Real Time Notifications for Critical Parameters in Operations and Maintenance

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ABSTRACT

Nowadays, information management is vital to the efficient global management of operations.

In a time of increased spreading of Information Systems, despite the vast number of options, it was acknowledged that they do not have critical information notification tools.

The use of real time notification tools is an efficient way of diminishing the process cycles and information flow increase.

This work consists of the study of the best way of notifying the right people in real time, decreasing response time.

The research and development of these applications was carried out in one of the production facilities of a multinational pharmaceutical company.

Communication and notification applications were developed appealing to the most modern computer science and system tools, like Ethernet communications, SMS notification, integration of several commercial SCADA, etc.

The obtained results were very positive. Therefore, the development is being extended to the other facilities generalizing its use to the entire company.
I. INTRODUCTION

The modern Maintenance Management has as one of its components a system of flexible information which is well adjusted to the company's needs. Nowadays, the new equipment is provided with information and communication technologies.

Communication devices are increasingly portable and miniaturized, offering users more mobility and better services. In this context, there is an unexplored area of industrial utilization services that may significantly improve the operations management. The event notification is increasingly receiving more and more attention in industrial business.

The analysis, design and development of a Computer Science System of Maintenance Management were performed in an industrial unit of a multinational pharmaceutical company. Applications of communication and notification were developed using the latest system engineering and computer science tools.

These projects contributed to the alteration of Maintenance's image, overcoming the strict vision of a cost center to a Responsibilities Center, refining the Cooperative Management.

II. COMMUNICATIONS OVERVIEW

A. Short Message Service (SMS)

The projects that were developed and are here described were required to have agile communication means, namely SMS, which work as a strategy of improvement and reduction of the processes' cycles. These means of communication have enhanced advantages for the intended goal, such as low cost,
comfort, facility of access and high density of receiving equipment, speed of communication and huge integration abilities.

The integration of these means of communication in the projects that were developed increased the access to information at the right time, which led to an improvement in the services supplied by Maintenance. The integration of communications via SMS exceeded the initial expectations, leading to the widening of projects to be implemented with this means of communication.

B. Web-based platform

With the purpose of speeding up the information flow, of making it reach the right people and of making it easily available to those who are interested in it in the shortest period of time, Web-based solutions were developed and integrated in a single application - Manupl@n.

Web-based applications have great advantages in relation to standalone applications, namely the compatibility and permeability of the several platforms of access to the service and of the operating system of the client. Being based in client-server architecture, the update tasks are simplified and reach every user, thus optimizing the whole management and administration process. After the adoption of the Web-based platform, there was no longer need for high requirements of hardware, particularly of memory, which are demanded of the application's client-user.

Another of its characteristics is its easy use. Its intuitive character helps users to familiarize themselves with the powerful tools that were developed. Furthermore, it has also a multi-user feature.
A. **Backgrounds**

In a 2001 study, a report in which the portrait of Maintenance is displayed diagnosing several organizational flaws was organized [3].

That same report showed as an important strategic vector the "Introduction of an Information System with accurate monitoring in order to be able to adjust it to the company and not having to adjust the company to it" [3]. It also mentioned the necessity of strengthening the structure of Maintenance, defining the maintenance process, implementing monthly reports, creating a development policy, implementing and controlling preventive and curative maintenance. Furthermore, it demanded a clear definition of the maintenance process: from the request for intervention to the record of Maintenance's action, assigning tasks, objectives, responsibilities and methods of ongoing improvement. Additionally, it recommended implementing records of guidelines, "controlling system of internally performed activities and subcontracted activities, knowing who controls it, how and what it registers" [3], referring the importance of the documental flow.

Before the project, the only means of communication used were the telephone and face-to-face contact, which involved loss of time, loss of information and difficulty in managing Maintenance projects. After Manuplan, all these problems came to an end.

As for the critical events, no differentiation between critical and warning alarms was made. There was just a sound signal activated only in the boiler and the water treatment room. There was also no access whatsoever to systems of process controlling supervision, whether internal or external.
B. Requirements and Specification

Labesfal's Maintenance and Engineering Management team has a strategic orientation line and a management philosophy which is defined by an ongoing improvement of the quality of the provided services without exaggerated investments in a short period of time. Therefore, it was decided that software should be developed within its information system, and this software should be able to adapt itself to the needs and requirements of the maintenance tasks. That CMMS would essentially be[2]:

1) **Simple** - without asking for too much information and easy to understand, allowing the improvement of the data introduction times, since the users are Maintenance technicians and their time for the use of these tools is scarce; data introduction would also have to be optimized in order to keep the users motivated.

2) **Reliable** - without noteworthy problems regarding data access.

3) **Accessible** - the software would be executed in all the computers of the company.

4) **Open-source** – source code available for minor changes.

5) **Linking production and Maintenance staff** - communication between these two sectors is crucial to the quality of the product and to the productivity of the company; it was necessary to speed up that communication but also to make it in a way that all job requests and response times from maintenance were registered for subsequent analysis.

6) **Web-based** – ability of being used in many different platforms and of being accessible from any point in the factory through a browser, easy to understand by the users that are already acquainted with the WWW.

7) **Centralized alarm management and real-time notification** – this was one of the features with more surplus value for the Maintenance, given the high number of alarms that occur everyday and the need to act on time on the critical equipment.
8) Collection, computerization and organization of management data such as equipment, routines, people, guidelines, etc.

9) Integration – the software to be developed would also have the chance to integrate more information and more modules beyond the ones usually used, such as calibrations management.

IV. MANUPL@N

A. Main features

Manupl@n is composed by several modules and functionalities among which we highlight the following [1]:

<table>
<thead>
<tr>
<th>Manupl@n – Main features</th>
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<tbody>
<tr>
<td>1    Equipment management</td>
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<td>2    Management and Planning of Preventive</td>
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<tr>
<td>Maintenance</td>
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<td>3    Management and Planning of Curative</td>
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<td>Maintenance</td>
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<td>4    Management of Calibrations</td>
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<td>5    Centralized Alarm Management</td>
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<td>6    Control of Water Pump via SMS</td>
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<td>7    UPS No Break Monitoring</td>
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<td>8    Management of Maintenance Contracts</td>
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<td>9    Management of Suppliers</td>
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Table. 1 – Main Features of Manupl@n
One of the differentiating points of Manupl@n is the Web-based platform.

Furthermore, Manupl@n is perfectly adjusted to reality and to the information flows of the company; it is also an intuitive system, easy to use and appropriate to the different levels of competences of the systematic users. Manupl@n is easily parameterizable, it has eight permission level privileges and, being internally developed, sporadic alterations are facilitated. This feature also allows the access to information to be personalized and safe.

![Fig. 1 Example of an image of Manupl@n](image-url)
According to the hierarchical distribution of Maintenance users’ permissions in Manupl@n, the information and functionalities available for each user depend directly on the associated permissions. For instance, a user who is "Maintenance Manager" has (almost) full power over the system and has a global vision of the events occurring in the industrial complex. On the other hand, a level 4 user has only freedom of action regarding the technical equipment associated with his production unit. A level 3 user only has access to information about the tasks associated with him and permission to complete them.

Another advantage associated with the fact of having it internally developed was the facilitation of the initial integration and the permanent contact with the users, which allowed for proper training to be given and elucidation meetings to take place, enabling monitoring activities and introducing improvements into the system.

Another important fact is the involvement of Production and remaining sectors of the company, clients of Maintenance services, in the utilization of the system, thus liberating Maintenance of part of the information processing.

B. Equipment Management

Manupl@n enables productive equipment management, utilities and facilities, as well as all information and features associated with it. Its hierarchical categorization is adapted to Labesfal's Cost Centers facilitating the organization and quick searches.
C. Management and Planning of Preventive Maintenance

The planning and management of preventive maintenance associated with all equipment are under the responsibility of every person in charge of a Maintenance Unit. Task management and its accomplishment are made in Manupl@n, enabling the creation of performance indexes per production unit and per employee, and making the monitoring of its evolution possible.

D. Management of Maintenance Requests

Tools to allow Production and other internal clients to request tasks were also developed in Manupl@n. According to the permits assigned to every user and according to the Production Unit in which they work, they can make maintenance requests through Manupl@n. Once the request is made, the technical service's recipient is notified by an SMS informing a task was requested from him.

E. Management of Calibrations

Calibrations management in Labesfal is under the responsibility of Maintenance. This management is made in Manupl@n. Its organization is made according to internal peculiarities in which it is possible, according to the user's permission, to verify the state of calibration of all equipment, to see the calibration plan, to access and download the certificates and even to analyze costs.

This module makes it possible to simplify the whole management of calibrations process and even bureaucratic matters by making information available. Presently, the information is always up-to-date and
available in a single source, Manupl@n, and it is accessible by any terminal with access to the internal network.

**F. Centralized Alarm Management**

Applications, which communicate with systems and essential processes and are responsible for forwarding critical alarms via SMS, were also added to Manupl@n. These applications are described in V. Manupl@n has also integrated alarm management tools in order to enable the analysis of the frequency of occurrences in the various integrated systems according to the period of time, thus allowing the supply of data to the Engineering so as to make improvements and check their evolution. It equally allows the parameterization of the alarms and their recipients.

**G. Control of Water Pump via SMS**

The main water source of the factory is at approximately 4Kms away from the premises, which hinders its regular surveillance.

The automation system allows the control and monitoring of the water pump and the sending of alarm messages, both through SMS. In addition to this, the interface with this application is Manupl@n, which allows not only that non-specialized technicians can easily control it, but also that the history record of remote operations and alarms in this equipment is built.

A GSM modem was added to the existing command. This modem's inputs are the signals of both the pump state and the thermal breaker. The modem sends the alarms to the established numbers as soon as there is a change in the considered normal state.
The modem, bound with the pump's command, sends an alarm via SMS to the technicians and to the server when the pump is disconnected or when there is a thermal increase. It is possible to connect and disconnect the pump via SMS. Every command operation is made in Manupl@n, thus simplifying it and avoiding the need of familiarizing the technicians with AT commands.

Furthermore, the system receives a daily message at a pre-established hour, in this way guaranteeing that it is operational (SMS alive message). In case there is a power cut in the pump's command system, as soon as the normal conditions are restored, it notifies the system of the incident and the period of time it lasted. Every operation and alarm's history sent/received is accessed through Manupl@n.

**H. Management of Passwords**

It is well-known how difficult password management is when users are obliged to use several access codes in different equipment and systems. In Labesfal's case, due to the technological density, there are countless systems which require authentication. When a system is less frequently used it is easy to forget the access code. The advantage of the management of this data in Manupl@n is the possibility of accessing it from any point in the company and having only to insert a single personal access code. Each user has access only to the passwords that were registered by him.

**I. Production and remaining internal clients' involvement.**

Maintenance should have in its information system a partner for making decisions, improving performance, controlling costs, etc. It should also be able to see this system as a way of improving the service provided to internal clients, making its use and the existing information available. This system is
flexible, easy to use, easily accessible and provided with powerful real-time communication tools. It is a
good enough argument to have the Production Department and remaining lacking information departments
as intensive users making maintenance requests. Usually, Production needs a quick response to damages.
In Manupl@n, when a maintenance request is issued the target technicians immediately receive a SMS
informing that the request was made and containing a brief description of what is intended. Additionally,
lower priority tasks, once ordered through the system, help to plan its preparation assuring that they are
not neglected.

This approach to the problem makes it possible for a larger number of tasks to pass through Manupl@n,
thus creating an enriched and more realistic history and compelling to an increase in Maintenance
technicians discipline [1].

This is also a way of shortening process cycles and response times, increasing internal efficiency and
reducing costs.

J. Communications via SMS

Communication tools available in Manupl@n are the key to the application's success and its generalized
use for maintenance requests. When a maintenance request is generated in the system, the person who is
supposed to respond to it immediately receives a SMS notification. Being that the use and access to
functionalities is limited by policies of hierarchical permissions, certain users may forward that same task
to other technicians. If they do so, the person they aim for is also notified by SMS. Once the task is
completed in Manupl@n, the user who made the request receives, also by SMS, a summary of the
intervention report with information about who accomplished the task and how long the intervention took.
The integration of SMS notifications in Manupl@n began in January 2007. In the server, where all the applications described in this paper run, also runs a SMS server which sends cyclical messages, in case they exist, to the specified recipient.

The reasons that led to the choice of SMS as the main means of notification are related to the necessity of a short response time to maintenance requests through Manupl@n. Since the technician's notification is immediate, the use of Manupl@n to carry out maintenance requests became reliable, practical and useful; therefore its use was generalized.

Thus, in January 2007 SMS services were already available to maintenance requests. If an operator makes a maintenance request to a certain technician, the latter is informed through the system about the new maintenance request, who ordered it and which equipment is concerned.

When the technician completes the task and its report in Manupl@n, the sender of the request is notified of the accomplishment of the task, of who accomplished it and how long it took to be completed.
Being that there are users with the permission to reassign tasks that were assigned to them, when this alteration is made the new recipient is informed of it.

From the administrator's view, there are a few other services via SMS available. For instance, if the associated cell phone has low battery, the administrator of the system is immediately notified of this situation by SMS. Furthermore, if the SMS server loses connection to the database, usually indicating an application or the Operating System's crash, the administrator is also immediately informed. Additionally, the administrator receives a daily SMS with the report in which are discriminated the total of messages sent, received and with sending failure.

The administrator also has access to the BackOffice for statistical tools of the SMS: reason of sending per date, total messages sent per date, per sending reason, per user, etc.

K. Results

<table>
<thead>
<tr>
<th>Number of notifications sent via SMS through Manupl@n</th>
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<tbody>
<tr>
<td>Number of registered users</td>
</tr>
<tr>
<td>Total logins in the system</td>
</tr>
<tr>
<td>Pieces of equipment in Manupl@n</td>
</tr>
<tr>
<td>Total tasks in Manupl@n</td>
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<tr>
<td>Total maintenance requests</td>
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Table 2- Information and communications flow via SMS in Manupl@n
v. **Central Alarm Management**

Applications of notification via SMS of critical alarms and centralized alarm management were developed with the intention of reducing the response time to critical events and with the advantage of making the information about these events available.

The chosen philosophy and architecture of communications, for having special particularities, deserve a greater descriptive detail justifying the reasons of their application.

The first systems integrated in the management and forwarding in real-time of critical alarms were the pre-treatment and the treatment of water, which are critical systems in terms of quality and productive availability. Because of the positive results, the project was generalized and expanded to other systems, some of which are still under development.

**A. Alarm specification and design**

An alarm condition is an alteration of the conditions that are considered normal or a situation which requires announcement or even a response from a qualified person.

Effective alarms can provide the following types of information:

1) **Alert** – calling attention to abnormal situations which require a swift response.

2) **Inform** – providing information about an abnormal situation.

3) **Guide** – providing the expected response to an abnormal situation.
The purpose of the several functions of the alarms in a manufacturing plant has a large coverage spectrum. Some alarms alert the technician to a process which is reaching the limit of a normal operation range.

An alarm of a higher hierarchical status can alert to a process that has exceeded the limit of its specifications, thus risking the quality of the product; therefore it requires meticulous investigation of the causes and possible impact on the final quality. Equally important are the alarms related to security, which alert to situations that may endanger both people and the integrity of the equipment.

Critical alarms warn the technician of a condition that may require his immediate action.

Because of what was stated, being quality and safety at stake, the foregoing alarm conditions must be reviewed periodically.

The specification and design of the alarms of an industrial plant are the result of the particular features of the different realities encountered. Thus, the implementation of a poorly structured alarm design risks providing unimportant alarms, supplying useless and, in some cases, even contradictory information, increasing the risk of having serious situations wrongly identified. It is easy to understand that a negligent implementation can bring negative, if not catastrophic, impacts to the quality of the product, to the employees in the plant as well as to a third party.

Therefore, the importance of the design, specification and implementation of the Alarm Strategy has to be taken into consideration in order to safeguard the needs and particularities of the company. This contributes to a perfect Alarm Strategy within a company.

A formal definition of an Alarm Strategy helps to define how the alarms are specified, namely the way in which they must be verified. An Alarm Strategy must guide the way the alarms are managed in normal operation, during maintenance activities or even in calibration tasks. If this is not taken into consideration, the alarm management approach will not be integrated nor disciplined resulting in an organizational gap,
usually accompanied by an excess of alarms which leads to an excess of information, most often contradictory. This generally causes more problems than it anticipates corrective action.

Alarm notification via SMS is part of our Alarm Strategy and originated two types of alarms:

1) Critical alarm – Typically the highest level of alarms, identified as a serious occurrence with a high degree of impact in the quality of the product, security and environment, notifying the technician in real-time, thus reducing the risk, minimizing the impact or even anticipating critical situations.

2) Warning Alarm – Typically the lowest level, announcing that the value of operations is out of the considered normal range or indicating the approach of a critical alarm condition. No SMS needed.

Flaws or damages, not only in the equipment of process but also in the equipment that generates alarms, must also be taken into consideration. The specificities of the company must equally be taken into account. For example, a visual indicator of a warning alarm may be enough if the process is supervised 24 hours a day or during its running period. However, these means of announcement may be insufficient if the process is not monitored during its execution. In order to respond to these particularities, the design must adjust to these realities, for instance through audible alarms, assuring that the technicians are made aware of the alarm condition. In order to notify technical staff, ways of notifying critical alarms by SMS were developed in this Alarm Strategy.

**B. Why forward alarms in real-time?**

The frequency and repetition of alarms may reach a point in which it will seem as if the process is out of control or not working well. A high frequency of alarms usually does not imply added value to work, but
the engineering work must focus on the effort of improving the process and that is why it is necessary that the engineers have tools to help the analysis at their disposal.

In the pharmaceutical industry, quality criteria are so strict that they demand zero-error effort and anticipation of the events before they jeopardize the quality of the product. The company aims at substantial reduction of rejected product with consequent loss of production and quality increase.

In addition to the quality criteria, real-time notification seeks drastic decreasing of the average response time to a critical alarm. An intervention in due time reduces also the dimension and seriousness of the damage, as well as its spread to other areas of the equipment and/or other systems. In this manner, it contributes to a growth of equipment availability.

Furthermore, by diminishing the seriousness of the damages, it is expected that the equipment's life cycle is expanded, that its LCC (Life Cycle Cost) decreases and its LCP (Life Cycle Profit) increases.

Having these purposes in mind, applications of forwarding critical alarms by SMS were developed for the most critical systems in the industrial complex.

C. Advantages of the Centralized Alarm Management and Forwarding

To the centralization of the alarm and notifications control we can add other advantages beyond the ones previously described.

The developed applications work in a network. They centralize the SMS forwarding in a server, which on its own avoids the overload of i/o's and of processing in the control and supervision equipment.

Besides this, centralizing SMS forwarding in a server also contributes to the uniformity, creating bridges between automation islands. In this philosophy, there is only one application which manages the SMS forwarding (SMS server) with several advantages from the management, administration and system maintenance’s points of view.
Centralized management allows also a better alarm and report of sent messages treatment. In this way, it allows to statistically treat data collected from all systems making more information available to the Engineering. It allows, for instance, to know with what frequency a certain alarm was activated in a certain period. It also makes it possible to verify the performance of the improvement interventions carried out. Additionally, it enables the knowledge and control of costs of the sent messages.

In this architecture there is no need to bind a cell phone or a GSM modem to every system/equipment to be integrated, thus decreasing the installation costs. Furthermore, when it is necessary to choose an established price it is more competitive to have only one piece of equipment sending hundreds of short messages everyday than to have many pieces sending only a few messages each.

In addition to this, having the norms which govern pharmaceutical industry in mind, the critical systems of which the quality of the final product directly depends are subject to strict performance and integrity tests - the Qualification of the Equipment/System. Once Qualified, any alteration should be subject to meticulous tests according to the GMP norms (Good Manufacturing Practices, a.k.a. Gimme More Paper).

With the continued communication architecture, having no direct interference with the systems' performance, there is no need for Change Control.

D. Communication architecture

Illustration 2 represents the system's architecture. In the middle is the database which communicates with the SMS server that, when there is a sending order, is responsible for the communication with the cell phone, communicates with the telecommunication network and proceeds to its sending.

The remaining applications running in the server are responsible for the communication with the systems existent in the field.
There are different applications developed or under development for each of the suitable SCADA's. Manupl@n, the Maintenance Management software is the WEB *frontoffice* with these systems. Here one has access to the messages, their content, their date of sending and the sender's id. One can also see the reports of the activated alarms and their frequency according to the system and period considered.

In this Real Time Notification Service design, the following modules may be distinguished:

1) Event channel component – Detection of alarms activated in the field.

2) Subscription lookup component - List of the alarms' recipients, of the alarms they receive and of the available receiving schedule.

3) Filtering component – Filtering in function of the hour of the occurrence, of the activated alarm and of its recipients.
4) Dispatching component (priority based) – Any activated alarm is written in the database and, in case the ‘filtering’ through the filtering component is positive, a SMS is sent to the parameterized receivers.

**E. Results**

![Graph](image_url)

**Graph. 1 – Number of SMS sent in 2007**

Looking at the graph you can see the positive evolution of the number of sent text messages, which reveals the increase of the number of recipients at operational notifications level (Manupl@n and others) as well as at critical alarms level. The evolution of the number of sent critical alarm SMS is even moreaccentuated. The peaks correspond to test periods of the new integrated systems; for instance, the Water Treatment U2 began its tests in December 2006, the HVAC U1 in April and the HVAC U4 in November. We must point out that the HVAC U4 is the most complex system with more users registered as recipients, which is evident in the graph. The reduction of the alarm number after the period of tests also
corresponds to an improvement in the systems, refining parameterizations, which is only possible through the application developed for the centralized alarm management.

VI. IMPROVEMENTS IN MAINTENANCE QoS

The goal of the company's department of Engineering and Maintenance is that its management system is neither static nor reactive but target of constant improvement, which is facilitated by being open-source, keeping the QoS high.

The projects here described enabled the increase of the QoS at several levels, decisively facilitating the whole maintenance management process. It also allowed organizing, treating and making available important data for the Engineering to make decisions and it was an important tool in the improvement projects. Besides this, the quick notification of technicians for the different operations allows a substantial increase in the response, and its quality, to the production's requests.

With these projects, an efficient solution for the company's quality requirements was obtained, and the effective traceability and maintenance action control were also made possible. We also achieved a greater efficiency in the organization and allocation of resources, better communication, more information and a way to measure and assess Maintenance Quality.

Despite the obvious success of the implementation of these solutions, the information system must be subject to a process of ongoing improvement so that it can be maintained in the quality system of the company. In order to achieve this goal the system must be continuously assessed and it must accompany the company's dynamics.
As a general result there is a greater availability of more accessible information, which has clear advantages at management level and in the construction of maintenance indicators.

The centralized alarm management tools and the SMS notification of critical events enabled the reduction of the average response time. It also enabled the decrease of the number and frequency of faults, increasing the equipment's availability.

![Graph 2- Preventive Maintenance VS Curative Maintenance in 2007](image)

The computerized management of the preventive and curative maintenance makes the construction of maintenance indicators possible. Thus, it is possible to accompany the adopted maintenance strategy,
which, as you can see in the graph, reveals a positive increase of the number of preventive maintenance tasks and, as a direct consequence, a decrease in the curative maintenance tasks.

VIII. CONCLUSIONS

With this work, without interfering in the company's organizational plan, we are led to conclude that we are drawing nearer a new maintenance paradigm: focusing on the process and the people instead of focusing on the "product".

These projects contributed to the alteration of Maintenance's image, overcoming the strict vision of a cost center to become a Responsibilities Center, refining the Cooperative Management.

An Information System in the scope of Maintenance, which consists in a network of communication channels in the organization, is the perfect tool to deal with great quantities of data, transforming data into information and information into knowledge.

The strategic information management and the competitive intelligence are among the main factors of success in organizations and particularly in Industrial Maintenance.
REFERENCES


[4] Forum IT Infrastructure SIG, IT Infrastructure Control and Compliance, ISPE, 2005


