detect potential deviations. Once the audit progress reaches the top of the pyramid, auditors have information about the real maturity of the organization and can formulate suggestions for improvement corresponding to the maturity levels.

Once the real maturity level is identified, problems are identified, and improvements

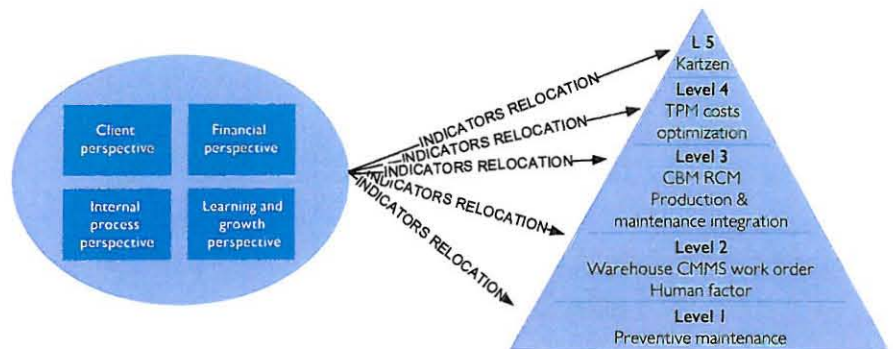


FIGURE 8. Relocation of indicators for audit.

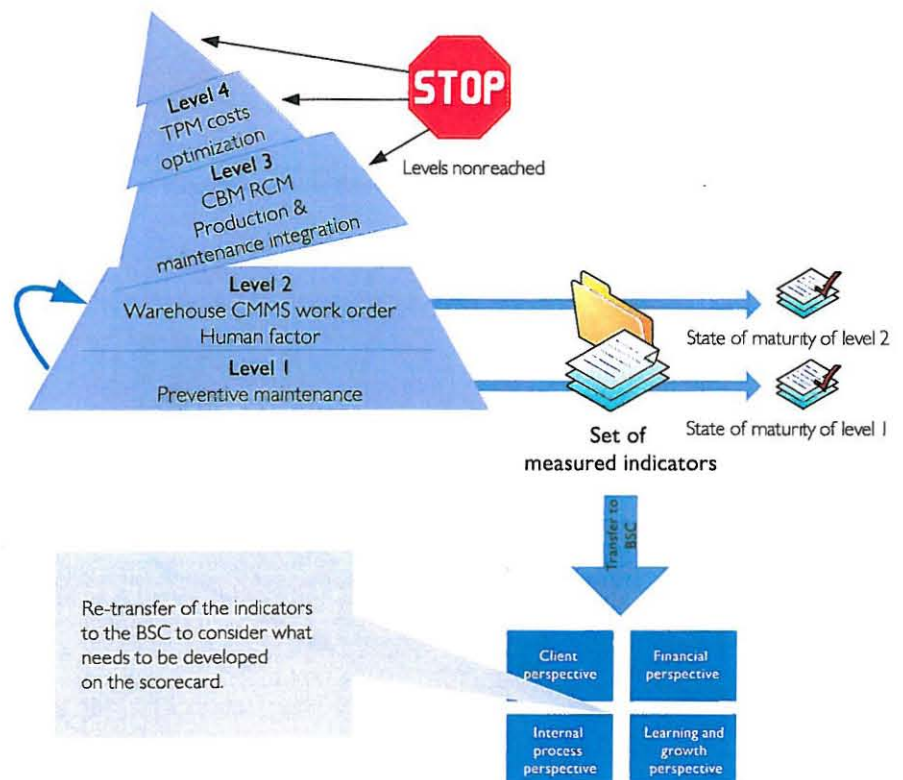


FIGURE 9. Process of the audit based on the degrees of maturity of the maintenance

are proposed, indicators can be transferred once again to the BSC. The last audit stage consists of the projection of the indicators measured with their benchmarks onto the four BSC perspectives. This will show a BSC of maintenance that has been properly completed, so that users will be able to monitor success in terms of strategies and objectives.

Therefore, a double set of information is obtained from this audit, as seen in FIGURE 11. First, we learn the state of maturity in the evolution of maintenance; this operating information is crucial if we wish to develop and use more complex methodologies to attain

greater efficiency and effectiveness. The audit's recommendations will describe suitable development of the maintenance function in the organization, showing the logical steps to be taken and indicating where shortcomings still exist. The chronology of accomplishment of the audit marks forms an evolutionary pyramid; for this reason, the errors indicated on upper levels will have their causes in lower levels. The analysis of the problems indicated by indicators or surveys will therefore be easily processed.

The second obtained result is the BSC itself, when the measurements realized in the pyramidal process are transferred back to it

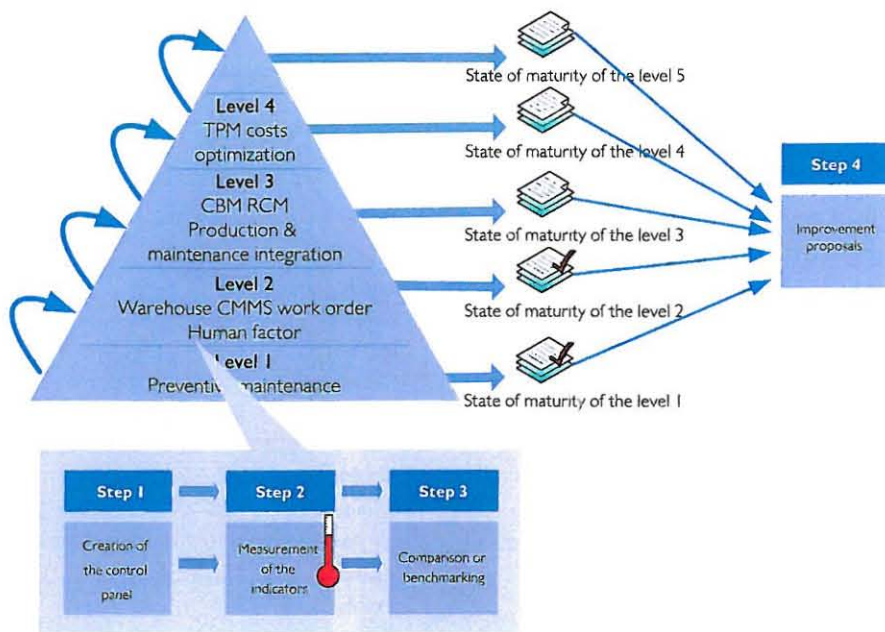


FIGURE 10. Partial and final results on the state of maturity of the maintenance in the organization.

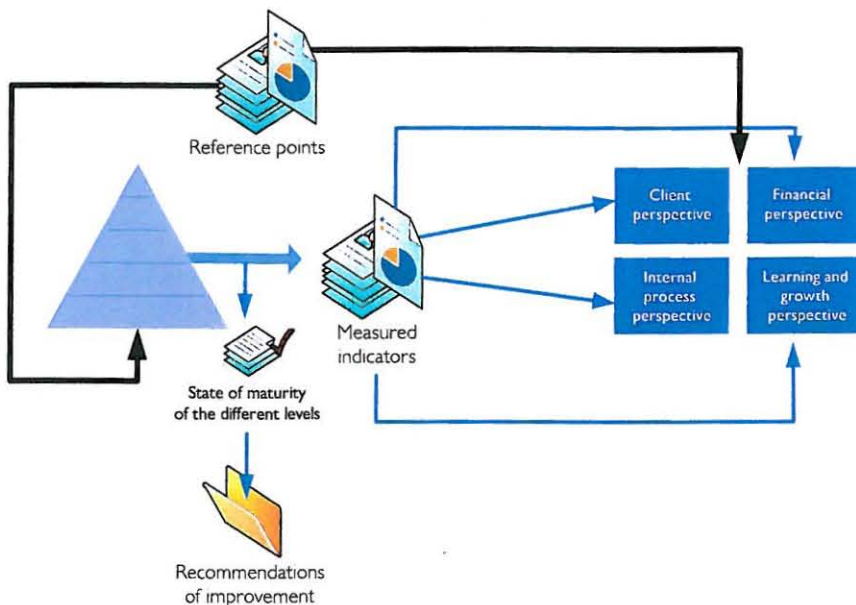


FIGURE 11. Movement of indicators to the BSC.

The indicators associated with maturity levels will offer a clear picture of the four perspectives of the BSC. This will prove useful for the organization, especially with respect to the efficiency and effectiveness of the maintenance department.

In FIGURE 11, one can observe how the transferred indicators fill up the scorecard's perspectives: the client's perspective will be especially relevant for production; the financial perspective will show the accuracy of the budget; the internal processes perspective will show the internal efficiency of the depart-

ment, mainly with respect to the direction of maintenance; and finally, the learning and growth perspective will show how the human factor is handled in the organization.

### Conclusions

The proposed model is a multidimensional integration of a series of uncontrolled aspects in the maintenance function, over time and in an isolated form. The proposed model includes methodological or technological tools proven successful elsewhere but not generally used in the management of assets.

More specifically, it integrates the following:

- It connects qualitative aspects of surveys, climate perceptions and attitudes and also includes quantifiable indicators of diverse natures and objectives.
- It considers maintenance at different vertical organizational levels, looking at the indicators on each level to fill out the overall audit scorecard. It defines the proprietor of the indicator, who contributes the information, who calculates it and who uses it in for decision making.
- It proposes a structured process to obtain the results most commonly demanded by users. It takes into account the target organization and the time when data are collected and audits are performed to get a clear picture of the progress in goal achievement.

An advantage of the system is its ability to determine the current maturity level of each level in the maintenance pyramid. The audit can be stopped at any point if there is too great a discrepancy between benchmarked measurements and the audit's findings. The combination of data collection (qualitative and quantitative) ensures valid results.

Finally, the audit is based on a set of indicators, hierarchized and organized, according to the four perspectives of the BSC. Once the audit is performed and the indicators are relocated in the BSC, the degree of development and the satisfaction of each stakeholder are reliably measured. ■

»WHO are the authors?

Dr. Uday Kumar obtained his B. Tech from India during the year 1979. After working for 6 years in Indian mining industries, he obtained a PhD degree in the field of Reliability and Maintenance in 1990. He then worked as a Senior Lecturer and Associate Professor at Luleå University from 1990 to 1996. In 1997, he was appointed as a Professor of Mechanical Engineering (Maintenance) at the University of Stavanger, Norway. Presently, he is Professor of Operation and Maintenance Engineering at Luleå University of Technology, Sweden. He has published more than 170 papers in International Journals and Conference Proceedings. >>>

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## ■ NEWS

### Brüel & Kjær Teams Up With InstanTEL for Construction Noise and Vibration Services

» **LARGE** infrastructure construction projects take several years to complete and are often located within built-up areas. This can give rise to significant noise and vibration nuisance which, if left unmanaged, can lead to project delays and significantly increased costs. Importantly, excessive vibration from pile driving and other construction activities can lead to damage to nearby property and potential litigation.

Brüel & Kjær has been active for many years providing noise monitoring solutions to manage noise nuisance around

the world and is pleased to announce a partnership with InstanTEL to add vibration monitoring to its Noise Sentinel managed services.

"We've chosen to partner with InstanTEL as they have field-proven instrumentation that we can integrate with our established noise monitoring technology to target solutions at the Construction industry," said **Phil Stollery**, Product Marketing Manager for Brüel & Kjær Environment Management Solutions. "Simultaneous noise and vibration monitoring will enable us to deliver unique solutions to the Con-

struction Industry that will help to reduce impact on communities, demonstrate compliance with regulations and manage project risk."

About the partnership, **Ron Mask**, Sales Manager for InstanTEL said, "We're obviously delighted that Brüel & Kjær has chosen InstanTEL and the Minimate PRO4. Brüel & Kjær is synonymous

worldwide with high-quality instrumentation and we are very pleased to be associated with them."

