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Maintenance Management Model for Industrial Smes

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Abstract

This paper presents the design and results of the implementation of a model for the evaluation and improvement of maintenance management in industrial SMEs. A thorough review of the state of the art on maintenance management was conducted to determine the model variables; to characterize industrial SMEs, a questionnaire was developed with Likert variables collected in the previous step. Once validated the questionnaire, we applied the same to a group of seventy-five (75) SMEs in the industrial sector, located in Bolivar State, Venezuela. To identify the most relevant variables maintenance management, we used exploratory factor analysis technique applied to the data collected. The score obtained for all the companies evaluated (57% compliance), highlights the weakness of maintenance management in industrial SMEs, particularly in the areas of planning and continuous improvement; most SMEs are evaluated in corrective maintenance stage, and its performance standard only response to the occurrence of faults.

Keywords: management, maintenance, exploratory factor analysis, evaluation, improvement

1. Introduction

Maintenance has been considered as a process of production support, and as such, voracious consumer of resources that have tended to minimize and in recent years to outsource; however, in so far as to production processes have been demanding

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higher quality and performance, the need to optimize the maintenance function has led to assess the actual impact of the same from the viewpoint of the value that can provide for the company.

The initial stage in the evolution of maintenance is the Corrective Maintenance, based solely on the breakdown repairs; only took place when it detected a fault and, once repaired, everything was here. In the next step, the Preventive Maintenance (PM), in which maintenance functions were established aimed at detecting and/or anticipate potential failures before they happen. The evolution continues to Productive Maintenance (PM), which also includes the establishment of a maintenance plan and considers maintainability (M) and reliability (F). The next stage is represented by the Total Productive Maintenance (TPM), a maintenance management program that includes the above and incorporates innovative concepts such as autonomous maintenance and continuous improvement. TPM is a preventive philosophy from design, through to improving the prevention of problems, which aims to eliminate the six big losses and improve performance through such means as the Autonomous Maintenance, Planned Maintenance and Maintenance Prevention (Cuatrecasas and Torrell, 2010).

Similarly, the technique Reliability Centred Maintenance (RCM) is developed, which provides a methodology targeted on system function, the failures relating to target function, and in particular to the effects of dominant functional system failures (Telang, 2010). Now, in the state of the art is Lean Maintenance, a relative new term based on principles established in Total Productive Maintenance, but applies some new techniques to TPM concepts to render a more structured implementation path. Optimizing the maintenance function first will both increase maintenance time available to do further improvements and will reduce the defects that cause production downtime (Smith and Hawkins, 2004).

The objective of maintenance and reliability in an organization is to ensure that the assets are available, when needed, in a cost effective manner. Maintenance is concerned with maintaining assets through the use of proactive and corrective maintenance techniques combined with how quickly equipment can be returned to operating condition after it has failed. Improving maintenance is a tactical task. Reliability is concerned with predicting and preventing failures to ensure assets will perform to their required or designed functions. Improving reliability is a strategic task. (Gulati, 2009)

There is a tendency to think that these models, which have yield excellent results in large enterprises, can be reproduced in SMEs and that their effectiveness will increase automatically; that is, SMEs would be a duplicate on a smaller scale for large enterprises. This deduction is risky because it ignores that SMEs are very different and have their particular characteristics. Hence, certain precautions must be taken prior to taking a successful model and incorporate it directly to an organization; although the basic concepts are universally applicable, details of a specific model will always have special considerations inherent in the reality of the companies concerned.

2. Methodology

The purpose of this research is to design a maintenance management model adapted to industrial SMEs, enabling these companies to incorporate the latest concept in the field of maintenance.

To identify key aspects of maintenance management, applicable to small and medium enterprises, joined the main highlights of the scientific literature to obtain results in a set of variables.

To characterize industrial SMEs a questionnaire was developed with the variables collected in the state of art review; the validity of the questionnaire was determined by the technique of expert judgment; for determine the reliability, was piloted on ten companies of the population to examine the instrument (n=30) and found to Cronbach´s Alpha=0,90, therefore it is acceptable (Alpha ≥ 0,80).

Once validated the questionnaire, it was applied to a group of SMEs in the industrial sector, located in Estado Bolivar, Venezuela.

In this study population is considered to Ciudad Guayana industrial SMEs registered in the Industrial Chambers, approximately two hundred companies (200). Of this number, only agreed to submit the study seventy five companies (75), i.e. 38%. The profile of the survey is shown in Table 1.

Table 1. Profile of the survey

Analisis unit	Industrial SMEs
Population	200 industrial SMEs
Geographical scope	Estado Bolívar - Venezuela
Sample size	75 SMEs (Index of response: 35.5%)
Profile of respondent	Manager – Supervisor of maintenance
Number of respondents	300
Information source	Primary
Technical data collection:	Questionnaire
Date of fieldwork:	January to May 2011
Information processing:	SPSS v.15
Statistical treatment:	Exploratory factor analysis
Sampling error	± 9 %
Confidence level	95% (z=1,96)

To identify the most relevant factors of maintenance management and building the model, was considered appropriate to use a statistical procedure such as exploratory factor analysis; the results of the questionnaire applied to the industrial sector of SMEs were used as data for the application of the technique.

The procedure used for exploratory factor analysis was:
Calculation and interpretation of the correlation matrix for the variables considered. To do this, recourse is had to the following indicators:

- Pearson correlation coefficients: higher value of the correlation coefficients greater the relationship between the variables. If the linear correlation between the variables is zero, the technique in not applicable. The resulting values in the correlation matrix are between -0,184 and 0,825, demonstrating that there is a high relationship between the variables.
- Contrast Bartlett sphericity: if the critical level (p-value or sig.) is 0,000, then there is significant correlation between the variables. If the critical level (p-value or sig.) > 0,05 there is no guarantee that the factor model is best suited to explain the data. For evaluated data yielded a p-value = 0,000 so it follows that there is significant correlation.
- Index Kaiser, Meyer and Olkin (KMO): if KMO > 0,5 data are appropriate to a factorial model. If KMO < 0,5 no adjustment. The resultant measure of simple adequacy was 0,852, so that is acceptable the use of factor analysis.
- Determinant of the correlation matrix: if this value is very small, indicates that the variables are linearly related, and there is the option to reduce the dimension. The result is 1,66.10-7 which indicates that the degree of correlation between variables is very high.

Extraction of factors: was used the principal components method to transform a set of interrelated variables into a new set of variables, linear combination of the first. Were used the factors whose initial auto values are greater than 1, according to the values presented in the correlation matrix.

Factor rotation: was applied the varimax orthogonal rotation. This technique achieves the weights of the variables in the factors have the greatest possible variance; this mean that the items tend to have high correlations with a factors and very low with others; for this is the clearest solution to differentiate sets of items.

Interpretation of factors: first, identify the variables whose correlations with the factor is higher in absolute value (deleted the factor loadings less than 0,5); and second, to name the factors, according to the structure of correlations with the variables.

During the process seven variables were eliminated by having a factor loading less than 0,5. Finally, maintenance activities were assessed through twenty variables (20), which were grouped into four factors, with a total explained variance of 68,510%.

The first factor, which represents 41,366% of the variance, is composed of twelve (12) variables that are grouped as a single block called *Plan*.

The second factor (12,944% of variance) involves the variable *Execution of the maintenance* and *Repair and correction* variable, grouped as *Do*.

The third factor (8,168% of the variance) consists of four (4) variables*: Analyze breakdowns*, *Evaluate effectiveness maintenance*, *Improve / modify facilities* and *Measuring customer satisfaction*, that constitutes the block *Check / Act*.

The fourth factor (6,032% of variance) includes variables *Improved Maintainability* and *Autonomous Maintenance - 5S* and has been called *Continuous Improvement*.

In the matrix of Table 2 shows the structure of the components rotated.

Table 2. Matrix of components rotated

	Component			
	1	2	3	4
Policies and objectives	,861			
Organize maintenance	,876			
Define documentation	,781			
Identify and classify equipment	,778			
Set budget	,627			
Analyze equipment criticality	,782			
Select model maintenance	,706			
AMEF analysis	,554			
Planning maintenance	,872			
Estimating execution time	,657			
Develop policies for spare parts	,614			
Schedule maintenance	,736			
Run maintenance plan			,758	
Repair and correct			,914	
Analyze breakdowns		,785		
Evaluate effectiveness maintenance		,913		
Improve / modify facilities		,795		
Measuring customer satisfaction		,703		
Improve maintainability				,733
Autonomous maintenance and 5S				,806

3. Findings

The maintenance management model has been structured according to the results obtained by application of exploratory factor analysis, which allowed explaining the interrelationships of the twenty variables, in terms of a smaller number of variables know as factors, finally presenting four factor representatives. The results of the questionnaire applied to the industrial sector of SMEs were used for the application of exploratory factor analysis, but these data are also used to characterize the maintenance management and determine both the aspects of greatest strength, which must be sustained, as the most weakness, which should be improved.

The assessment tool was designed to assign points according to the degree of compliance of each variable; the variables with lower scores represent areas for improvement in management. Thus, as a result of the evaluation, the group of companies obtained a compliance percentage value, indicative of their level of maintenance management. However, the score is anecdotal and is only used to prioritize actions and to compare results. The empirical evidence gathered was structured according to the four fundamental processes of the model: a) Planning b) Do c) Check / Act d) Continuous improvement (Figure 1).

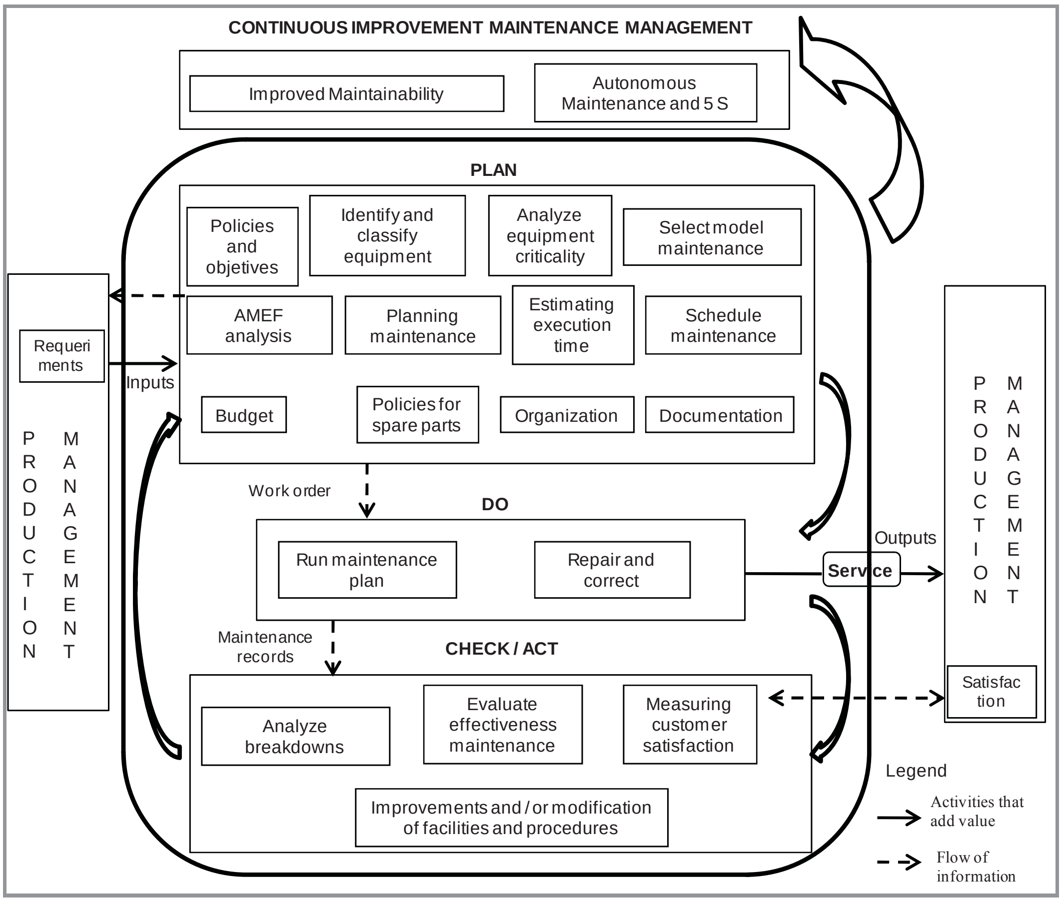

Fig. 1. Maintenance management model

The overall compliance for the seventy-five firms was 57%. Next, shown in detail the results obtained for each process.

Process: Planning

Very few companies have defined a maintenance policy although most established objectives; the equipment is identified and classified, with coding systems not providing any additional information.

Although not been carried out a formal analysis of criticality of equipment are known which are critical equipment but not quantified the incidence of equipment failure on other; the maintenance model mostly used is corrective (includes visual inspections, lubrication and repair of faults arising), although some companies are trying to strengthen the preventive maintenance (predictive maintenance is not know); a general maintenance plan is developed then becomes a program, with a brief preliminary analysis of failure modes and effects and a weak estimation of execution times, making it difficult to estimate the volume of maintenance work that can be run; a complete overhaul of the equipment is not covered by the plan;

only when the equipment failure is repaired but the lack of prioritization impedes the proper management of work orders.

Not formally defined replacement policy and the tendency is to maintain the minimum availability of spare parts and only for critical equipment; maintenance personnel depends on the unity of production and most companies manage work orders; procedures to carry out corrective maintenance are defined; there is budgetary provision for the purchase of spare parts, maintenance payroll and contracted services.

Process: Do

The execution of the maintenance plan covers only activities such as lubrication and replacement of wear parts; the highest rate of implementation of maintenance corresponds to repair and correction; production time lost due to breakdown is quantified.

Process: Check / Act

There are records of the breakdowns but there is no systematic analysis of the same to avoid repeating; time spent on repairs is not controlled; handled only available indicators; informally measured the internal customer satisfaction; uncontrolled maintenance costs for equipment; improvements have been made in the facilities and procedural changes for increasing the effectiveness of maintenance.

Process: Continuous Improvement

Were detected efforts to improve maintainability; very few companies use the concept of autonomous maintenance and production workers refuse to handle simple maintenance task; workshops were given 5S but the conditions of order and cleanliness in general are no suitable.

Table 3. Results of characterization of SMEs

VARIABLE	%	VARIABLE	%
Process Planning (average)	**54**	**Process Do (average)**	**76**
Policies and objectives	47	Run maintenance plan	75
Identify and classify equipment	48	Repair and correct	78
Analyze equipment criticality	64	**Process Check / Act (average)**	**57**
Select model maintenance	50	Analyze breakdown	56
AMEF analysis	48	Evaluate effectiveness maintenance	57
Planning maintenance	66	Measuring customer satisfaction	54
Estimating execution time	52	Improve / modify facilities and procedures	60
Schedule maintenance	68	**Process Continuous Improvement (average)**	**55**
Policies for spare parts	64	Improve maintainability	54
Organization	48	Autonomous maintenance and 5S	56
Documentation	45		
Budget	48		

4. Conclusions

The maintenance management model for industrial SMEs presented as a product of this research, consists of four factors, which represent twenty variables resulting from the application of exploratory factor analysis. The extracted factors were categorized into the areas corresponding to Maintenance Planning (Plan), Maintenance Execution (Do), Measurement, Evaluation, Analysis and Modification (Check / Act) and Continuous Improvement.

As a result of the characterization, all the companies evaluated received a score de 57% compliance, which underlines the weakness of the maintenance management system in industrial SMEs in Estado Bolívar, particularly in the areas Planning and Continuous Improvement.

From the point of view of cause and effect, this weakness can generate, among other effects, decrease the effective time of production and increase of defective parts, which in turn leads to increase costs and decreased satisfaction customers; to quantify the impact on these and other variables of production management research will extend to this area.

At stages of evolution of maintenance management, most SME are evaluated at the initial stage (corrective maintenance), and its performance standard only response to the occurrence of faults, very few support their management in the planning and control.

The challenge for SMEs in the region is to evolve the paradigm of the correction to the practice of prevention, however, to take on this challenge, the manager must conceive maintenance as a key element of competitiveness rather than a necessary evil, because maintenance, serves to support the management of production and has an effect on reducing waste and costs.

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