

A functional approach for maintenance audit

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Abstract

The increasing numbers of complexities in production systems have a major impact on the maintenance service. In recent years, there have been many attempts to develop methods and tools in order to improve the availability, reliability and maintainability of production resources. In this respect, our main goal is to develop a method of audit in maintenance within manufacturing companies; we are keening also to have a major role in the continuous improvement of this field. This research is also a complementary section of our work regarding the development and selection of measure indicators as well as the observation of indicators used in monitoring the performance of the maintenance function [Elf 03]. Our approach is based on the a functional analysis of the maintenance (known as the APTE method), thus we will use a set of tools which will help us to develop a set of audit standards and create a set of indexes to analyze the results. This of course will allow us to elaborate a diagnosis of the maintenance function within each company.

Keywords: *Maintenance, Audit, functional analysis, APTE, maintenance index, referential.*

1. Introduction

Nowadays, the industrial company undergoes major and profound changes. It is constantly confronted to a world of ruthless competition which always seeks to improve the quality and prices of products as well as the production time. Therefore, manufacturing companies have

production systems which have become more complex and sophisticated, and which are, at same time, more powerful and more fragile [ZWI, 96]. However, they undergo unexpected disruptions related to the availability of production facilities, the non-generated quality, and safety concerns about people and goods or even problems related to the environment respect. All the above mentioned reasons demonstrate the urgent need and the importance of the maintenance to all equipments throughout their life cycle.

According to the French standard NF EN 13306, maintenance stands for a set of all the technical, administrative and management activities during the life cycle of an entity, these activities are designed to maintain or restore it to a certain state to perform a required function. The current activity of maintenance goes under the framework of participating in the achievement of productivity goals, next to profitability and business growth. It is therefore crucial to ensure the well-functioning of the maintenance service.

This study aims at elaborating diagnosis and measuring the performance of maintenance function within the company. We used a functional approach to divide the maintenance function into a set of sub-functions, in order to elaborate a referential as well as to define a set of efficiency indexes that help to examine the case under study and evaluate the performance of the maintenance function. Using this method will help us determine a well positioning in accordance with a reference rather than an interior situation in the frame of a continuous improvement process.

2. Brief History of the audit of maintenance:

Since the beginning of the industrial era, maintenance has become more organized and developed. Now the simplest act of maintenance has become an important factor to improve quality, guarantee safety, respect deadlines and productivity or the competitiveness of big companies [Mon 00]. Moreover, it is clear that maintenance has experienced throughout this evolution important improvements under the aim of making it both effective and optimum. In this respect, we can mention: the systematic preventive maintenance, the conditional preventive maintenance, the predictive maintenance, the integrated maintenance in the design, the overall cost of lifecycle, the total productive maintenance, maintenance based on reliability, the computer-assisted maintenance, aid expert systems for diagnosis, or even maintenance audit [Zwe 96], [Mon 00], [Fra 99], [Lav 92], ...

According to the international standard ISO 9000: 2000, an audit stands for a methodical, independent and documented process to obtain audit proofs to be evaluated objectively in order to determine to which extent the audit criteria were satisfactory». An audit enables us to compare between plans and achievements as well as to characterize the suitability between the referential and the target goals [Lav 98].

In this context, several studies have been carried out in the field of maintenance audit. In addition to that, many companies have developed their own internal audit methods of their production systems. However, only few studies have been published. In this respect we can mention the studies carried out by Y.LAVINA and those of l'ADEPA and CETIM [lav 92], [Ade 95].

3. Functional analysis: APTE method

The standard X50-150 defines:

- The Functional analysis is an approach used to identify, characterize, organize, prioritize and enhance the functions of a product,
- Functions as well as actions of a product or even one of these components are expressed exclusively in terms of finality.

The product can be:

- A material (existing or new, simple or sophisticated, repetitive or unique)
- A process (industrial or administrative)
- Or a service (within the company or for external sell).

During this study, we opted for an inventory method from the external environment (APTE Company's property), this method fits the organization and the description of the company's performance and uses a different vocabulary:

- Service functions (SF) are called basic functions; they include main functions (MF) and constraint functions (CF):

- The main functions (MF) represent the purpose of the maintenance service (product) and reflect the urgent needs. Each MF should be connected to at least two external services (satellites) via the maintenance service (the central pole). They are translated by verbs expressing the action of the maintenance service regarding external services.

- Constraint functions (CF) reflect the actions and/or reactions of the maintenance service performance compared to the different external services and being used in a system (company) and in a certain environment. Each CF should be connected to the maintenance service (the central pole) and an external service (Satellite).

- Technical functions (TF) cover both the elementary functions and design features [Del 91].

The application of this method requires the following three steps:

- Looking for the fundamental need,
- Looking for exterior environments,
- Looking for different functions.

4. proposed model: implementation of the APTE method to the maintenance function:

4.1 Searching for the fundamental need:

It consists of discovering the basic need of the maintenance service.

4.2 Searching for exterior environments

Generally speaking, external services of the maintenance service in any manufacturing business are the following: Management, Finance Department, Sales Department, Purchasing and Suppliers Department, IT, Health and Safety Department, Human Resources Department, The Production Methods Department, Department of Outsourcing, Quality Department, Environmental department, Production Department, Stores and Stocks Department, After sales Services, and Training services.

4.3 Searching for different sub-functions (components) of the maintenance function:

The implementation of the APTE method in the maintenance department in order to determine functional diagram bloc that demonstrates the internal mapping of the maintenance function requires determining; firstly; all of its internal and connected components (sub-functions) which are justified by the design of the maintenance department [Elf 03]. They are determined as follows:

- **A recording function, management and decision:** It is the unit of receiving the various orders soliciting the different maintenance services; it is also the center of making decisions and management and it includes: management of maintenance activities, materials management, management of stocks and supplies, the economic management, the investment management, the management of human resources, conflict management [Ber 96] and security management,...
- **A historical function, databases and feedbacks:** This function contains all the information about the maintenance department. Its main role is to ensure the control of documentation that are related to the maintenance department (the input, measurement, control, storage, processing, distribution ...) [Ber 96]
- **Analysis and studies function:** This function deals with the study of reports, the analysis historical interventions. It used to identify, classify and codify all production equipments, carry out studies and researches (AMDEC machine, fault-tree analysis, FMDS...) on strategic equipment to prevent their dysfunction and develop a set of indicators which allow the orientation and evaluation of the maintenance function ...
- **Methods function:** its mission is to define the policies and maintenance rules as well as the relevant procedures (based on certain data, analysis, diagnosis and expertise...).
- **A preparation function:** it's responsible for planning, defining and providing the best conditions for the execution of maintenance work. Its main mission is making procedures, determining needs and publishing business records [Mon 00].

- **Planning and scheduling function:** this function is responsible for managing time for maintenance works and makes schedules for them with the major program of production (cutting, detection of links between various tasks, and finally detecting priorities).
- **Stocks and spare parts function:** it's responsible for maintaining an acceptable threshold level of spare parts and stored tools. Its main role is to find a compromise in order to obtain the positive role of indicated regulations for minimal costs [Cou 95].
- **An execution function:** it is the achieving component of the maintenance function. Its mission is to use the means at its disposal and following the given procedures (that have been already established) and guidelines to maintain or restore the equipment to the indicated state.
- **The control and operating function:** Its mission is to control the well-functioning of the equipments that went under maintenance interventions and provide suitable conditions for their performance.
- **Staff and training section:** Due to continuous technological progress and in order to make the maintenance staff acquires new diagnostic skills, this section is designed to provide a continuous training to agents and to implement update programs [Smi 94].
- **Outsourcing function:** this function aims to determine the maintenance interventions to outsource, choosing subcontractors, developing the relevant contracts and launching an intensive and continuous control to tasks progress.
- **Accounting and valorization function:** Its mission is to enhance the different solutions

adopted through calculating the overall costs in order to compare them with estimated figures. In the case of a given device, when there are several maintenance policies, this function enables the user to choose between the various equipments from the same given program in order to enhance the maintenance policy of the equipment in use, it is used also to determine the optimal age for replacing equipments and estimating the maximum of the allowable budget for maintaining the necessary equipments [Bou 98].

4.4 The determination of the basic functions:

As we have mentioned above, we used the same approach for the implementation of indicators for measuring the performance of the maintenance function [Elf 03] as illustrated by the new diagram below:

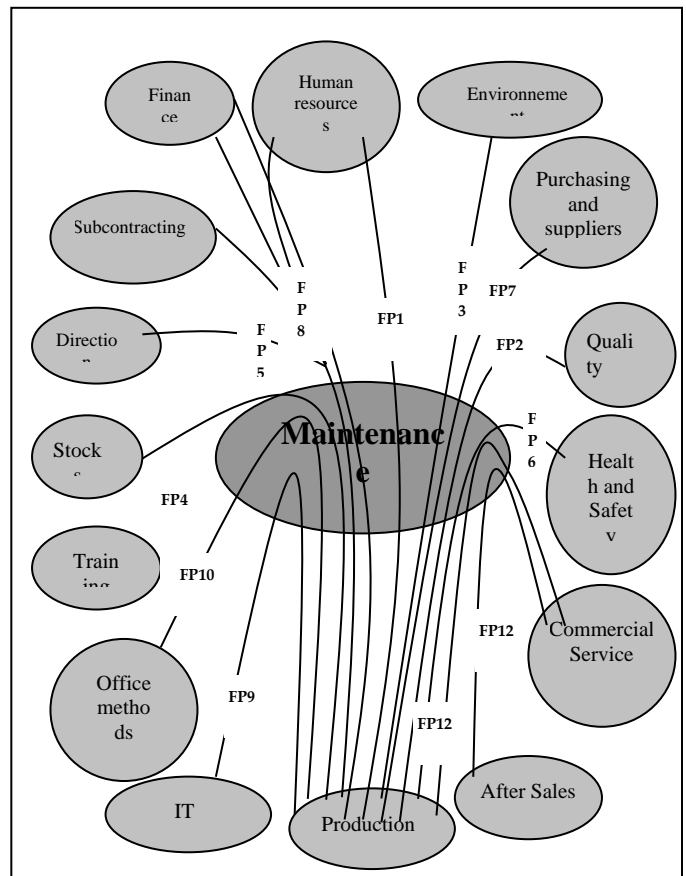


Fig 1: Main functions diagram

Table 1: Main functions and constraints generated functions

Main functions (MF)	Constraint functions (CF)
<p>MF1: allows production to meet the requirement of the commercial and marketing function (quality, amount, costs and deadlines).</p> <p>MF2: allows the production function to meet quality requirements</p> <p>MF3: allows the production function to respect environmental requirements.</p> <p>MF4: allows function of storing management to indicate the needed equipments of production in terms of spare parts.</p> <p>MF5: along with other functions such as the production function, management, human resources, and contracting and finance function, this function contributes to specify the needed maintenance tasks to be subcontracted, and helps to choose subcontractors and also to develop the relevant contracts</p> <p>MF6: enables the production function to function in accordance with health and safety requirements</p>	<p>CF1: collaborates with the production function to achieve the main plan of production (MPP)</p> <p>CF2: collaborates with the production function in order to specify and integrate maintenance proceedings in the main plan of production (TPM)</p> <p>CF3: involves production staff in data collection regarding the equipments performances.</p> <p>CF4: involves production staff when analyzing errors.</p> <p>CF5: participates in a new or an updated implementation of production equipments</p> <p>CF6: works in collaboration with the production function in identifying,</p>

Main functions (MF)	Constraint functions (CF)
<p>MF7: contributes along with the purchasing and suppliers function to defining specification, selecting suppliers, purchasing suitable equipments and participating in their set up</p> <p>MF8: sets a budget to the maintenance function in order to maintain production tools.</p> <p>MF9: Contributes to the computerization of all tasks including the maintenance of production means (archive, processing, planning)</p> <p>MF10: Contributes to the improvement of products, processes and production means (ameliorative maintenance, integrated maintenance in design)</p> <p>MF11: Along with the human resources function, this function contributes to the coaching, employment, training and integration of the production staff within maintenance programs</p> <p>MF12: Together with the function of after sales, commercial and marketing function, this function makes sure that the company's customers are satisfied (reparation, availability of spare parts and other services).</p>	<p>prioritizing equipments as well as in collecting basic and matching data.</p> <p>CF7: works with the function of storing on providing the best stock service for spare parts.</p> <p>CF8: collaborates with the human resources function to recruit, train and motivate the maintenance function staff.</p> <p>CF9: works with methods department on comparing the company's maintenance tools to those of similar enterprises or to those proposed by technology.</p> <p>CF10: undertakes corrective actions of maintenance on the production means</p> <p>CF11: applies conditional measures while maintaining the production tools</p> <p>CF12: applies systematic maintenance measures on means of production</p> <p>CF13: applies</p>

Main functions (MF)	Constraint functions (CF)
	maintenance improvement measure on means of production

At this stage of our methodology, we have developed all the basic functions. They establish a general representation to the different situations where maintenance is valid in the frame of fulfilling its purpose within the company. In other words, how it responds to the requirements of its environment (external environment: production, quality, environment, after sales ...). They describe all situations where actions take part in the maintenance function: preventive maintenance, corrective maintenance, ameliorative maintenance, outsourced maintenance, repetitive maintenance. Hence, the technical functions (elementary functions and design functions) will describe the internal mechanisms (internal maps) of the maintenance function whenever this latter is valid [Ric 96], [Ade 95], [Lav 92], [Fra 99], [Lav 98], [Per 96], [Lee 94], [Bou 98], [Smi 94].

The main goal of this approach is to detain a referential through established technical functions which form a detailed and an exhaustive representation (description) of the logical functioning of various activities of the maintenance function when performing a basic function in a certain given situation.

Once the set of standards is gathered, the auditor has the right at first to ask questions allowing understanding the maintenance function through using and implementing the collected data. Then comparing the obtained results to our set of standards as well as

identifying the level of conformity and evaluating differences. This approach can be also applied for placement in an internal situation in the frame of a process of continuous improvement of maintenance function.

During this audit approach, the auditor is free to ask questions that are considered useful to estimate effectiveness (progress, performance ...) of each technical function. He/she can therefore add or subtract questions in accordance with the particularities of each company. The auditor can also remove some basic functions if their use is not necessary. Therefore, the audited company will not be charged for the unused of the functions.

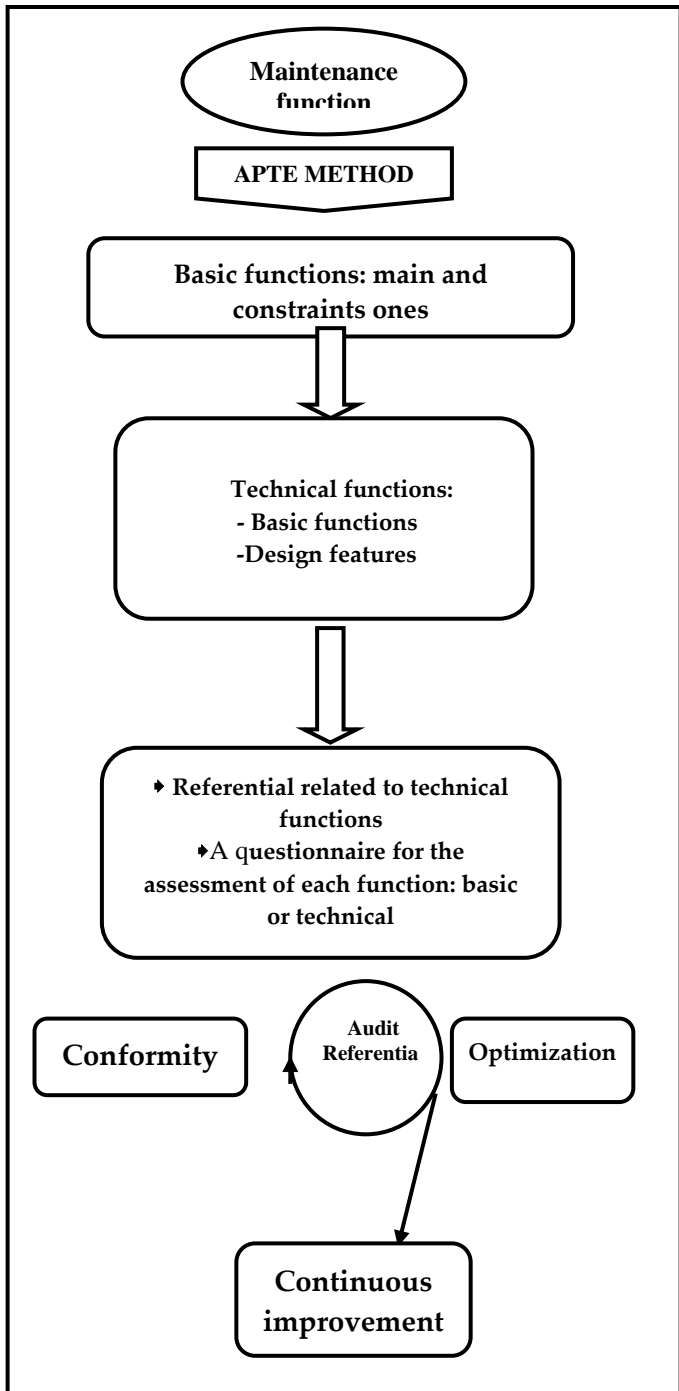


Fig 2: Summary diagram of the proposed model

The industrial implementation of our approach of maintenance audit, as well as the elaboration of indicators for measuring the performance took place in a company of plastic and textiles that is certificated ISO 9000 and owns both very old and modern equipments.

In the following, we will give a detailed presentation about the gathered results during the processing of the main function MF1: that enables production to meet the requirements of the commercial and marketing function in terms of quality, quantity, costs and deadlines. Therefore we will consider the following situations:

- Deferred corrective maintenance
- Urgent corrective maintenance (in case of delayed)
- Preventive maintenance (conditional and systematic).

After checking, we will be working on the case of deferred corrective maintenance:

5. Application:

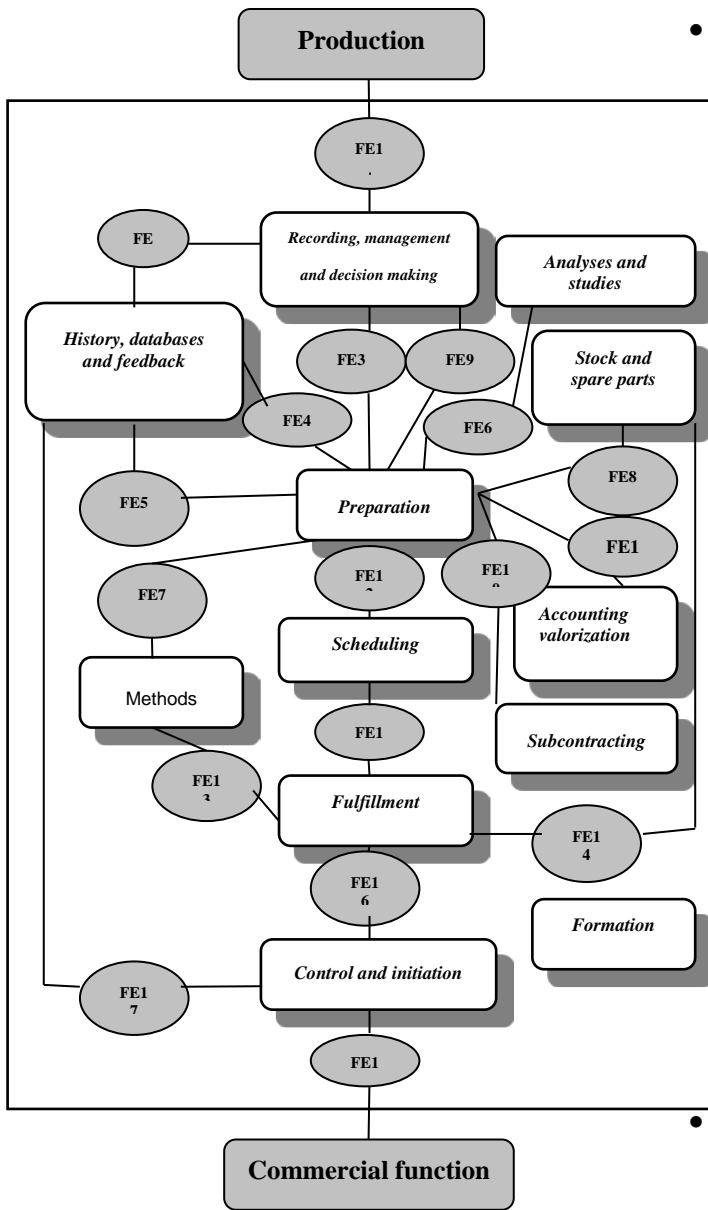


Fig3. Functional diagram of non-urgent corrective maintenance

The technical functions arising are (See Fig3):

- **FE1:** Receive record and determine maintenance intervention requests.
- **FE2 :** archive recording and decisions

- **FE3 :** launch the preparation of requested task

FE4: identify the equipments in question.

FE5: use (consult) the documents related to equipments (machines files).

FE6: consult (use) documents related to analysis and specific studies related to the equipments in question.

FE7: use (enable) the procedures of maintenance interventions that are pre-established by method function.

FE8: specify tools and spare parts in need.

FE9 : specify staff in need

FE10: specify external services to solicit.

FE11: evaluating costs.

FE12: planning maintenance tasks.

FE13: launch the established procedures related to the safety instructions.

- **FE14:** supply the tools and predefined spare parts.

- **FE15:** perform maintenance works according to the schedule.

- **FE16:** control and set up equipments.

- **FE17:** report the effectiveness of maintenance (development, causes, duration, used means, controls, setting up machines and remarks ...).

- **FE18:** restart production.

We then assume the part of our relative set of standards for non-urgent corrective maintenance, as well as the performance index for assessing the effectiveness of its functioning as the following:

Table 2. Referential (set of standards) related to the status of non-urgent corrective maintenance.

Constitutive Technical Functions of the main function (MF1)	Note (Ni/10)
<ul style="list-style-type: none"> - Reception, recording and making maintenance intervention requests. - Recording archiving and undertaken decisions. - Launching preparation of requested tasks. - Identification of equipments in question. - Consulting documents related to the equipments in question (machines folders...). - Consulting documents related to analysis and specific studies of equipments in question. - Launching procedures related to maintenance interventions that are made by the method function. - Specifying tools and spare parts in need. - Specifying personal in need - Specifying external services needed. - Estimating time needed for a certain operation. - Estimating costs - Planning for prepared tasks. - launching procedures which go in conformity with safety instructions. - Supply tools and spare parts in need. - Executing tasks according to the schedule. - Checking and restarting equipments. - Making reports (about functioning, 	

Constitutive Technical Functions of the main function (MF1)	Note (Ni/10)	Weight (Wi)
causes, duration, used means, control, remarks...). - Re-launching of production.		

6. Evaluation system proposed:

1. Every technical function is assigned to a score Ni between 1 and 10, which represents an estimation of the degree of achievement in relation with the reference. Determining this score was achieved through a questionnaire related to the achievement of the technical function in question.

Example of the evaluation of the first technical function: possible questions are related to the way and practices of receiving and recording requests (supports, procedures, effectiveness...), as well as how to make decision (concentration, prior evaluation) .These questions may differ from one company to another; they depend on the history, the establishment, the activity section and particularities or characteristics of the company in concern.

Questions used in the case of our company:

All these questions are related to methods and requirements of applying the standard ISO 9000:

Q1: Is there a procedure which describes receiving mode of maintenance work orders? If so, who's responsible for ?And how?

Q2: Is there a procedure which describes decision-making concerning maintenance orders? If so, who's responsible for? And how?

Q3: Are tasks orders evaluated (nature, estimation, deadlines)? If so, who is in charge of this? And how?

Q4: Are those decisions made based on assessments? If so, who is in charge of that? And how?

Q5: Is there a procedure which describes recording management mode (tasks orders and decisions)? If so, who is in charge of that? And how?

Q6: Are those records established, maintained, legible and easy to identify? If so, who is in charge of this? And how?

Q7: Are retention periods defined and enforced? If so, who is responsible for that? And how?

Q8: Do computer backups perform appropriately? If so, who's in charge for that? And how?

2. Each technical feature is assigned to a weight W_i between 1 and 5; it is an estimation of its degree of relevance and importance.

3- We determine the assessment of the realization degree of the deferred corrective maintenance in case of the main function MF1 by calculating the overall average of estimations of the technical functions (sub-functions) that compose it:

$$(1) \quad M = \Sigma(N_i * W_i) / \Sigma W_i$$

This approach can be applied on other situations of the main function MF1 (urgent corrective maintenance, predictive maintenance) and other basic functions (the main functions and constraint ones) constituting the maintenance function. This will determine the strongest and effective points as well as the unfulfilling or unsatisfactory ones.

Thereafter, we will apply this same approach to the overall maintenance function:

Table 3. Evaluation of basic functions

Items of maintenance function	Note (Mi)	Weight (Ki)
- <i>Main function 1</i>		
<i>Situation1</i>		
<i>Situation2</i>		
....		
- <i>Main function 2</i>		
-		
- <i>Main function 12</i>		
- <i>Constraint function 1</i>		
....		
- <i>Constraint function 2</i>		
-		
- <i>Constraint function 13</i>		

In order to evaluate the effectiveness of the overall maintenance function, we can proceed as follows:

1- For each basic function (main function or constraint function), we assess its achievement degree by calculating its average M_i as it's already explained. It represents an estimation of its progress effectiveness.

2- We affect to each basic function a weight K_i between 1 and 5; it represents an estimation of its degree of relevance.

3- We determine the evaluation of the well-functioning of the overall maintenance function progress by calculating the overall average of the basic functions (**Table 3**):

$$MG = \Sigma(M_i * K_i) / \Sigma K_i$$

These various indexes will allow to evaluate the performance of the maintenance function within manufacturing companies as well as to estimate differences in comparison to the reference. They can also help in assessing the effectiveness of each of these internal components.

Results of the audit in the case of our company:

- Lack of life-cycle cost,
- Lack of studies AMDEC,
- Lack of environmental protection procedures,
- Lack of tracing regarding some performed tasks,
- Lack of check listing related to certification,
- Bad management of documents related to equipments,
- Lack of knowledge in terms of maintenance management.

7. Conclusion

Being exposed continuously to severe constraints in terms of cost, quality, delivery, and safety, industrial production systems have become more complicated and sophisticated. This makes the maintenance function facing daily complicated problems that need a set of concepts, tools and methods to be solved as well as to enhance and improve the maintenance service. In line with this, this study is based on the functional approach (APTE method) to audit the maintenance function in the frame of a continuous improvement process. This is an original approach which let to determine all situations which necessitate acting and elaborating an audit referential of the maintenance function.

Using this approach will enable us to evaluate the performance of each component of the maintenance function. It will also help in terms of detecting and correcting dysfunctions,

preventing errors, and optimizing the use of resources in order to have a dynamic and a continuous improvement with significant gains in terms of performance, deadlines and cost.

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