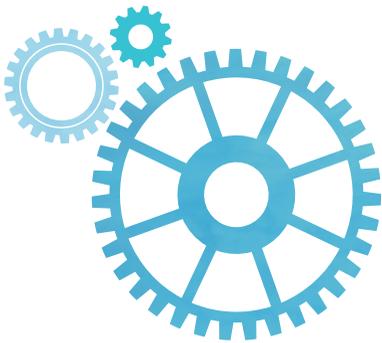


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Maintenance Management in Web ASP.NET MVC Applications

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Abstract – Maintenance presents itself as one of the key factors for increasing the productivity of companies. Its importance is increasingly recognized due to the need for greater efficiency in the management of physical assets and resources that are associated with it, thus avoiding unnecessary costs.

This article presents a management system to support maintenance management, which is being developed, named GESP, designed with the help of ASP.NET MVC Web program, which transacts the data through a base data developed in SQL. This system intends to perform inventory management, human resources outsourcing (subcontracting) and maintenance of the activity itself. The differentiating feature of this tool stems from its ability to measure in real time variables of control (hours, kilometer...) of physical assets and the ability to automatically schedule working orders, even taking into account the physical structure of the active targeted for intervention.

Keywords—Maintenance management; Stocks management; Maintenance resources; Outsourcing; CMMS.

I. INTRODUCTION

Maintenance presents itself today as one of the primary factors that contribute to the productivity of enterprises. Its importance is recognized because the aim for greater efficiency in resource management, thus avoiding unnecessary expenditure of funds.

Maintenance management is an arduous task that involves human resource management, physical assets, including stocks, and yet, when applicable, the management of subcontracted services. All of this should be done in harmony with the production sector to minimize the losses caused by the stoppage of production. However, it is impossible to predict all the failures in physical assets, being mandatory some unplanned interventions, forcing sometimes a re-schedule of previously planned maintenance interventions.

Mainly in large organizations, the maintenance cannot be only focus on an expert, existing systems that store and keep updated detailed information about the overall physical assets of an organization. The systems commercially available are differentiated by their ability to share information with different departments of the organization, data collection, data management, including artificial intelligence applied in several processes, giving to the maintenance manager a set of information in order to improve the efficiency of maintenance management.

Considering all the precedent characteristics, this paper presents a tool, which stills under development, to support maintenance management encompassing stock management, human resources outsourcing (subcontracting) and own maintenance activity, scheduling maintenance events and classifying them according to their AFNOR standards, [1]. Current system version is being designed in ASP.NET MVC Web [2] linked to a model database in SQL [3]. This system has the peculiarity to communicate in real time with the physical assets in order to check their variables of control (hours of work, kilometers...), analyze them and so pre-scheduling its planned maintenance interventions. It is mainly useful for non-periodic / aperiodic interventions.

The paper is structured as follows:

- Chapter two is the approach to programming in ASP.NET MVC C#;
- Chapter three, maintenance data management, presents a general approach to manage data maintenance, including the following items:
 - The permissions system;
 - The technological decomposition;
 - The management of planned maintenance;
 - The stock management;
 - The scheduling of working orders (WO);
 - Analysis of the history;
 - Classification of the maintenance tasks.
- Chapter four presents the GESP application;
- Chapter five defines future development application for GESP;
- The chapter six presents the conclusions and finally;

II. APPROACH TO PROGRAMMING IN ASP.NET MVC C#

The GESP system is developed in ASP.NET [2] which is a Microsoft's platform for developing Web applications. It is a component of IIS (Internet Information Services) that allows, through an integrated programming language in the .NET Framework to create dynamic pages. ASP.NET is based on NET Framework [4], which inherits the features of .NET application. The platform offers advantages such as the development of the following applications:

- The code is written in several languages, in this case the GESP is developed in C # [5] NET that can be developed in Visual Basic NET [6];
- Application development in Visual Studio.NET [7] facilitates the programming work, with visual components to create forms of Web pages. Whilst it is possible to develop ASP.NET applications using only a text editor and compiler. NET;
- It is possible to reuse the code of any other draft written for NET platform, even if the language is different;
- Despite the code of the application is not written in VB.NET [8], this tool allows you to call components written in C # and Web Services written in C ++ [9];
- The ASP.NET applications are compiled before execution, giving a sensitive performance gain;
- Allows you to run ASP.NET applications on other platforms (Linux [10]) through the module that enables the Apache HTTP Server to work in conjunction with NET Framework and ASP.NET applications running on the , or is, mod_aspdotnet project.

The MVC pattern [2], represents an important role in computing, particularly with regard to the creation of architectural patterns related to the construction of UI (User Interface). A key feature of this pattern is the separation of responsibilities, thus contributing to the code used in a given area is isolated from that used in the construction of graphical interfaces. Thus, the division of responsibilities contributes to simplify development (simplifies the modularization), simplifies testing of the various components and improves the maintenance of the application at the expense of a small increase in complexity. Thus, a single standard lists three elements: model (Model); control (Control); and the view (View) - The model is a class or set of classes that encapsulates the data and business rules that are applied to them; The view is responsible for generating a graphical user interface presented to the user; Control is responsible for managing the interaction between the model and the view.

III. MAINTENANCE DATA MANAGEMENT

The management of all information affects the maintenance activity which is a complex process including the influence of some processes against others in a bi-directional way. Often a multi-criteria analysis is performed, but it may be too complex that only with the aid of computer tools is can be solved and thus manage efficiently the overall maintenance sector of an organization [11-12].

A. Sytem permissions

The proposed maintenance management system has several pre-defined access patterns, manage by the system administrator, depending on individual background and position of each collaborator. People on the same positions but different background may have different access to information, such as a mechanical technician compared with an electrical technician. Although the system has a predefined set of accesses, as schematised in figure 1, the administrator of the

system can set new levels of access to different profiles and others background specialties.

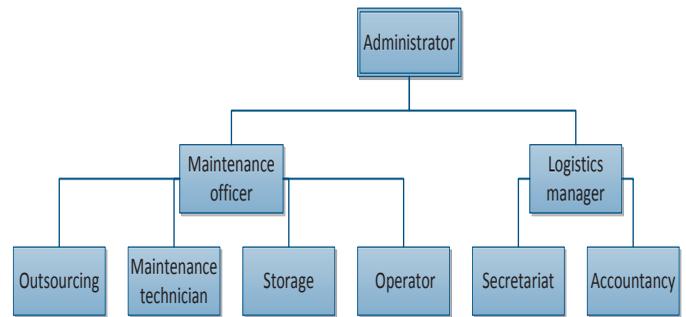


Fig. 1. Permissions of the GESP users

B. Technological decomposition

Technological decomposition of each physical asset is important and highly relevant to the performance of the proposed system. Each asset is classified according to its condition, family, manufacturer's recommendations as well as their references, especially useful in the selection of replacement parts.

Thus, each asset is classified according to its state of condition such as:

- Operational - meets all requirements of normal operation;
- Out of order - when a failure occurs and the physical asset is under maintenance works;
- Slaughtered - physical assets whose life cycle has ended.

Regarding family, each physical asset is identified as follows:

- Equipment Parent - category of physical assets;
- Integral Part - indicates the main equipment of which the physical asset in question is an integral part;
- Alternative Part - alternative to part.

In the case of a physical asset be a part of a production line (an induction motor for example), that line is the Integral Part and the alternative part a similar production line whit the same characteristics as the Integral Part because in case of an engine failure the whole production line is stopped. If the physical asset is one defibrillator, it is itself the Integral Part being the alternative another defibrillator. Highly important are the recommendations of the manufacturer about regular operational conditions and maintenance plans in order to extend as much as possible the life cycle of each physical asset and not lose the warranty, which is sometimes lost due the improper use of physical assets or for not fulfilling their maintenance plans.

The references, these are used to manage orders and for market analysis and acquisition of physical assets, aiming to achieve better prices and identify alternative parts that allow similar performances.

C. Management of planned maintenance

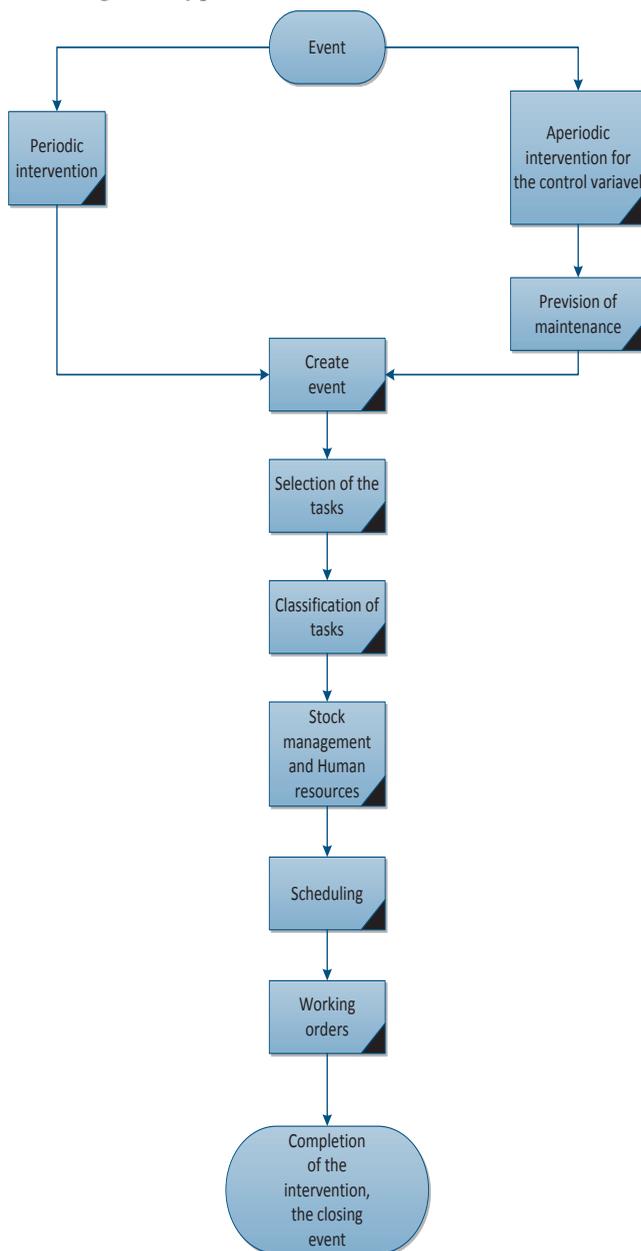


Fig. 2. Processing management from planned maintenance, in GESP application

The management of planned maintenance interventions is performed through the maintenance events following the structure shown in Fig. 2. The order of creation of a new maintenance event is given by temporally periodic or aperiodic maintenance interventions. In the latter case, the creation of a maintenance event depends on a variable of control and a prediction of the event scheduling. This is supported by a communication module, connected to assets, in order to obtain

the data from the variable of control and analyze operating periods in order to make the best possible prediction to the planned maintenance intervention that should occur.

Created the event, it is selected the tasks that must be performed, not only based on the specifications from the technological decomposition but also from the analysis of the physical asset's history and or its family, which may result in additional tasks.

Each task is classified according to the AFNOR standards in order to manage efficiently the human resources available for the period in which the maintenance works are performed. The system will be prepared to indicate not only the internal organization's human resources as well as the outsourcing services if applicable or demanded. The availability of parts that need to be replaced in stock is also important for scheduling interventions.

After all this information is gathered, it will be the maintenance manager who will decide the exact moment when the maintenance intervention should occur and identify who is responsible for carrying out each task by issuing working orders (WO).

In spite of what were presented above, it will be able not only for the technician but also the operator to report failures or evidences that will be evaluated by the maintenance manager and, if applicable, create an event with appropriate tasks to ensure adequate operational conditions of physical assets. Given the nature, this is considered a "preventive Event".

All the parameters to schedule interventions are pre-defined in a database. The management system will compare the pre-defined in the database with the values from the variables of control that are monitored in real-time, being the communications carried out via a PLC, following the structure shown in Fig. 3.

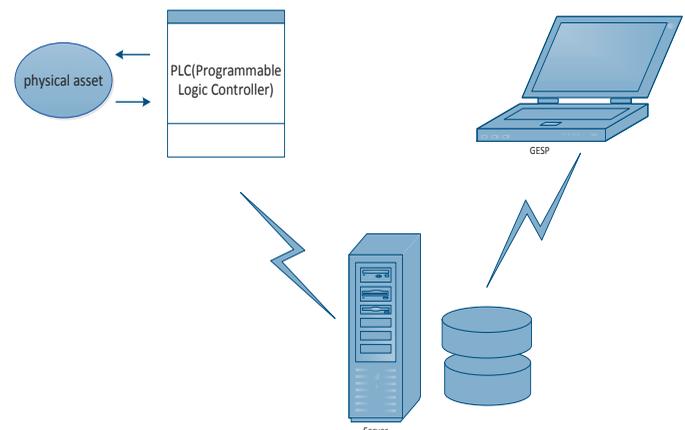


Fig. 3. Communication of the physical asset with the GESP application

D. The stock management

A good stock management of reserve parts predicts the required resources for a certain period of time, thus ensuring all necessary parts will be available on time. Throughout the historical analysis, the maintenance manager may provide the

recommended quantity of parts that should be always available in case of a failure.

An efficient stock's management means having the minimum parts in storage to guarantee the maintainability of physical assets.

It is planned a stock form that gathers all the information regarding the components and materials available for each physical asset, presenting its definition and classification. The classifications are created by the user and consists of assigning a category within a classification and description.

Upon delivery of the goods, the organization creates a record of delivery. In this, the average and actual purchase price is determined on the stock form, being the amount of available parts also updated appropriately.

The states of deliveries and the periods of states are a vital information to predict the physical assets that must be available for a certain maintenance event.

E. Scheduling of working orders (WO)

The events are related to specific maintenance tasks, which flow through the system and contain the information stored. After the creation of an event, a WO is generated according to the tasks that must be performed.

F. Historical analysis

The history of the technological decomposition consists in storing information of interventions that have been performed, their description, including the timeline in which they were performed. The data collected from monitoring each physical asset is also part of the historical, being the system in future versions enriched with mathematical tools to analyze patterns in order to identify and detect behaviors that represent a high probability rate of failure. Thus, the maintenance manager will be provided with an additional tool to schedule preventive maintenance events in time.

G. Classification of maintenance tasks

The maintenance tasks classification is a very important point, it describes the level of importance of maintenance events, allowing to perform optimal resource management (Figure 4). Events are classified according to the levels defined in the AFNOR X60-010 and the type of maintenance to be done (Figure 5).

Maintenance levels defined in the standard AFNOR X60-010 are as follows [1]:

Standard 1 - Simple tunings provided by the manufacturer without equipment disassembly or replacement of accessible elements;

Standard 2 - Repairs performed from the replacement of standard elements provided for this purpose or minor repairs preventive maintenance (rounds);

Standard 3 - Identification and diagnosis of faults, repair by replacement of functional components and minor mechanical repairs;

Standard 4 - Important works of curative, preventive or corrective maintenance;

Standard 5 - Work of renovation, construction or major repairs in a central workshop or by subcontracting.

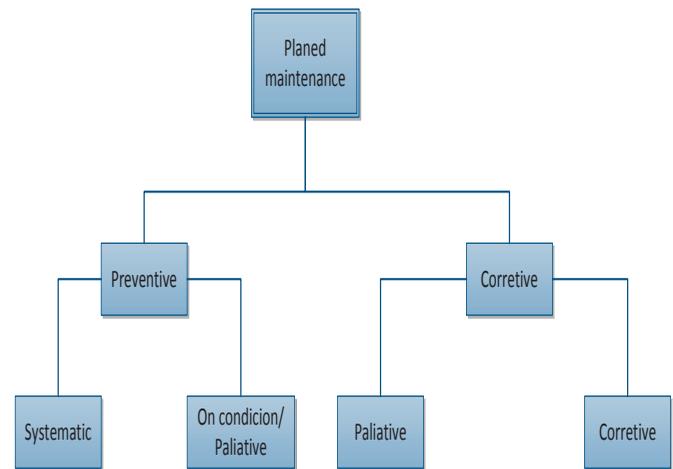


Fig. 4. Classification of planned maintenance in GESP application

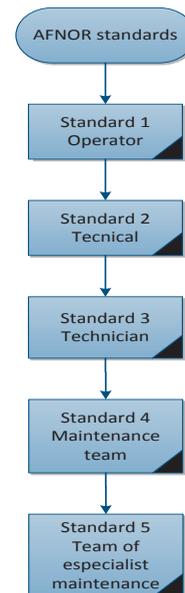


Fig. 5. Classification of specialties of users according to the AFNOR X60-010

IV. GESP APPLICATION

The GESP system is architected to have a friendly user interface, according to the structure illustrated in Figure 6. The main menu of the application consists of four buttons, which allow access to four major groups that are related to maintenance management.

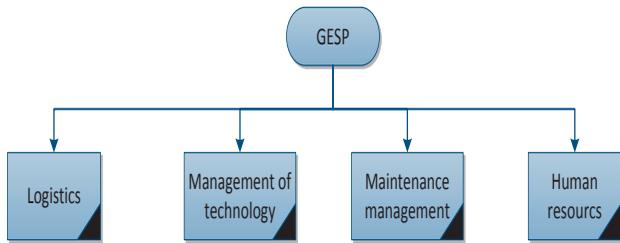


Fig. 6. GESP application main menu

Logistics is a submenu of the main menu which consists of four main buttons, two submenus give access to others two, as seen in Figure 7. The logistics contains the information on the resources and internal and external relationships of the organization, to carry out the maintenance.

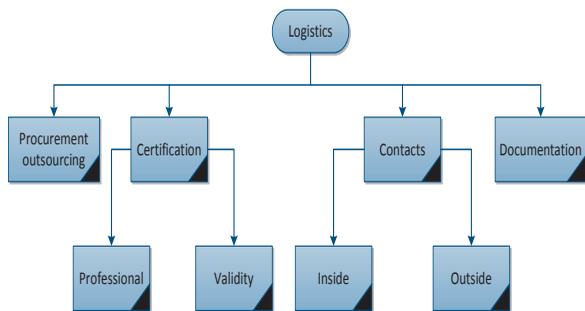


Fig. 7. Logistics submenu of the GESP application main menu

The management of technology comprising a total of six buttons where four of them buttons provide access to relative submenus, such as shown in Figure 8; this submenu contains the data subject to maintenance on physical assets.

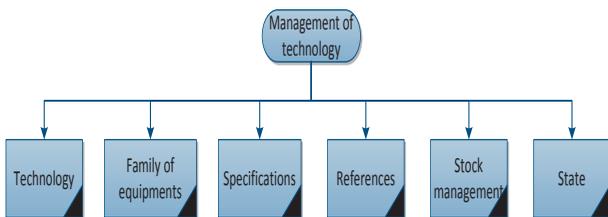


Fig. 8 - Technology management submenu from GESP application main menu

The family of equipment is a submenu of the technology management application that contains information to classify the family of physical asset, according to the structure of Figure 9.

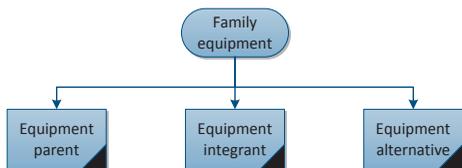


Fig. 9. Family submenu of the equipment submenu of the technology management GESP application

Specifications are accessed through a submenu of the technology management application that contains information to classify the active physical specifications to meet the main menu, following the structure of Figure 10.

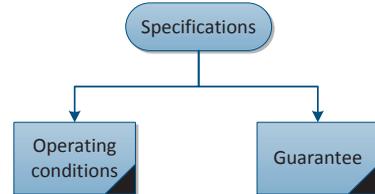


Fig. 10. Submenu of submenu specifications of the technology management GESP application

The references correspond to a submenu of management technology main application menu containing the information of the reference physical asset, according to the structure of Figure 11.

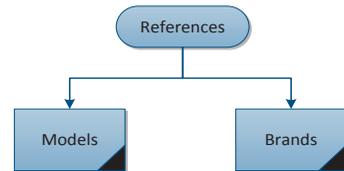


Fig. 11. Submenu of references submenu of the technology management GESP application

The stock management is accessed through a submenu of the technology management application, which contains the necessary information to make the management of stocks of physical assets main menu, according to the structure of Figure 12.

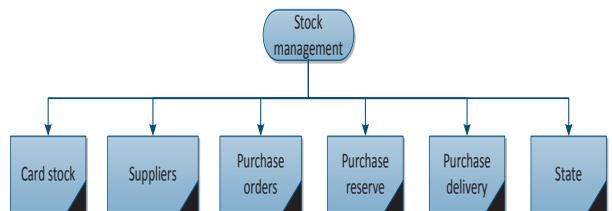


Fig. 12. Submenu of stock management submenu of the technology management GESP application

The management service is accessed through a submenu of the main menu of the system, which is composed of four submenus, according to the structure illustrated in Figure 13; this submenu contains the relevant information of the maintenance management of physical assets where the application will be implemented.

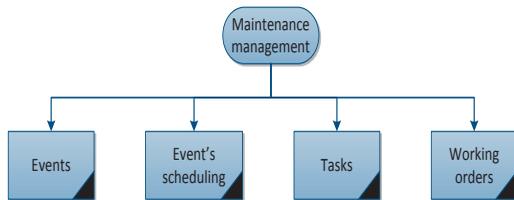


Fig. 13. Submenu of the maintenance management of the GESP application main menu

The events correspond to a submenu of the maintenance management, which follows the structure of Figure 14 containing information about its description, classification and analysis.

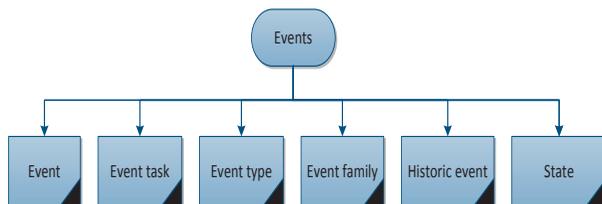


Fig. 14. Submenu of events submenu of the maintenance management GESP application

The event schedule corresponds to a submenu of the application maintenance management, which follows the structure illustrated in Figure 15, which contains information about scheduled periodic maintenance events and variables of control in case of aperiodic planned maintenance events.

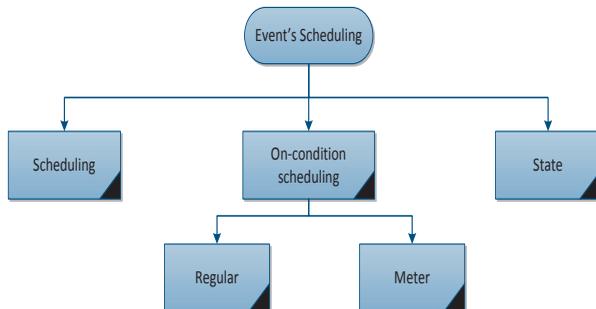


Fig. 15. Submenu of cheduling the events submenu of the maintenance management of the GESP

The tasks corresponding to a submenu of the application maintenance management, which follows the structure of Figure 16, contains information of the maintenance work performed in the organization.

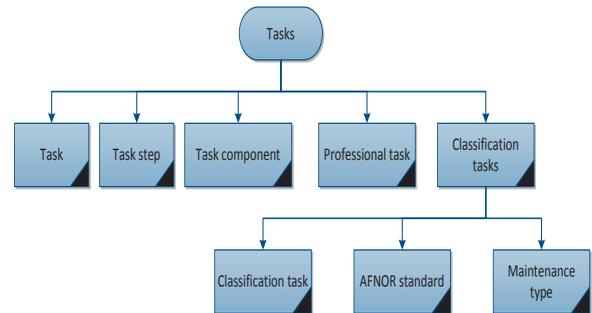


Fig. 16. Submenu of the submenu of the maintenance management of the GESP application tasks

The WO correspond to a submenu of the maintenance management application, which follows the structure illustrated in Figure 17, containing the data of the maintenance work performed in the organization.

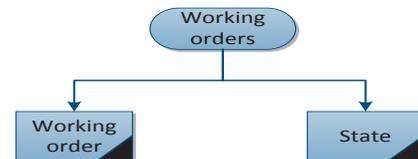


Fig. 17. Submenu of work orders from the submenu of the maintenance management of the GESP application

Human resources represent a submenu of the main menu of the application, consisting of two submenus, according to the structure illustrated in Figure 18, where is traded data of human resources for maintenance.

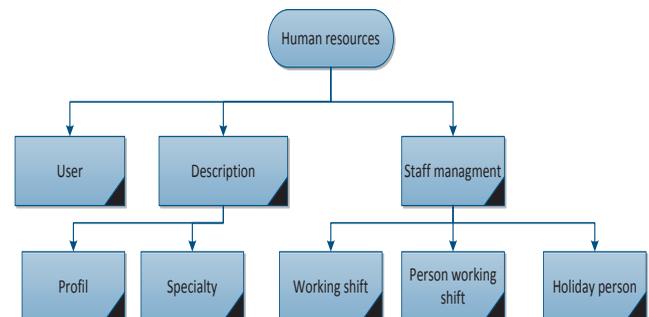


Fig. 18. Submenu of human resources of the GESP application main menu

V. GESP APPLICATION – FUTURE DEVELOPMENTS

The next challenge to be reached by the system is the development of a scheduling system in real-time, prospecting an automatic maintenance management, embedded with a failure prediction model based on dynamic modeling, where a historical analysis of the physical assets, the monitoring and the analysis of critical features will be made.

The next version of the proposed system (GESP) aims to manage maintenance operations with greater autonomy and

robustness, being the tasks selected automatically by the system and evaluated the alternatives with respect to human resources.

It is estimated that the maintenance condition assumes particular relevance in the following years as well as the application of e-Maintenance concept [13]. In maintenance condition sector several studies were performed, one of them highlights a prediction model applied to wind generators based on vibration analysis [14], or a failure prediction by the analysis of diesel engine exhaust gases without being required the historical of physical assets [15].

Due to the high degree of complexity of performing maintenance interventions, paper-based instructions are falling into disuse, being replaced by its equivalent in electronic version to be accessed by tablets or smartphones. The use of these devices opens doors to new horizons as the introduction of augmented reality in industrial environments [16], a technology that consists of superimposing virtual content to the real environment, which allows to display, on intuitive way, the sequence of instructions that technician must perform.

VI. CONCLUSIONS

The GESP is a CMMS in development, based on the concept of managing multi-events occurring and planned maintenance. The management of the same is done in accordance with available resources, being the priorities of operation established in accordance with the levels of AFNOR X60-010.

The application allows for systematic events of planned maintenance or control variables according to previously established parameters, and perform preventive maintenance events, in order to maximize the lifecycle of the physical assets and reduce maintenance costs.

Besides maintenance management of physical assets, the proposed system also allows the management of resources and outsourcing, from professional certifications to work shifts, as well as holiday periods and pre-established tasks.

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