KNOWLEDGE BASED SYSTEM FOR MANAGEMENT OF CRITICAL FACTORS RELATED TO RELIABILITY CENTERED MAINTENANCE

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Abstract: *The ability of modern companies to manage its assets with competency and efficiency, in order to achieve a competitive advantage, is highly associated with its maintenance management. Within this context, RCM (Reliability Centered Maintenance) is a consolidated alternative which preserves in its methodology, the company´s intellectual capital. RCM implementation and management does not always take place in an appropriate, harmoniously and consistent way, which results in lack of commitment and, in some critical situations, in the abandon of the RCM program due to a lack of synergy with the company's goals. Besides these technical aspects, the management and organizational factors also influence the success of the RCM program. This article proposes a discussion about some of the critical factors to the success of a RCM program, including its implementation and also management based on a synthesis of the industrial maintenance situation in Brazil. The proposal defended in this article is the usage of institutional as well as expert´s knowledge in the RCM implementation and management, organized with Management Knowkledge (KM) techniques and carried out by a Knowledge Based System (KBS) which embodies diagnosis and decision-making criteria. With this methodology it is possible to minimize the risk of being unsuccessful during the implementation and management of the RCM as well as having a holistic view of its interactions and needs.*
Keywords: *Knowledge Based System, Knowledge Management, Reliability Centered Maintenance.*

1. GENERAL ASPECTS

The maintenance management policy is highly associated to a competitive advantage that is imperative to the companies when managing their assets. Within this context, the Reliability Centered Maintenance (RCM) is a consolidated alternative that preserves in its methodology, the company's intellectual capital.

It is worth to point out that, regardless its maintenance management there is no sustainable competitive advantage, if not through what the company already knows, how it uses this knowledge and the rate with which it learns new things. In such a context, the Knowledge Management (KM), associated to Artificial Intelligence (AI) specially the Knowledge Based Systems (KBS) is consolidating itself as a fundamental and helpful tool to the maintenance management policies.

This article proposes a confluence of the aspects mentioned above (RCM, KM, KBS) to reduce the risks related to the success critical factors of a RCM program. These factors include the ratification of the RCM as a more suitable methodology to the company's characteristics, to the requirements that must be observed for its implementation and to the accompaniment and management of the RCM program in order to confront its results to the ones initially expected.

2. CURRENT SCENARIO OF MAINTENANCE

The implementation and management of the RCM does not always take place in an appropriate, harmoniously and consistent way, which results in lack of commitment and, in some critical situations, in the abandon of the RCM program due to a lack of synergy with the company's goals.

Besides these technical aspects, the management and organizational ones also influence the success of the RCM program (Moubray, 2001). Some of the main problems related to the failure of the RCM are, according to Siqueira (2005): the preview and management of costs in human resources as well as equipment that end up with an increase in the investments return time; lack of support from the high administration resulting in low commitment and limitations or even the abandon of the RCM program and, lack of previous necessary conditions to fulfill the RCM program (failure reports, deep knowledge of the process or equipment and of the practice of the maintenance and of the operation group).

Another important aspect that has to be analyzed is the difference in approach to the traditional process of implementation and management of the RCM, which was originally structured to the aviation industry and the peculiar aspects of other industrial branches, for instance: petrochemical and electrical energy power plants. An example of this difference is the knowledge about the assets historical failure. In the aviation industry, due to regulations, this knowledge is highly explicit while, in other industrial branches, a great part of this knowledge derives from a tacit nature that confirms the need of the KM.

The maintenance management policy plays an important role to keep the logistic of the company, which affects its competitiveness directly, according to Teixeira (2001) and Kardec (2003). Thus, the methodology of the maintenance management has to be part of a strategy to the effectiveness of the company excellence which, according to Tsang (1998), goes beyond the view of a sector of maintenance with an exclusive tactic and operational function. To ratify the importance and strategic function of the maintenance management in Brazilian companies it is important to check the 2005 National Document, which is a survey elaborated and conducted by the Brazilian Association of Maintenance (ABRAMAN). In 2005, according to Tab. 1, the maintenance activity demanded 23.651 own employees from the companies that corresponds to 21,74% (average value) of the total amount of employees in each company.

Table 1 – Company's Own Staff in Maintenance.
Source: 2005 National Document – ABRAMAN.

Year	**Company's Own Staff in Maintenance**		
	Total Amount of Workers in the Companies (TE)	Total Amount of Workers in Maintenance (TM)	TM / TE (%)
2005	108.784	23.651	21,74
2003	109.794	31.504	28,69
2001	159.454	33.015	20,71
1999	133.650	26.257	19,65
1997	154.250	30.750	19,94
1995	320.650	67.375	21,01

Figure 1, resulting from Tab. 1, shows the percentage of the company's own staff in maintenance and the growth tendency curves of own staff maintenance during the last years. In this article, all the tendency curves were drawn by using polynomial regression with a second degree polynomial.

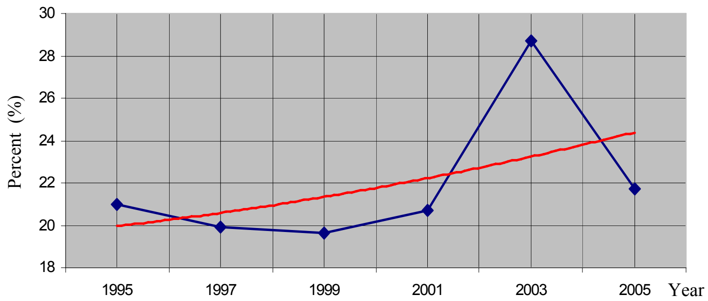


Figure 1 – Percentage of Company's Own Staff in Maintenance.
Source: 2005 National Document – ABRAMAN.

In what the profile of this own staff of maintenance is concerned, it is possible to observe in Tab. 2 that from 2003 to 2005, there was a slight decrease of the staff with a higher education as well as of qualified workmanship in the maintenance activities. The same table shows that within the last years, in general, the companies are keeping or improving their staff qualification level in the maintenance area.

Table 2 – Qualification of Maintenance Staff
Source: 2005 National Document – ABRAMAN.

Year	**Qualification of Maintenance Staff (%)**				
	Higher Education	Technicians With Mid Level	Qualified Workmanship	Non-qualified Workmanship	Non-classified
2005	7,06	16,07	36,05	7,91	32,91
2003	7,20	14,85	40,62	4,94	32,39
2001	7,64	14,81	38,72	7,63	31,20
1999	7,08	13,35	38,06	6,77	34,74
1997	6,18	14,78	40,63	8,07	30,34
1995	6,65	13,52	17,15	8,81	53,87

According to Fig. 2, resulting from Tab. 2, it is possible to observe that the non-qualified workmanship has been kept below 9%, with an average of 7,36% and a standard deviation of 1,36%.

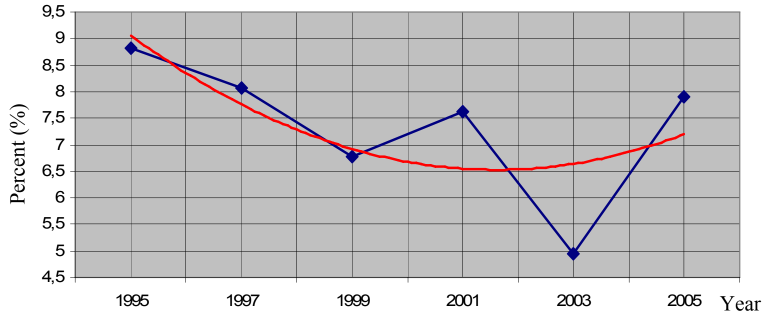


Figure 2 – Percentage of Non Qualified Workmanship in Maintenance.
Source: 2005 National Document – ABRAMAN.

Table 3 shows that in the last years there was an increase in the usage of maintenance performance indicators, which demonstrates the companies' awareness to create guidance for decision making, searching for an efficient management of maintenance. The same table shows the main indicators which were used and the average degree of importance of these indicators to the companies that were researched.

Table 3 – Main Performance Indicators Used.
Source: 2005 National Document – ABRAMAN.

Main Performance Indicators Used							Level of Importance in 2005
Types	1995	1997	1999	2001	2003	2005	
Costs	26,21	26,49	26,32	25,91	21,45	21,96	1
Operational Availability	25,20	24,70	22,60	23,24	19,58	19,81	2
Failure Frequency	17,54	12,20	14,24	16,22	11,66	12,17	3
MTBF (Mean Time Between Failures)	-	-	-	-	11,89	11,69	4
MTTR (Mean Time To Repair)	-	-	-	-	9,56	11,46	5
Customer's Satisfaction	13,91	11,01	11,76	11,86	8,62	8,11	6
Backlog (Accumulated Work)	8,07	6,55	8,98	10,41	9,32	6,92	7
Rework	9,07	5,65	8,36	8,96	6,06	6,68	8
Does Not Use Indicators	-	2,09	2,79	1,22	1,63	0,72	-
Use Other Indicators	-	11,31	4,95	2,18	0,23	0,48	-

Another evidence of the companies' efforts in the search of excellence in maintenance is the increase in staff maintenance training programs, exposed in Tab. 4 and Fig. 3.

Table 4 – Staff Maintenance Annual Training Program
Source: 2005 National Document – ABRAMAN.

Staff Maintenance Annual Training Program (% of Companies)						
Year	1995	1997	1999	2001	2003	2005
Yes	74,11	81,51	73,04	85,92	76,19	96,77
No	25,89	18,49	26,96	14,18	23,81	3,23

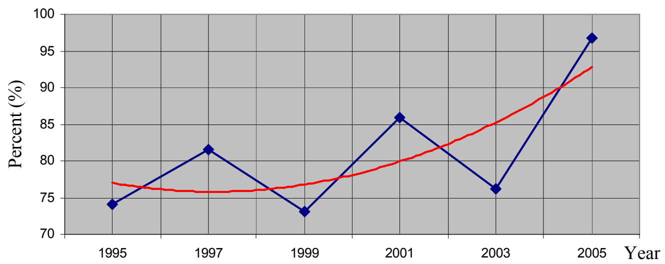


Figure 3 – Staff Maintenance Annual Training Program
Source: 2005 National Document – ABRAMAN.

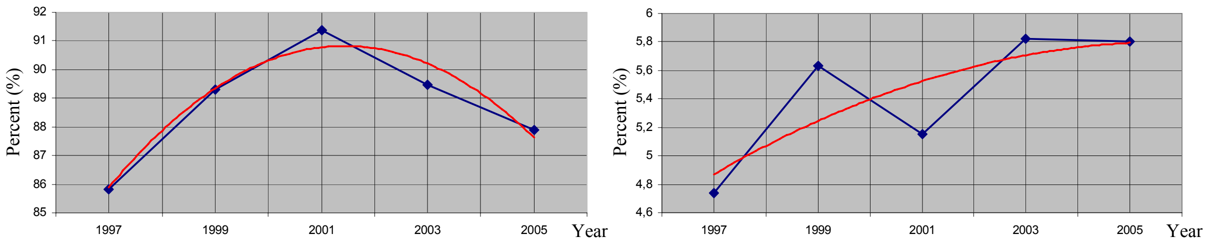
Despite the several positive aspects mentioned so far, the 2005 National Document shows that the Operational Availability decreased within the last years, while the Unavailability Due to Maintenance is gradually increasing, as shown in Tab. 5. According to the preceding information, some actions that were taken and that should have resulted in benefits for maintenance and, consequently, to the increase of the Operational Availability are:

- The increase of the company's own staff within the last years should result in an increase of the maintenance staff commitment;
- With the low level of non-qualified workmanship, it was to be expected an appropriate specialization as well as more effective actions from the maintenance groups;
- The increase usage of maintenance performance indicators should result in a more efficient management of maintenance;
- The increase of staff maintenance training programs should contribute to the organization of better prepared groups as well as more effective maintenance actions.

Table 5 – Availability Indicators.
Source: 2005 National Document – ABRAMAN.

Availability Indicators (%)					
Types	**1997**	**1999**	**2001**	**2003**	**2005**
Operational Availability	85,82	89,30	91,36	89,48	87,90
Unavailability Due to Maintenance	4,74	5,63	5,15	5,82	5,80

In relation to the Operational Availability, it is possible to observe in Fig. 4(a) an increasing tendency from 1997 to 2001 and a decrease from 2001 to 2005. According to the 2005 National Document, the six best indicators (above 90%) showed an average of 93,92% to the Operational Availability. In relation to the Unavailability Due to Maintenance, it is possible to observe an increasing tendency within the last years, in Fig. 4(b).



a) Operational Availability b) Unavailability Due to Maintenance

Figure 4 – Availability Indicators
Source: 2005 National Document – ABRAMAN.

How can we then justify that, despite a great amount of proactive actions in search for excellence in maintenance, this has not resulted in an increase of the Operational Availability or the decrease of Unavailability Due to Maintenance?

Surely, the majority of these actions resulted in a momentary or short term evolution, which was reverted to maintenance benefits and, consequently, to the availability. The ephemeral nature of these actions suggests possible failures related to KM along with a misleading methodology of maintenance management. Such methodology cannot be related to market issues or intuitive decisions by the decision makers. These market issues are mainly associated to the acquisition of commercial CMMS (*Computer Maintenance Management Systems*) that does not always satisfy the specific needs of a certain company or system. Intuitive decisions are, invariably, partial and do not evaluate the entire context of application and/or of the company, which results in lack of commitment and discredit of the maintenance management program (FUENTES, 2006).

Each methodology, specifically the RCM, presupposes requirements and needs whose adequacy from the company/system has to be previously evaluated so that its implementation results in the desired effects. Besides that, when adopting a maintenance management methodology, its implementation and management has to be followed, so that nonconformity behaviors can be rapidly corrected and, thus, maximize the benefits that the methodology provides (BACKLUND, 2006).

3. RCM PRINCIPLES

The principals of RCM appear in the 50´s as a result of several reliability studies developed by the American Civil Aviation industry. However, RCM concepts (design for maintenance, prediction and prevention) were developed in the 60´s by the American Aerial industry as a response to the new scenario that was coming up, that means, a gradual increase in the maintenance costs and the low reliability in the traditional preventive maintenance based on time. Besides that, other factors also contributed to it such as: the increase in the quantity and diversity of the physical assets to be maintained, more complex and optimized projects, new maintenance methodologies and the increasing importance of the maintenance responsibility inside an organization.

In the 70´s, RCM consolidates itself with the studies of Nowlan and Heap (1978) who propagated the name RCM and provided the theoretical basis to its development. From these studies, two conclusions can be highlighted:

1. Programmed reviews have little effect in the total reliability of a complex equipment, unless there is a dominant failure mode and,
2. There is lots of equipment to which there is no effective ways of programmed maintenance.

Besides these initial studies by Nowlan and Heap (1978), other authors and institutions provided slightly different methodologies for the implementation of the RCM (SMITH, 1993 - MOUBRAY, 2000 - NASA, 2000).

In order to regulate the RCM implementation process, SAE - JA1011 standard, from August 1999, established the following criteria for an adequate RCM process:

- Any RCM process has to assure that the following seven questions can be answered satisfactorily and in the sequence:
  1) What are the desired functions and the associated development patterns of the asset in its context of current operation? (functions)
  2) In which way can it fail in fulfilling its functions? (functional failures)
  3) What causes each functional failure? (failure modes)
  4) What happens when each failure occurs? (failure effects)
  5) In which way each failure counts? (failure consequences)
  6) What has to be done to predict or prevent each failure? (proactive tasks and tasks intervals)
  7) What has to be done if an appropriate proactive task cannot be found? (pattern actions)
- The equipment operational context has to be clearly defined before the implementation of these seven questions starts;
- All equipment functions being studied must be identified, that means, all its primary and secondary functions, including all protection system functions;
- All failure states associated with all functions must be identified;
- All failure modes that may cause each functional failure have to be identified;
- The failure effects must include all necessary information to support evaluation of consequences of each failure mode;
- The categorization process of consequences must distinguish hidden failure modes from the evident ones;
- All routine tasks must be technically viable and attractive from the cost-benefit point of view;
- Any statistical or mathematical treatment used in the implementation process, especially to calculate the task intervals, must be logically consistent and must be available as well as approved by the equipment users

The methodology offered by the RCM recommends a systematic documentation of auditable failure modes. The Analysis of Failure Modes and its Effects – FMEA (*Failure Mode and Effects Analysis*) or FMECA (*Failure Mode, Effects and Criticality Analysis*), in case the criticality is also analyzed, became standard procedures in the industry to define and document all potential failure modes. Normalized procedures to FMEA implementation can be found in military standards such as: MIL-STD-1629 and MIL-HDBK-217. Practical recommendations to the organization of a FMEA/FMECA can be found in SAE -J1739.

So far, it is possible to conclude that the implementation and management of a RCM program demand a high level of experience and knowledge from the executors, mainly during the FMEA/FMECA conception. The present project framework is based on the premise that KM associated to the AI, in particular the KBS´s, can decisively contribute to support the decision making process.

4. THE IMPORTANCE OF KNOWLEDGE MANAGEMENT TO RCM

It is possible to conclude so far that the implementation, continuation and performance evaluation of a RCM program development involve issues based on qualitative and quantitative data, which is normally available to the operators and maintainers. This information can be accessed from the company's own database, the best option from a reliability point of view, or even from a generic database available to the manufacturers or institutions linked to reliability analysis.

KM creates routines and systems so that all knowledge acquired in a certain environment develops and is possible to be shared. The KM process, Fig. 5, includes generation, codification, dissemination and appropriation, throughout the entire organization, of knowledge that is usually restricted to an individual or group of people, thus, enabling the generation of new kinds of knowledge. This process, provided by Nonaka and Takeuchi, is called Knowledge Spiral and it presumes the overcome of a competitive and egocentric environment by a cooperative one in harmony with the organization purposes.

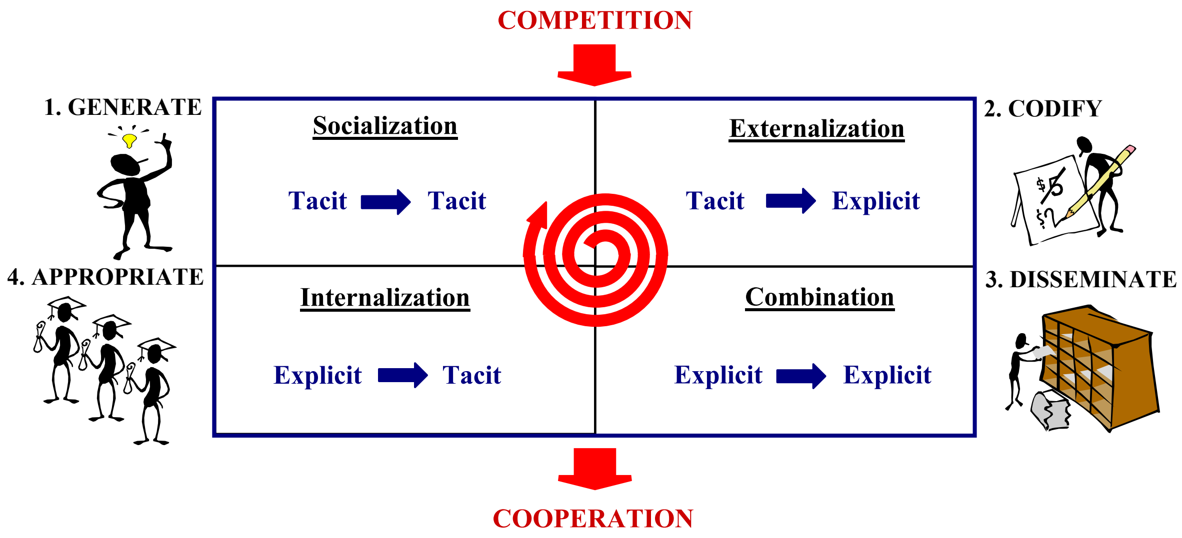


Figure 5 – Knowledge Spiral.
Source: Adapted from Nonaka and Takeuchi, 1997.

The more used and spread knowledge is, the greater its value will be and, in order to be measured, it needs to be transformed into action, allowing its measurement through financial results, process efficiency, increase in quality and through product innovation. According to Davenport and Prusak (1998), the only sustainable advantage that a company has is what it knows collectively, the efficiency with what it uses this information and the promptness with which it acquires and uses new knowledge.

The measurement of produced knowledge is expressed through performance indicators that are based on maintenance cost, operational availability, reliability (Mean Time Between Failures – MTBF), maintainability (Mean Time To Repair – MTTR) and rates of accidents with people, installations or damages to the environment. The following items demonstrate the relationship and the importance of a KM system to RCM.

Characterization of the Problem

The RCM methodology characterizes itself by involving not only representatives of the maintenance and experts, but also representatives of operation, security and quality both in its studies and in the propositions of new maintenance plans. Thus, it guarantees that the view and expectations of each sector are represented in the decisions concerning the new maintenance policy to be adopted.

This group must analyze the strategic needs of the company in terms of the increasing availability and reliability of the assets and also the best economical way to reach these goals. Then it is possible to define the systems and subsystems that will be analyzed as well as its frontiers. The decision process and knowledge related to it must be documented to guide the subsequent decisions and steps of the process.

Knowledge Production and Codification

The study of failures and the RCM proposition is carried out through the equipment and components chosen to be strategic ones. For each identified function of the assets, it is necessary to describe: possible functional failures (failure modes), their effects on the equipment or process, failure causes, its consequences for people or company, the frequency of failure occurrence and, depending on the needs, the criticality and risk associated to effects and failure modes, respectively. All these items can be inserted in a KBS, which will help the decision-making during this and other stages. With the results of the previous study plus the knowledge the company has about its assets, the study group searches for answers to the following questions:

- What can be done in order to predict or prevent each failure?
- What can be done if a proactive task cannot be found?

The answers to these questions depend on the following aspects: if the failure is evident to the operator; which are the risks to the operator or installations; what is the impact to the environment and in the production volume or quality; if there is any preventive action or applicable periodical change; if there is a need for a re-design of the equipment; if the maintenance for this item will actually be necessary.

The necessary knowledge to fulfill this stage is normally synthesized by a FMEA/FMECA which can be converted into rules for a KBS; thus, helping the maintenance teams in future interventions and/or for training. So, depending on a process of inference of the KBS, the maintenance tasks can be altered by unpredicted reasons in the initial analysis such as: changes in the operational context of the system; alteration of the interfaces between systems and/or subsystems; modifications in the external environment of the system can alter the Failure Modes and its Effects; evolution of maintenance techniques and/or system operation and alteration in the operation and maintenance teams.

Knowledge Integration

Having defined the activities, it is necessary to group them all aiming to get together the ones that have the same periodicity, specialty and type of intervention in only one maintenance procedure. The goal of this stage is to establish standard maintenance procedures that can be exported to the company's maintenance management system.

The schedule tasks can be postponed or anticipated according to the current operational situation of the assets. Having the scheduled maintenance tasks carried out, the KBS must be retrofitted so that the intrinsic knowledge can be incorporated to future system application.

Knowledge Dissemination and Appropriation

To get competitive advantages from an efficient maintenance management, it is necessary to spread the produced knowledge through the RCM usage. Such a spreading occurs with trainings which must highlight the stages documentation as well as the knowledge involved in failure correction, specially hidden failures or the ones which were not predicted in the initial FMEA/FMECA and that were detected during a systematic or not intervention. Thus, it is possible to guarantee that the maintenance procedures be carried out in the correct dates and by specialized staff, enabling the results measurements of implementation of new knowledge.

From this documentation, it is calculated the equipment reliability and extracted data to simulation of availability, adequacy of periodicity interventions and the spare quantity in storage.

Expected Results

The qualitative results deriving from KM implementation combined with RCM are:

- Working optimization by putting together the activities and dynamic analysis of real necessary tasks in order to guarantee the functional stability of the active;
- Continuous improvement focused on organizational learning;
- Retention of experiences and knowledge;
- Operators involvement in the maintenance actions and assets conservations due to a greater knowledge about their functions and failure modes;
- Organization and update of the technical documentation of assets and their components.

The intended quantitative results are:

- Increase of mean time between failures (MTBF);
- Diminish of mean time to repair (MTTR);
- Increase of the systems operational availability;
- Reduction of the Maintenance Costs;
- Reduction of accident numbers;
- Production increase.

5. THE ROLE OF ARTIFICIAL INTELLIGENCE FOR RCM

Knowledge Based Systems are inserted in the AI context. They are systems capable of solving problems by using specific knowledge about the implementation dominium and which are usually inserted in the management process of a system or organization. They also involve data collection and manipulation of several kinds of knowledge, for instance: procedural, heuristic and explicit (RUSSELL; NORVIG, 2004).

By analyzing the 2005 National Document (ABRAMAN, 2005), it is possible to verify the importance and the strategic function of KBS´s to maintenance management in Brazilian companies. Such importance can be concluded with the analysis of Tab. 6, which shows the Level of Specialization of Maintenance Staff.

Table 6 – Level of Specialization of the Maintenance Staff.
Source: 2005 National Document – ABRAMAN.

Level of Specialization of the Maintenance Staff (%)						
Task Type of the Maintenance Staff	1995	1997	1999	2001	2003	2005
Same Specialty	8,69	6,90	5,22	6,99	37,98	48,72
Same Specialty + Complementary Tasks	51,39	38,79	37,39	50,35	15,51	9,40
More Than One Specialty	39,92	54,31	57,39	42,66	46,51	41,88

Figure 6 shows the tendency curves that were drawn based on Tab. 6. The graphic of Fig. 6 shows a tendency to a multi-specialization (multiple functions) of maintenance staff up to 2001. In the 2003 and 2005 surveys, we can observe a strong concentration of maintenance staff in tasks with the same specialty, which means that more maintenance tasks have been carried out by experts.

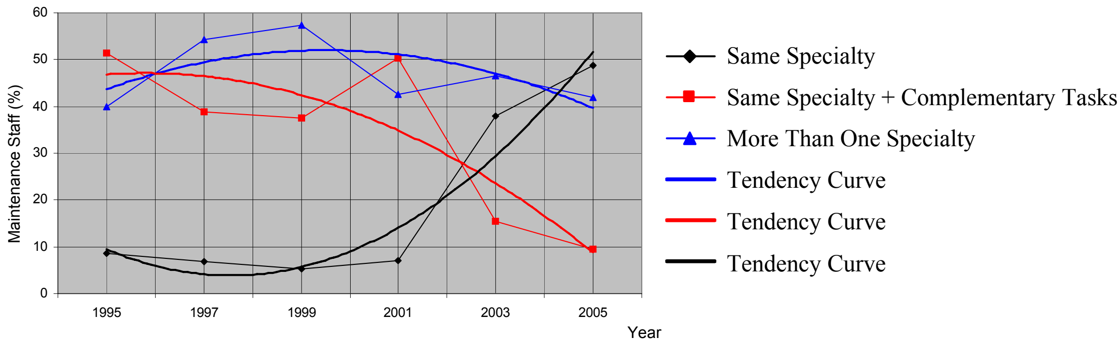


Figure 6 – Level of Specialization of Maintenance Personnel.
Souce: 2005 National Document – ABRAMAN.

The importance of KBS´s, emphasized by the surveys, is related to the preservation of the corporative memory, the creation of repositories of the specialists' heuristic knowledge, besides being a tool for staff training and also an instrument for the consolidation of KM, specially in in terms of knowledge documentation and dissemination. A KBS can be the edge of a company that faces the lack or loss of an expert and also represents the necessity of fast answers for maintenance requirements. One of the most important considerations in KBS´s development is the treatment of uncertainties, once the adequate dominions to the implementation of KBS´s are characterized by not being modeled by any general theory, which implicates in incomplete, uncertain and inaccurate descriptions (REZENDE, 2003).

The possible uncertainty sources in a KBS can be caused by data problems, for example: absent or not available data; available but not reliable or ambiguous data; data representation that can be inaccurate or inconsistent and data that can be based on *default* values. Such values can have exceptions or the data can only represent a better assumption of the human expert, based on plausible associations or observable statistics, which can or cannot be considered in all situations. Besides the input data, the uncertainty can be presented in the problem solution or in both (GONZALEZ e DANKEL, 1993).

Considering these several mistake sources, the majority of KBS´s require the incorporation of some form of representation of the uncertainty in the input and in the reasoning. The uncertainty presented in the knowledge structure which is intrinsic to the implementation and management of RCM has a lexical nature. Therefore, this article proposes the usage of the Fuzzy Logic for the treatment of this uncertainty.

The expression Fuzzy Logic was firstly mentioned in 1965 by the electronic engineer Lotfi Asker Zadeh, professor of Systems Theory at Berkeley University, who developed in the 60´s the Fuzzy Set Theory and who, in the 70´s, proposed its extension with the linguistic variable concept (CAMPOS, 2004).

Fuzzy Logic represents the uncertainty by inaccuracy, that means, it works with sets that have inaccurate limits. It is largely used to represent inaccurate linguistic terms. In the classic logic and based on the Sets Classic Theory, an element belongs or not to the set, while, in Fuzzy logic the same element has a level of pertinence to the set which varies from 0 to 1. This level is obtained by means of a pertinence function that represents the set. Therefore, Fuzzy logic can be used to help the KBS inference process which will, then, store the experts´ knowledge concerning the RCM implementation and management. At the same time, during the usage of the proposed system, the uncertainties in the input data will be contemplated with the usage of linguistic variables to help in the decision making process.

The verification of the company documents is an example of the implementation of the proposed methodology in order to verify the adherence of the companies to the RCM program needs ; thus, reducing its factors of failure during its implementation and management. Concerning this aspect, the evaluation considers 3 criteria:

- The existence of a consistent documentation of maintenance actions (Failure Reports, MTBF, MTTF, MTTR).

- The system to which the RCM will be implemented has an adequate technical documentation (technical drawings; layout; components relation, etc).
- The existence of a management system of information and/or knowledge implemented in the company to support the maintenance.

Each evaluation criteria is considered as a Fuzzy Set. The evaluator must answer each assertion with a grade (0 to 10) or a concept (awful, low, good, high, great) referred to the adherence of his company to the assertion that represents the item being analyzed. This grade or concept is evaluated in a Fuzzy KBS (a doctoral thesis prototype) whose linguistic variables are previously partitioned in case of a specific industry or, default values are used according to the experience of an expert in RCM implementation and management.

With the answers referred to the evaluation criteria, the prototype runs the Fuzzy inference process which, on its turn, will end up with the diagnostic for that company/industry. Fig. 7 shows the inference process and the software interface, developed for the implementation of the methodology proposed in this article and in order to evaluate the necessary documentation for the RCM implementation.

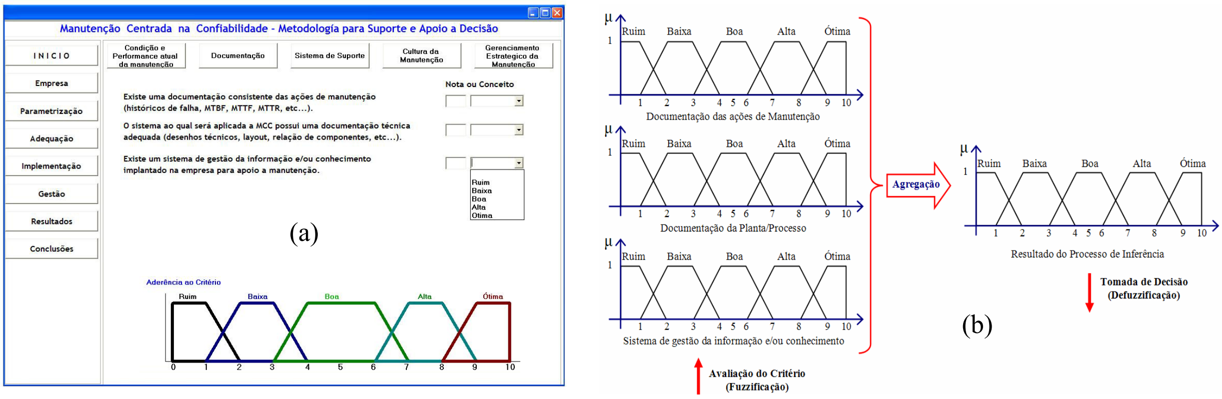


Figure 7 – a) Software Interface b) The Process of Fuzzy Interference.
Source: the Authors

A defuzzification is carried out by using the center of the mass method. Along with the results of the defuzzification, the prototype provides guidance for decision-making and KM, for instance, the explanation about the inference process; commentaries about the adherence of the company to the RCM needs and recommendations for future actions based on the current situation of the company.

6. FINAL REMARKS

This article is part of a doctorate project that aims to integrate the concepts of KM and KBS´s in order to assist decision-making during the implementation and maintenance process of RCM, especially in what its critical factors of success are concerned. Some advantages of this integration are:

- The usage of the KBS improves the reliability of the decision-making process. Human beings tend to forget relevant factors, especially if they are under stressful conditions or in a critical situation. Intelligent machines are immune to such factors;
- The KBS´s offer an increase consistency in the relative importance given to different factors of decision. They also present a greater accessibility and better explanation abilities;
- To the RCM, the KBS´s are reverted in economical advantages to the companies, concerning the agility and efficiency of the implementation and management process;
- The Knowledge Management is an important ally to avoid reworks and interventions that have already demonstrated to be inefficient in the past and, due to lack of information, are repeated, as well as to preserve the intellectual capital of a company, at the same time;
- KBS can accelerate the maintenance process reducing the time loss of the function of the system.
- KBS can be used as an instrument for staff training.

From a technological development point of view, we consider that the concepts mentioned in this article can contribute with useful solutions to the study of the knowledge engineering applied to the decision-making during the implementation and management of the RCM to the intrinsic activities of this process.

7. ACKNOWLEDGEMENTS

The authors thank UTFPR (Technological Federal University of Paraná), UFSC (Federal University of Santa Catarina), CAPES (Commission on Improvement of Higher Education Professionals) for their support granted until now.

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