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# Development of a Mobile and Web Based System for Maintenance & Repair and Asset Management

**Kenan KOÇER[1,*], Serdar BİROĞUL[2]**

[1]Department of Technology Development Zone, Kocaeli University Bimser Çözüm A.Ş., Kocaeli , Turkey
[2]Department of Computer Engineering, Düzce University Faculty of Technology, Düzce, Turkey
*Corresponding author: kkocer@bimser.com.tr

**Abstract** Enterprises (Operations) need IT-based systems in order to carry out repair and maintenance works. To ensure the proper functioning of the repair and maintenance system, it is necessary to obtain and store data on the operations that are carried out. Managers of the enterprise can reduce the cost of repair and maintenance by using the graphics and reports that they can produce with the system with the help of the recorded data. Thanks to maintenance& repair systems, cost and duration of maintenance and downtime are reduced, performance of the personnel is improved and the expected lives of the assets are increased. At the end, enterprises have a stronger position in terms of their future in their respective sectors and increased profitability. In this work, feedback coming from the customer has been reviewed and evaluated to make the maintenance and repair system more complete and compatible with the operations of the companies and institutions. Software has been improved in accordance with feedback taken from the customer. New models have been added. Integrations have been completed; and electronic signature application has been included. Thus, the work has aimed at making the maintenance and repair system, which is designed in line with the needs of the companies, compatible with new developing technologies. New modules have been added by developing new features in accordance with the changing customer demands. With these newly added modules, a user-friendly maintenance & repair system has been designed. Moreover, thanks to the new system, solutions have been developed to problems, which could pose serious challenges to enterprises in repair maintenance, such as cost increases, erroneous planning of resource-work program and increase in downtime due to delays in approval flows.

***Keywords:*** *maintenance & repair system, asset management, approval flows, resource calendar, analysis*

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## 1. Introduction

While establishing a company, first, a physical unit is created. A plant is established and necessary equipment is purchased. To initiate the production, raw materials and means of production are channeled into the process. The marketing and sale of the product which is obtained as a result of these processes make the continuation of the (production) cycle possible, enabling the regular operation of the plant.

In this situation, the company has to make planning of its resources and raw material in order to survive the competition and to grow. It has to closely follow resources and performance of the work force used in production and to keep these resources robust. Moreover, another very important factor in increasing the profitability of the company is keeping regular maintenance of the equipment bought and the plant established by the company in order to make production possible. At the end, the functioning of the plant's production capacity is maintained and its useful life is extended.

Behind the companies' success in achieving efficiency and increase in profitability there are asset management systems. Personnel responsible for the maintenance of the assets have command of work steps and related maintenance plans, which are necessary to realize the maintenance of the assets. Nevertheless, when the enterprise gets bigger and asset lines are extended, even experienced maintenance personnel cannot keep up with the work load.

This fact forces the company to employ new resources and personnel. As a result, additional costs are incurred. Moreover, transferring the knowledge of work steps and maintenance of instructions could create some problems. Asset management system is needed for documentation and management of these work steps and maintenance instructions

Company managers want to have information on the kind of maintenance work carried out daily, monthly and annually; the costs; the situation of the personnel management; downtimes for the machines and the system; and working hours of the employees. The graphics related to such information could be produced by the maintenance and asset management systems.

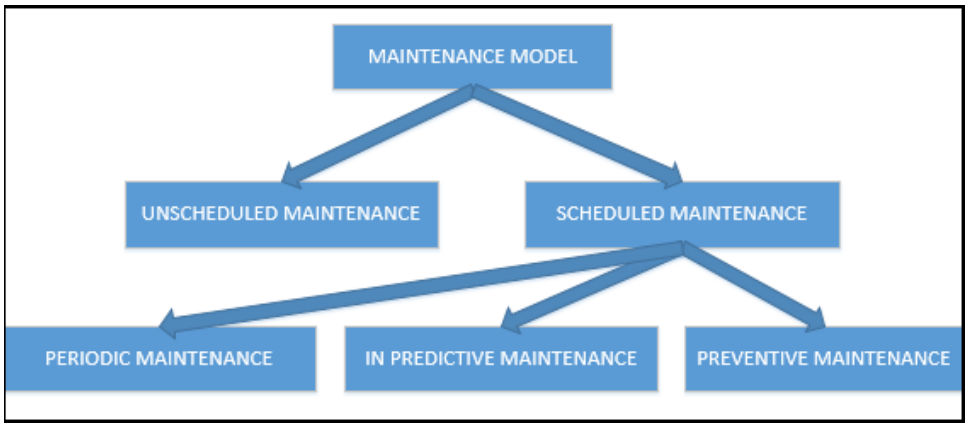



**Figure 1.** Diagram of Maintenance Model [4]

# 2. Maintenance Management

## 2.1. Concepts in Maintenance Management

Maintenance could be defined as all technical actions that could be taken to preserve a part in a condition/ way in which it can maintain all required functions during its life time [1]. Maintenance management can be defined as all managerial activities and responsibilities related to (maintenance) application such as determination of maintenance priorities & strategies, planning, control and supervision [2].

As a result of insufficient maintenance management, machines breakdowns occur; raw material is poorly managed; there could be halts in production process [3]. Delays and cancellation in the production can only be prevented by implementation of maintenance activities in a programmed and proper way [3].

In Figure 1, diagram of maintenance model is presented. Maintenance Models could be divided into two groups: scheduled maintenance and unscheduled maintenance. Unscheduled maintenance is the maintenance and repair activities carried out as there is a breakdown in the operation. Scheduled maintenance is the maintenance which is carried out in a controlled and regular manner, including all different types of maintenance activities.

In unscheduled maintenance, no maintenance service is provided until equipment is broken down. This is the most primitive maintenance system. Maintenance is done after equipment fail to operate. On the other hand, in scheduled maintenance, maintenance activities are carried out in pre-determined intervals while the equipment still performs its function.

Preventive maintenance is to make the machines work-resistant by eliminating basic factors that may give rise to malfunction. Pre-diagnosis of the problems and their elimination before they come to surface is called preventive maintenance [5].

In predictive maintenance, working conditions and characteristics of the equipment are taken into account. In line with a program (Schedule), some parameters are measured and controlled without interrupting the production processes. Possible malfunctions in the equipment are examined according to the results obtained. If a fault is determined, required spare parts are obtained and production is interrupted, repair and maintenance are done within short period of time and production is promptly continued [6].

Total Productive Maintenance (TPM) can be defined as productive maintenance where involvement of all personnel is foreseen, and which is carried out through activities of small groups. It necessitates involvement of all resources and equipment within the Organization (enterprise). Operators are responsible for the maintenance of the equipment which they operate. It is an approach to maintenance where malfunctions are prevented by increasing efficiency of the equipment. It is a concept developed by Japan Institute of Plants Maintenance, which aims at zero-fault and minimum production loss for the equipment [7].

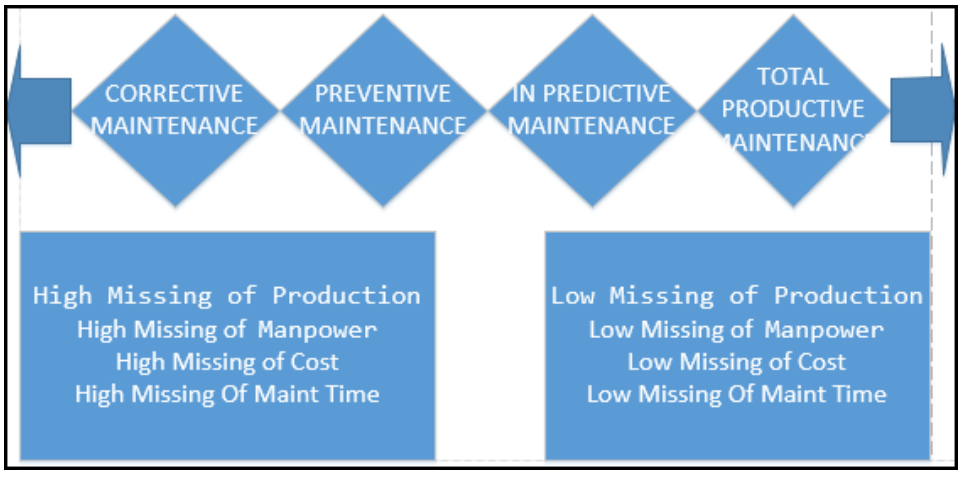



**Figure 2.** Different approaches to maintenance

#### 2.1.1. Comparison of Maintenance Methods

Among these different methods of maintenance, unscheduled corrective maintenance is the most expensive one, causing highest loss of workforce and production as well as longest repair time. Predictive maintenance planning is a method, of making predictions about the health of the machines by tracking the tendencies, in time, of the measurements of physical parameters [8]. Total productive Maintenance is the most effective and developed approach to maintenance. Total Productive Maintenance is a management system aiming at zero accident, zero error, and zero unplanned downtime, by enhancing employee's knowledge and skills, protecting the equipment in the best possible way, tracking all maintenance and repair activities in a computerized environment and taking the necessary measures [9]. In Figure 2, different methods of maintenance are compared.

### 2.2. The Role of the Computer in Maintenance System

A maintenance management system should keep record of workforce, requests, history and list of equipment, and e equipment tree), list of components and location information, existing material and warehouse information, preventive maintenance and measurement plans and costs & expenses.

Maintenance software should:

- Be in harmony with coding structure and hierarchy adopted within the company.
- Be able to generate reports in required formats and enable development of that formant in time.
- Be extendible and flexible together with the company's business.
- Be usable in portable equipment.
- Be optimized with different databases and servers.
- Require less work force for data entry and use of the programs; causing less waste of time as much as possible.
- Be able to work on different operating systems.
- Have different levels of authorization in the program (reading/writing, viewing etc).
- Keep records of the history of equipment and breakdowns
- Enable creation of time schedules for maintenance; personnel assignment, and material stock control should be maintained; It should be possible to monitor costs and the root reasons of the failures; it should enable calculations for downtime (outage time) and cost of improvements.
- Keep records of data in relation to asset management, on company's equipment, sub-equipment asset tree list of spare parts and guarantees.
- Include, in relation to stock management, functions such as management of spare parts, equipment and materials used in maintenance follow-up of orders and stock-acceptance procedure

## 3. Maintenance & Repair and Asset Management System (Boys)

Maintenance & repair and asset management system enables a healthy execution of the maintenance of the equipment and machines existing in a company and recording of related activities. It also makes it possible to monitor usage and stock control of materials and spare parts used during these activities. It records information with regard to working time of the personnel and other resources, labor time and labor costs. It manages and records purchasing processes for spare parts and materials in decrease.

As previous commercially used Maintenance & repair and asset management system and existing one are insufficient in meeting customers' demands, it has been updated in line with the findings of this work. New developments have been made in line with customer demands. In this context, new modules and functions have been added. The program has been made more user friendly, meeting the demands of an increasing number of users. Developments are continuously made as if it were a living organization.

### 3.1. General Features/ Characteristics of BOYS

- It is possible to generate all kind of information and reporting, which are requirements of sector specific standards such as those set by ISO and QI.
- Table for preventive maintenance is prepared; spare parts and work force to be used are determined; when time for the maintenance comes, a work request is automatically produced.
- Calibration of equipment used could be monitored by BOYS.
- Predictive maintenance systems and applications, which are being used, can be managed.
- Work request can be sent directly to mobile devices by "BOYS Mobile" and all activities related to work requests can be managed on the go.
- All fixed assets in the enterprise can be managed by BOYS.
- Data on maintenance costs, labor cost, materials cost and total costs can be generated in terms of machines, machine groups, consumption point, and work request, in all currencies.
- BOYS can establish a decision support system for usage of internal and external resources.
- Within determined intervals, the resources of the materials and labor force are determined for preventive maintenance and maintenance planning is made.
- As maintenance work is carried in accordance with some standard maintenance directions, the possibility of making mistakes is diminished. Efficiency of the work increases and an important information repository is created with regard to maintenance management in the management of the operation (enterprise).
- The performance of the maintenance personnel is analyzed both in terms of departments and in terms of individual employees.
- Special equipment (electric motors, pumps etc) in the operation (enterprise) can be monitored and maintenance information related to this equipment can be reported.
- As the preventive maintenance plans can be followed in a live and healthier manner, production

planning personnel are helped in their work to improve planning of the production.
- Detailed information on the past maintenance of the machines can be produced through records kept historically in terms of machines and machine groups.
- With the help of reports produced, it is possible to have a better understanding of the expected lives of the machines.
- By reports generated according to types of faults/breakdowns, it could be possible to identify the frequency of breakdowns and chronic faults.
- It could be possible to monitor maintenance according to the type of the work (electrical, mechanical etc).
- The ratio of preventive maintenance to contingent maintenance (unscheduled) can be monitored with BOYS.
- The annual usage of spare parts and materials can be monitored. In this way minimum levels of necessary stock for spare parts and materials can be identified.
- The amount of spare part and materials used can be monitored in terms of consumption points and machines.
- By using most common analysis more than 4000 graphics can be obtained with BOYS. With this information, it is possible to make all kinds of analysis for the operation (enterprise).

## 3.2. BOYS's Benefits to the Operation (Enterprise)

During the reviews made at the managerial level at the companies using BOYS, compared to the insufficient systems of maintenance & repair, the following has been observed:
- 15-30% savings in maintenance costs.
- 15-20% savings in the cost of spare parts stock.
- 25% decrease in downtime.
- 40-80% reduction in the number of breakdowns.
- Reduction in the intervention time to the failure.
- Opportunity to analyze information on maintenance activities in detail, on demand.
- Positive image of the company in audits in terms of maintenance.
- Healthier planning and management of maintenance budget.
- Opportunity to plan maintenance work.
- Higher quality production due to better maintenance controls.
- Reduction in production costs as a result of reductions in maintenance costs.
- Better identification of training requirements for the maintenance personnel.

## 3.3. BOYS's IT (Computer) Infrastructure

BOYS Maintenance & Repair Management Program is a computer-assisted and mobile and web-based application. The system is designed in a way so as to cover all maintenance unit and activities in an organization. It facilitates the application of Total Productive Maintenance, providing infrastructure for computer-assisted measurement and improvement process.

## 3.4. BOYS's System Architecture

### 3.4.1. System's Scope

BOYSWEB Asset and Maintenance Management System is a web-based system, with a "Service-Oriented Architecture (SOA)" on "Net framework", working over "Internet Information Services (IIS)". Service-Oriented Architecture is a system design understanding, which enables independent services and applications, to become integrated systematically [10]. Services in SOA Technology could be compared to the pieces of a jigsaw puzzle. Replacements among the services and functional changes are as flexible as assembly and disassembly of pieces of a puzzle or addition of new pieces. If the processes were united as a block, rather than being fragmented, it would not be easy to add and remove new parts and to hold them together [11]. Microsoft SQL Server and Oracle data bases can be used as system data sources. In Limited use, client tools, such as process design (for maintenance work request and buying processes) and system management, can access to the server over the services through Port 80. In this way, there is no need to make additional systemic adjustment to the clients (such as opening a port).

System architecture is composed of three layers: framework(data layer), middle layer and client layer[12].

Communication among these three layers and their contents are shown in Figure 3.

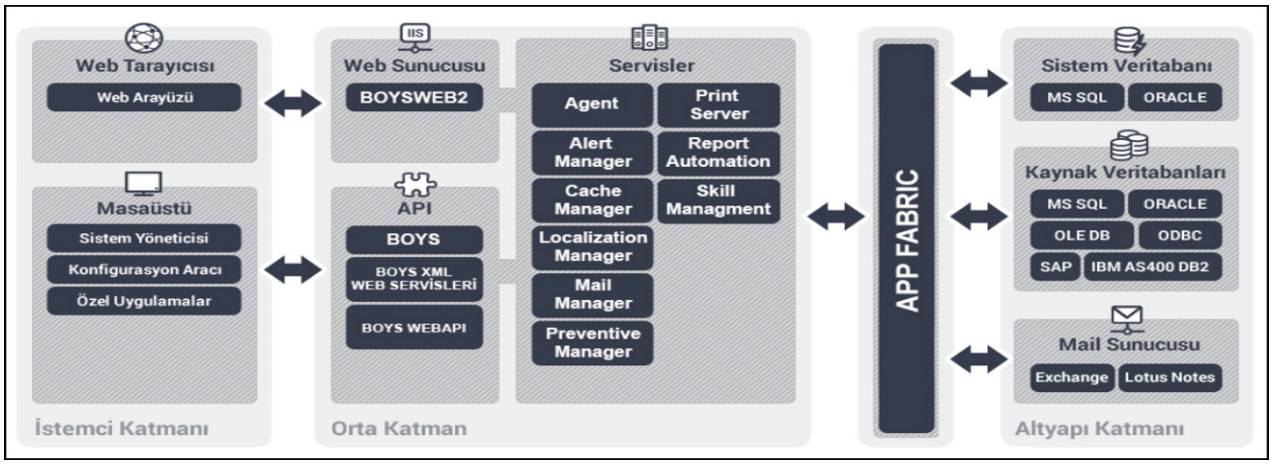



**Figure 3.** BOYS's System Architecture

#### 3.4.1.1. BOYS's Framework Layer

It consists of system database and existing operational systems. It is made up of three parts: system database, source database and mail server.

- System database: It is the database which will be used by BOYSWEB2 system. Microsoft SQL or Oracle database can be used.
- Source databases: System can access to the existing databases and use the related data in the maintenance (work) order and/or in the material management system. The Following are among some of these databases: MS Sql, Oracle, Ole Db, Odbc, AS 400 DB2, SAP, LOGO Tiger, LOGO Unity, NETSIS and Xml Web Services. In addition to that, it is also possible to configure external data connector.
- Mail Server: this is the service by which mails are sent over the system. If the mail server supports MMTP, POP3I, this is sufficient.

#### 3.4.1.2. BOYS's Middle Layer

This is the layer comprising server's components. In addition to all services of BOYSWEB2, IIS Web Server and BOYSWEB APIs are also working in this layer. Services are communicating among themselves and with framework layer. It provides services to Web servers and APIs. Web server and APIs function as an intermediate unit between client and the services, providing an insulated structure.

The general function of BOYSWEB2 Services is explained below:

- Agent: It performs scheduled maintenance and some small data transfers.
- Alert manager: it is responsible for performance of alert jobs adjusted by user in the application.
- Cache manager: it is responsible to save much-used data over the server and make it ready for use.
- Localization manager: it enables the interface of the application in a multilingual structure.
- Mail manager: it is responsible for sending e-mails of the application.
- Preventive manager: It is responsible for scanning the system regularly, to generate work request from among periodical maintenance definitions for which the necessary maintenance time has arrived.
- Print Server: It is responsible for sending work requests and work orders waiting in printer queue to related printer.
- Report automation: it is responsible for automatic distribution of reports determined by the user.
- Skill Management: it is responsible for automatic assignment of personnel to work orders in line with competence/ability.

#### 3.4.1.3. BOYS's Client Layer

Client layer is composed of applications giving service to the end-users and administrator-users. It has two sections: Web applications and mobile applications

- Web: it is a web-based program to which end-users can access through their web-browsers.
- Desktop: Windows-based desktop applications which are made up of management tools of BOYS application

- System manager: it is the management tool by which daily records of the system tools can be monitored and managed
- Configuration Editor: It is the management tool by which application usage parameters are set and monitored
- Workflow studio: it is the work-flow management tool, with a limited use license, by which work request and buying processes are built.
- Server Configuration Editor: It is the administrator's tool by which database connection is adjusted
- AppFabric Configurator: A cache is a shared memory area that can be accessed / set by any program that knows the required configuration. Each cache area is presented for use on its own unique name. Regions are structures within caches, which are fields that can carry additional data [7]. Over the regions, you can do all standard operations that you can performs with caches, you can reach the object of your choice via key. Besides these features; All objects within the region can be searched for thanks to fields which called tags, which can keep string type data [13]. AppFabric Configurator is an AppFabric helper administrator tool that creates deletes and manages cache and region on Boys.
- ExcelImport: it is the administrator's tool that transfers data from Excel to the target table in accordance with a pre-determined structure.

### 3.4.2. BOYS's User Interface

It provides users with a practical, easy and fast user-interface through its application based on HTML5, CSS3 and ASP.NET. Moreover, it provides service to its users in every platform with its native applications compatible with IOS and Android mobile operation systems.

### 3.4.3. BOYS's Configuration

When the companies choose to use this system, first, it is necessary to prepare a test environment in customers' servers. In this test environment, speed and stress tests are applied. These tests are expected to identify possible problems in case users start using the program, leading to an overloading of the servers.

The problems which are detected are solved and the system becomes hassle free. The companies are required to set up servers whose specifications are pre-determined for the Boys' installation and proper operation in test and live systems. The recommended configuration features required for the Test and Live System are shown in Table 1 below.

### 3.4.4. BOYS's Architectural Advantages and Limitations

Windows Server AppFabric is developed for web applications and layer (layer) services. It provides features such as hosting and caching. Windows Server improves the usability of the operating system. Thanks to its hosting feature, Windows Server AppFabric, includes additional

administrator's tools for Internet Information Services (IIS), Windows Process Activation Service (WAS) and .NET platforms. Thanks to caching feature of Windows Server AppFabric, it provides an extended platform for .NET and ASP.NET applications which require high performance. AppFabric can be downloaded through installation wizard or by using command prompt parameters. Moreover, it also makes the scaling of .NET applications possible with lower costs by merging the memory capacities over more than one computer. Since BOYS is working over AppFabric Architecture, it can adopt to the high accessibility and scalability scenarios.

As it is a web-based, (web-enabling) application, it can be reached from anywhere. Application works on the new generation browsers without any problem. Moreover, native application support is available for IOS and Android operating systems as well. Since BOYS is an application based on .NET it can only work on Windows operating system

## 3.5. Connections between BOYS's layers

The connections between BOYS's layers are described in detail in Figure 4.

- Presentation Layer: This is the layer where data is presented to the end-user in a comprehensible manner. In this layer, there are BOYSWEB2 interface and native mobile applications. This layer is connected to services and business layers.
- Services: This is the layer which works in the background and assumes the functions of data distribution and communication.
- Business layer: This is the layer where work-logic of the application is placed. It has connections with data, entity and framework layers.
- Data layer: This is the layer where access to data base is maintained and transactions are managed. It has connections to database, framework and communication layers.

**Table 1. Minimum requirements for BOYS's Test and Live systems**

| Test System Requirements | |
|---|---|
| Server processor | Min Intel Xeon Quad-core processor |
| Server Ram | 16 GB |
| Server Operating System | Windows 2008 or above 64 Bit |
| Web Server - Framework | IIS7 or above, Microsoft .NET Framework 4, AppFabric |
| Database | MS SQL Server 2008 or above |
| DB Disk Space | 100 GB |
| Application Disk Space | 50 GB |
| Live System requirement | |
| Server Processor | Min Intel Xeon 4 Quad-core processor |
| Sever Ram | 32 GB |
| Server Operating System | Windows 2008 or above 64 Bit |
| Web Server – Framework | IIS7 or above, Microsoft .NET Framework 4, AppFabric |
| Database | MS SQL Server 2008 or above |
| DB Disk Space | 500 GB |
| Application Disk Space | 200 GB |

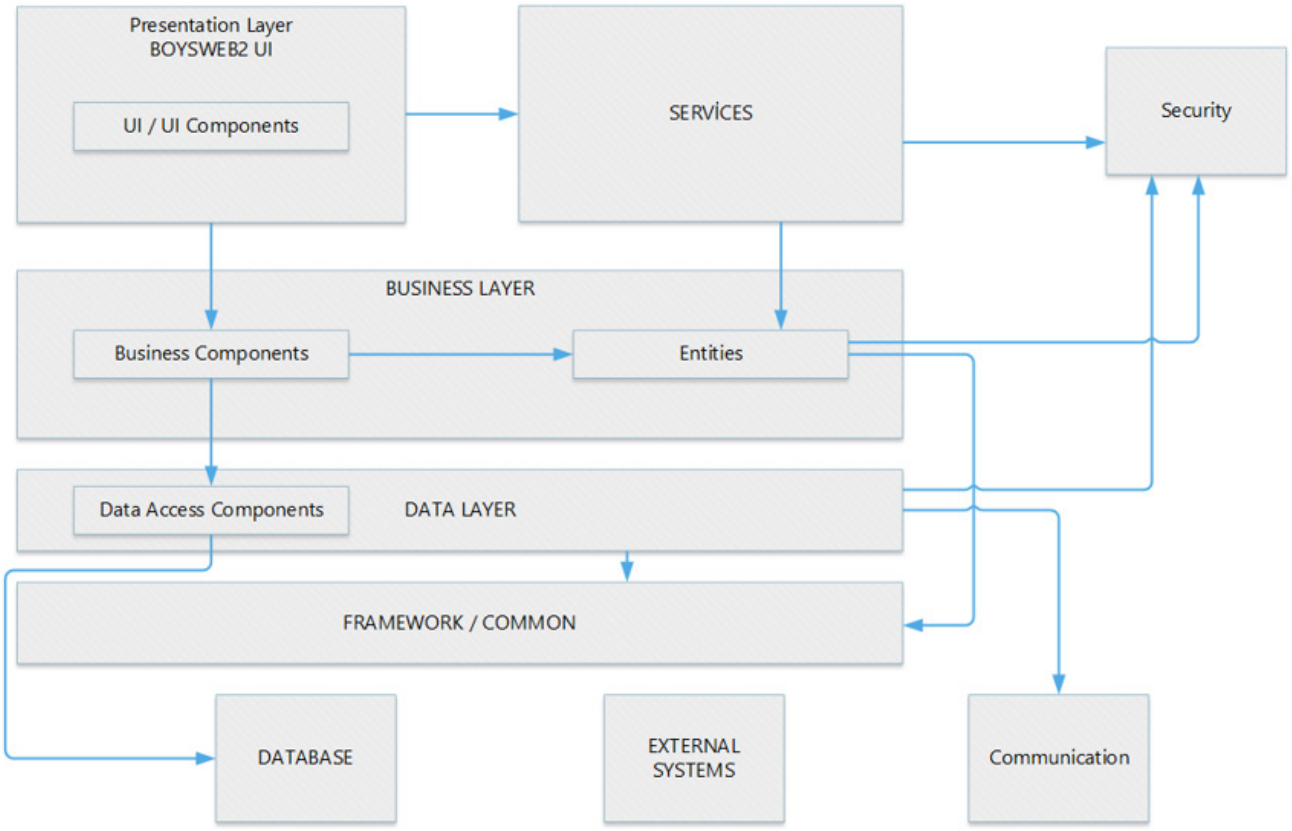



**Figure 4.** Boys Layers

## 3.6. Boys Database Diagrams

There are many databases and tables used in BOYS program. Since it is not possible to explain all of them here, a sample database and table will be explained.

### 3.6.1. Work Request

Maintenance operators report the failures, which they notice, through work requests. Maintenance risks, notes, preventive measures and the documents related to this failure are also attached to the record. “bc_wok_request” is the table where work request record containing the data submitted is kept. In this table, the number of the work request, notification date, explanations related to the request and similar data is kept in relation to the main record.

There are additional tables containing information such as place of maintenance, maintenance risk, preventive measures etc. The main table “bc_work_request” and the table showing the details “bc_work_request_mntpoints ” are interconnected by a”1-n” relations. A work request may contain more than one maintenance places. Association is made, as presented in Figure 5, with the help of a talepid (secondary key) by establishing “1-n” relations.

### 3.6.2. Work Order Database Diagram

“bc_work_order” is the main table of work orders. The information related to work orders are kept in this table. “bc_work_order_directions” is the table in which work steps of the periodic (Scheduled) such as work order number, work order year, status of work order, reporting date and hour of work order, completion date and hour are kept. Since there could be more than one work steps in a work order, “1-n” relationship is established. As a secondary key “isemriid” is used. Connection network is established, as shown in Figure 6, by establishing a1-n relations with the help of a secondary key (isemriid).

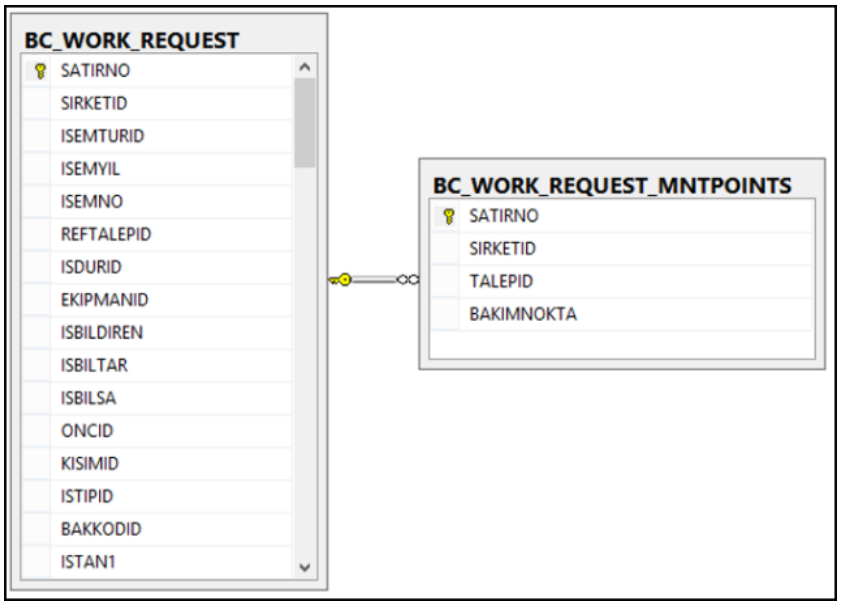



**Figure 5.** Work Request Database Diagram

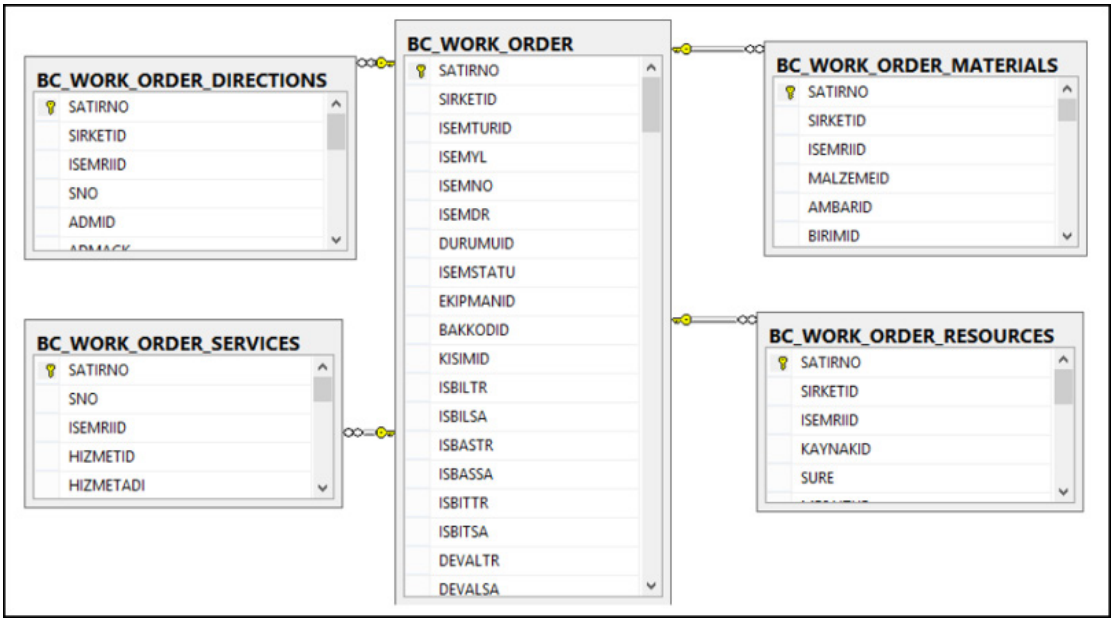



**Figure 6.** Work Order Database Diagram

## 3.7. Boys Distribution Diagram (Deployment View)

Deployment Diagram is the perspective that is revealed by the physical architecture of the hardware over which the software will be working. Figure 7 shows how BOYS system is working.

## 3.8. Main Modules of BOYS Maintenance Management System

### Asset Management System

There are 3 breakdowns in BOYS Asset Management definitions: Operation (enterprise), consumption points and sections. One company could be composed of more than one operation (enterprises). Under Assets Menu, these operations (enterprises) are listed, and then these enterprises are further divided according to consumption points. Consumption points are divided into sections. For example there are buildings within a block. And there are flats inside each building. And there are goods/articles inside each flat. And articles could be divided into infinite number of parts and could be defined in the system.

If we want to define a refrigerator in the system, it is possible to define B Blocks as Enterprise (operation); 3rd Building as consumption point, 2nd floor as section and the refrigerator as the asset. Then we can define the motor of the refrigerator as a sub-asset. Hence, once a failure related to the motor of the refrigerator is identified we can open a work related to this motor.

It is possible that one could be demand to change the consumption point or section information of an asset or to move an asset to another section. In order to provide the user with ease of use, a hierarchical form, called Asset Tree is designed. Asset Three enabled the assets to be located in a much easier way. In Figure 8, the assets in the Assets Tree and breakdown of the assets are shown.

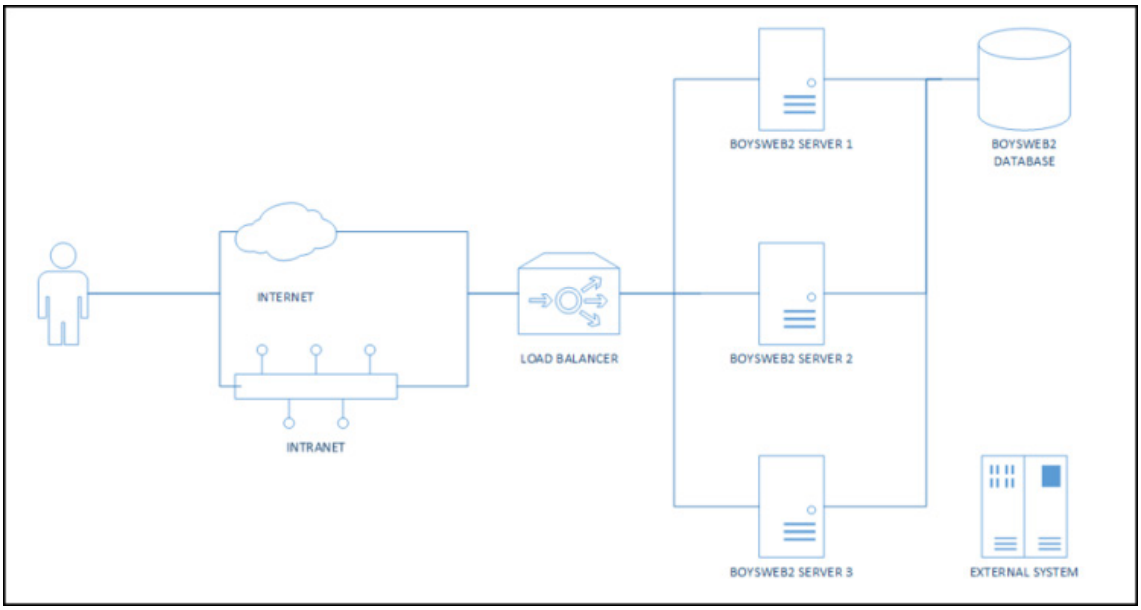



**Figure 7.** BOYS Distribution Diagram

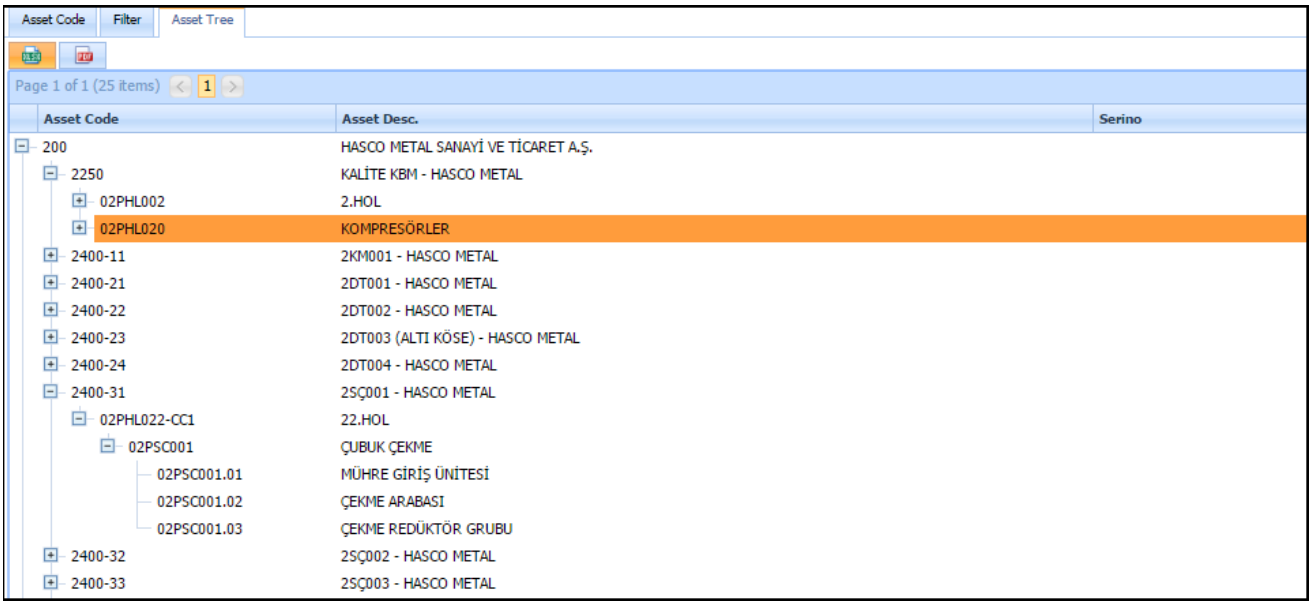



**Figure 8.** Display of BOYS's Asset Tree

**Maintenance Management**

BOYS maintenance management system enables the carrying out of different types of maintenance for the equipment defined in the system, such as breakdown maintenance, preventive maintenance, predictive maintenance and scheduled maintenance. These maintenances are opened in the system as work orders.

Before a work order is generated for breakdown maintenance, a work notification is opened. This notification informs us that there is breakdown maintenance in equipment and that whether this has caused an interruption in the production. This notification is called work request in BOYS system.

The work request becomes a work order after it is approved by the Operator. Before scheduled and preventive maintenances are notified to the system, it is necessary to keep the record of information on steps, by which the scheduled maintenance will be completed.

Primarily, work steps are identified and introduced to the system. As the work steps will be executed under a plan, these work steps are attached to a maintenance plan and incorporated into a "package".

The date, hour and periods or measurements of the scheduled maintenances are defined into the system. This is called periodic maintenance definition. Maintenance plan is added into the definition of the related maintenance. Work order is produced for the maintenance for which the foreseen time period elapsed or the counter has shown the pre-determined measurement. This work order is displayed in the screens of the operators that will carry out the work.

**Work Requests**

Work request can be accepted as the first notification given for completion of a work. After an examination, if it is determined that the work has to be done, work order is created. The work notifications can be either made by maintenance unit or operation unit or other units.

**Work orders**

In BOYS maintenance management system, activities related to maintenance are defined by generating work orders. Work orders menu is the most commonly used part of the system. Related unit, type of the maintenance, its date, priorities, duration of the work, labor force, cost of the maintenance, employees in charge, whether it necessitates halt of production, used materials and detailed explanations related to the work are all mentioned in the work order.

**Maintenance Directions**

BOYS Maintenance Directions Menu is created in order to standardize and facilitate the works to be done, and to relay information to personnel about the special jobs that will be carried out. Quality Management System work directions can be created under this menu. In this way, system is working in harmony with the Quality Management System.

**Scheduled Maintenance - Work Steps**

Due to the characteristic of the Scheduled Maintenance, primarily, work steps are created. While creating work steps, documents reflecting the previous experiences of the personnel are also used. Documents obtained from the suppliers of the assets are also utilized.

**Maintenance Plans**

After the selection of the related work steps from the work repository, maintenance plans are created. Such a structure provides some conveniences to the user. A single plan can be generated for assets for which same plans are applied and this plan can be associated with all related assets.

**Preventive Maintenance Definitions**

Scheduled Maintenance definition step is the one in which asset relation is established. While making the scheduled maintenance definitions, maintenance plans generated in the previous step are utilized.

# 4. Software Development for Maintenance and Asset Management System

## 4.1. Development of Periodic (Daily) Control Module

For some equipment existing in the companies, daily maintenance would be made before a halt is observed and/or breakdown maintenance is necessitated. Control of this equipment could be of vital importance. Failure of the equipment could result in the breakdown of a whole line of equipment. Recovery of the costs faced during the downtime could be very difficult. Even the failure as a result of non-observance of the daily maintenance in this equipment could risk the life of security of the working personnel.

For example, daily measurements are made over the sensors located on the steam boiler. If certain values such as temperature, moisture, pressure are measured above and below the tolerance values, work order with urgent code is generated by the system. This process could be held in the BOYS System.

However in cases where there is no such equipment like steam boilers which could be considered under risk groups, for each equipment, individual work steps and definitions of measurements are separately determined and work orders are generated.

This situation creates disorder in the system. Operators have to filter urgent work orders from among all other types of work orders. The working plans for personnel are tried to be set in accordance with these work orders.

This situation makes the follow-up of the works complicated. Failure to notice some work orders may result in non-execution of some daily work orders. The companies may have negative feedback about the non-compliances with regard to job safety risks.

Figure 9 shows the location of the menu for control module under maintenance management and its bottom layers. Daily control mode is made up of control template, and the control forms which are triggered by this template.

The purpose for development of this module is the collective generation of work orders for daily maintenances which could be generated by utilizing more than one maintenance plan for more than one equipment. Work steps are generated for each equipment under each plan in daily control forms. The information of duration for work steps is entered. Work orders are automatically generated for problematic work steps.

If measurements have to be made in equipment maintenance, first, types of measurements are defined in the system. Then, measurement locations on the equipment are determined. The environmental conditions for measurements are specified. And the measurement packages, into which standard measurement levels are entered, are defined.

The measurement packages are selected for the equipment. While daily controls are made, if measurements are outside the determined levels, the problem notifications are made in the system. Taking the measurement location of the related equipment as the basis, related operators are asked to go to this location.

As a result, damages and defects are determined by carrying out daily controls. These damages or defects are repaired before equipment brakes down, without interrupting production system. With the help of the reports generated from the system, the work force and the costs are calculated for the equipment concerned. The information on the frequency of damages, defects and failures are collected and presented to the management.

### 4.1.1. Daily Control Template

In the daily control template, there is a page where all templates are listed. There is also a second page which is designed for making changes and generating new templates. Figure 10 illustrates the page prepared for listing all templates.

While daily control template is being generated, the information on assets for which control will be made is entered under “assets tab”. The information on the work steps that will be executed on this equipment are entered under “maintenance plans tab”. Figure 11 shows the screens in which information on measurement packages, work steps and equipment will be entered in the daily control template.

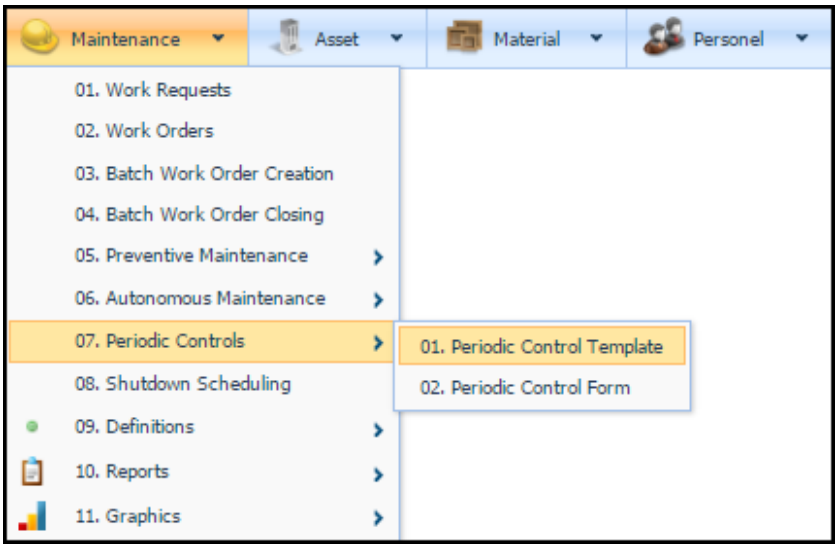
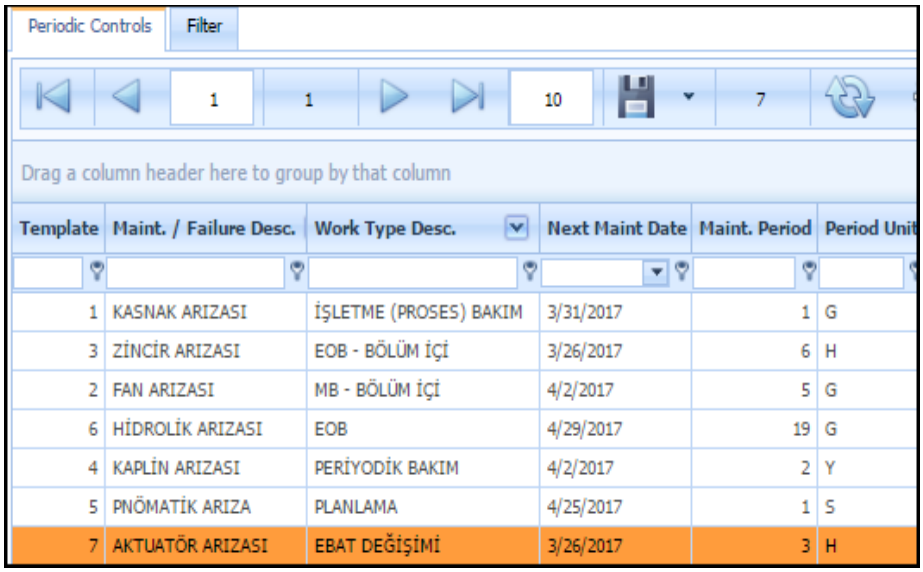



**Figure 9.** Daily Control Module




| Template | Maint. / Failure Desc. | Work Type Desc. | Next Maint Date | Maint. Period | Period Unit |
|---|---|---|---|---|---|
| 1 | KASNAK ARIZASI | İŞLETME (PROSES) BAKIM | 3/31/2017 | 1 | G |
| 3 | ZİNCİR ARIZASI | EOB - BÖLÜM İÇİ | 3/26/2017 | 6 | H |
| 2 | FAN ARIZASI | MB - BÖLÜM İÇİ | 4/2/2017 | 5 | G |
| 6 | HİDROLİK ARIZASI | EOB | 4/29/2017 | 19 | G |
| 4 | KAPLİN ARIZASI | PERİYODİK BAKIM | 4/2/2017 | 2 | Y |
| 5 | PNÖMATİK ARIZA | PLANLAMA | 4/25/2017 | 1 | S |
| 7 | AKTUATÖR ARIZASI | EBAT DEĞİŞİMİ | 3/26/2017 | 3 | H |

**Figure 10.** Daily Control Template

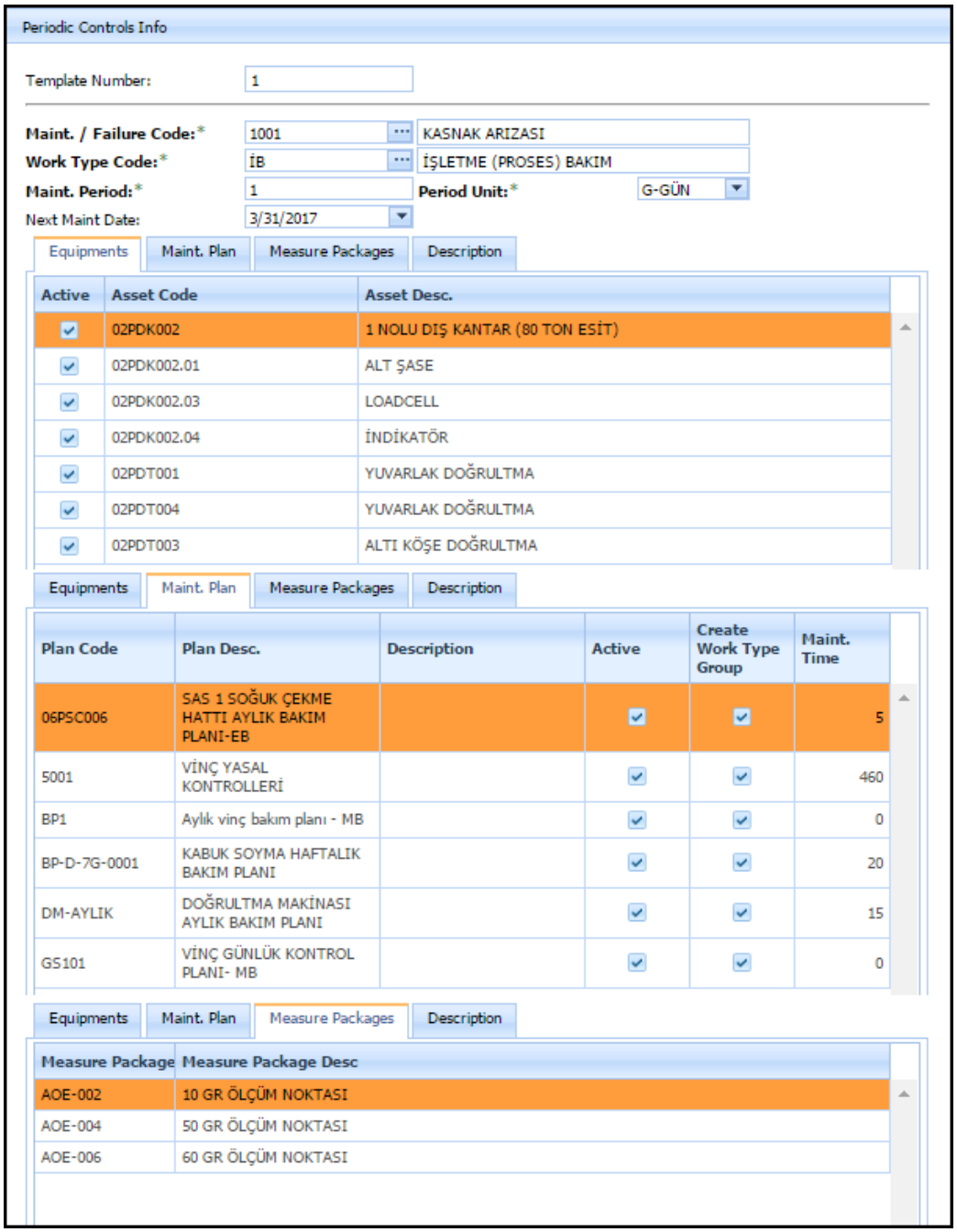



**Figure 11.** Filling up "Daily Control Template"

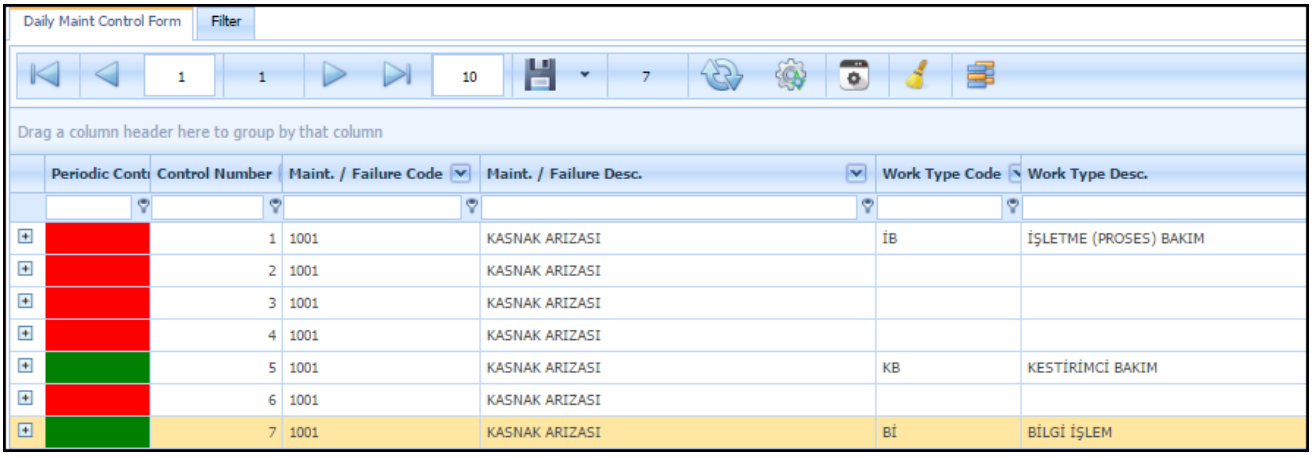
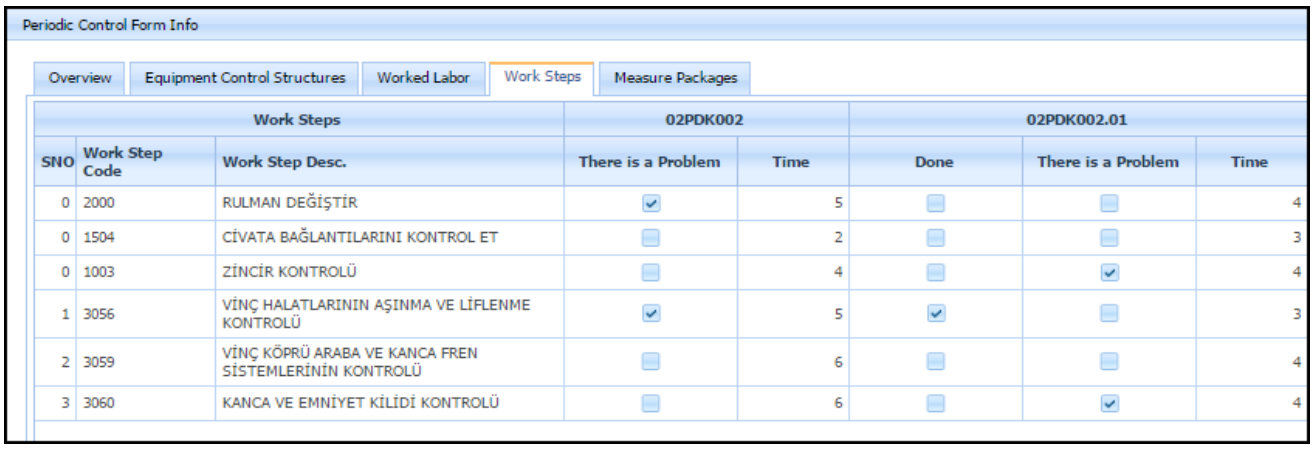



**Figure 12.** Daily Control Form Main Screen




| Work Steps | | | 02PDK002 | | 02PDK002.01 | | |
|---|---|---|---|---|---|---|---|
| SNO | Work Step Code | Work Step Desc. | There is a Problem | Time | Done | There is a Problem | Time |
| 0 | 2000 | RULMAN DEĞİŞTİR | ☑ | 5 | ☐ | ☐ | 4 |
| 0 | 1504 | CİVATA BAĞLANTILARINI KONTROL ET | ☐ | 2 | ☐ | ☐ | 3 |
| 0 | 1003 | ZİNCİR KONTROLÜ | ☐ | 4 | ☐ | ☑ | 4 |
| 1 | 3056 | VİNÇ HALATLARININ AŞINMA VE LİFLENME KONTROLÜ | ☑ | 5 | ☑ | ☐ | 3 |
| 2 | 3059 | VİNÇ KÖPRÜ ARABA VE KANCA FREN SİSTEMLERİNİN KONTROLÜ | ☐ | 6 | ☐ | ☐ | 4 |
| 3 | 3060 | KANCA VE EMNİYET KİLİDİ KONTROLÜ | ☐ | 6 | ☐ | ☑ | 4 |

**Figure 13.** Control form Work Steps List

### 4.1.2. Daily Control Form

The real transactions are executed over the daily control form. Generated templates are transferred into daily control forms and dropped into the lists. Operators intervene into the maintenance work in accordance with these lists.

In the Daily Control Form, there is a screen where all control forms are listed. There is also a second screen which completes and closes the control forms that have been produced. The screen of the daily control forms shown in Figure 12 is the screen where all forms are listed.

The screen shows control forms according to maintenance/ failure codes and dates. The status of the control form, whether it is open (pending), closed or canceled are shown with different colors.

In Figure 13, Work steps belonging to the equipment in the control form are listed in the order of application. The Operator who will close the form will notify the system through this form about work steps that are completed and work steps in which problems are encountered.

The same logic is also valid for measurement packages. Measurement packages are listed in terms of equipment to which they are applied in the "control form measurement packages" tab. Information about the abnormal values that have been measured are transferred to the system in this screen.

The operator who carries out the maintenance changes the status of control form to "closed" Beginning and finishing dates are inserted. Assets are directly transferred to the control form from the Maintenance Template. If maintenance is applied to additional equipment or to a sub-equipment these assets are added to the control form by the Operator.

Information on working personnel, time periods, shifts, time actually used in maintenance (in minutes) are all entered in "working personnel" tab. In this way, information on the cost of maintenance could be obtained.

Work steps defined in the maintenance plans of the control template are transferred into "work steps" tab of the control form.

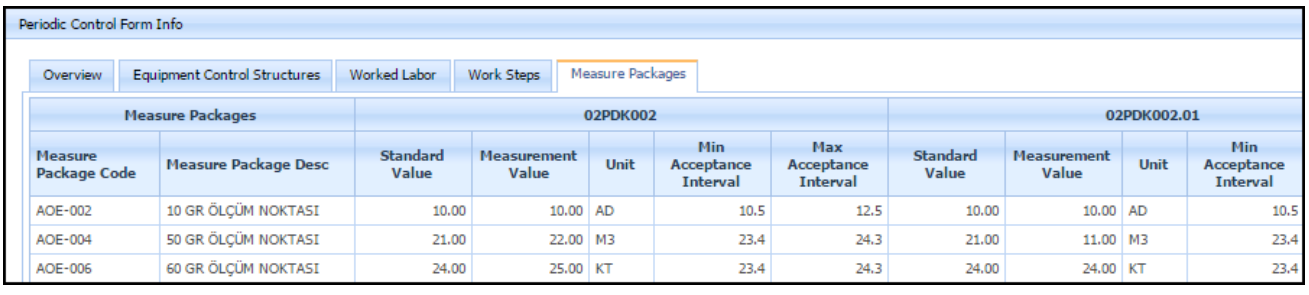
Equipment list appears in the upper part of the screen, while work steps are indicated in the side section of the screen. In this way, it is possible to enter the data on whether a work step is done. Operator who enters all this data closes the form. Therefore, creation of word order for the equipment is triggered based on the work steps of same equipment with the problem.

Figure 14 displays control form measurement package tab. In this tab, in the upper section equipments are listed while in the side section measurement packages are listed. This table shows the measurement packages used for the equipment. Standard values and values measured at the measurement point are entered into the system.

Then, work order is generated for measurements in which values are outside the range of standard values. Operator carry out maintenance repair activities in line with the work order generated, and then work order is closed by Operator.

There are two ways for transformation of control templates into daily control form. First one is by using the "new control form" button placed under the control template. Second way is the activation of the daily control service after necessary adjustments are made.

The display of the screen where daily control adjustments are made is shown in Figure 15. With this screen adjustment is made for the day and time at which template is required to be transformed into a form. Without any daily intervention, control templates are transformed into control forms and are shown in the screen of the operator.




| Measure Packages | | 02PDK002 | | | | | 02PDK002.01 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure Package Code | Measure Package Desc | Standard Value | Measurement Value | Unit | Min Acceptance Interval | Max Acceptance Interval | Standard Value | Measurement Value | Unit | Min Acceptance Interval |
| AOE-002 | 10 GR ÖLÇÜM NOKTASI | 10.00 | 10.00 | AD | 10.5 | 12.5 | 10.00 | 10.00 | AD | 10.5 |
| AOE-004 | 50 GR ÖLÇÜM NOKTASI | 21.00 | 22.00 | M3 | 23.4 | 24.3 | 21.00 | 11.00 | M3 | 23.4 |
| AOE-006 | 60 GR ÖLÇÜM NOKTASI | 24.00 | 25.00 | KT | 23.4 | 24.3 | 24.00 | 24.00 | KT | 23.4 |

**Figure 14.** Control Form Measurement Package List

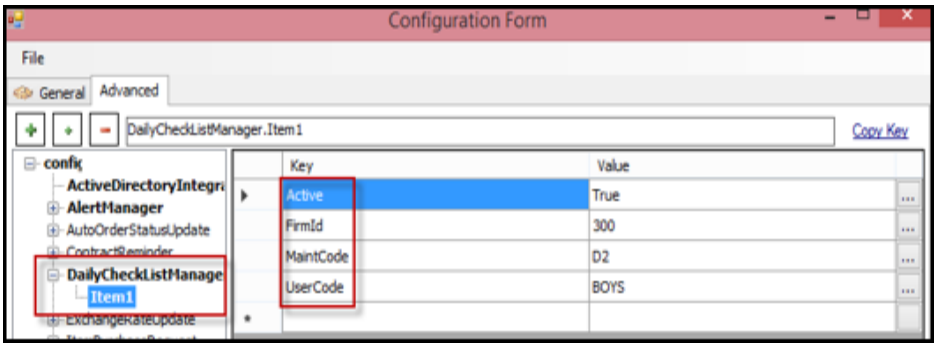



**Figure 15.** Daily Control service Adjustment Screen

### 4.1.3. Values and Graphics

Maintenance operators complete the control and maintenance work that came to their attention as a result of the creation of a daily control template and they close the control template. Automatic work orders are generated by the system for the equipment for which problems are faced during implementation of the closed control template.

As a result of the new work orders generated, operators carry out new maintenance work, they change the status of the work order to "closed". Number of resources used in the completion of these works, and the labor hours are calculated

If equipment is halted due to failures, downtime is also calculated. Total maintenance time is calculated. Total time that has passed form the notification of the work until the completion (Maintenance +intervention time) is calculated. The data which is calculated according to locations of the equipment (consumption points) is sent to the managers as e-mails. Graphics Screen of the most commonly used analysis is displayed In Figure 16.

MTBF is described as the mean number of life units during which all parts of item perform in their specified limits, during a particular time interval under stated conditions. MTBF is a basic measure of reliability for repairable items[14].

Mean Time To Repair (MTTR) and Mean Time Between Failures (MTBF) are calculated. Graphics are created according to time, data collected in terms of Equipment, section, consumption point, enterprise (operation) user, type of the work, maintenance/failure code etc. This Graphics screen is called MTBF/MTTR Analysis Screen. The screen of distribution graphics of MTBF-MTTR is presented in Figure 17.

According to (MTBF=Working Time/Number of unscheduled halts) formula, it is assumed that during the 8$^{th}$ month of 2016, the total number of maintenance works initiated was 1228. If it is assumed that during 10 of this maintenance work the machines stopped, MTBF is calculated as 122.8 units.

Here, the company would like to decrease the number of non-scheduled stops in order to increase MTBF value. It can achieve this target, by making its daily controls regularly using the periodic control module. It is necessary to plan the maintenance and make the controls through scheduled maintenance module.Therefore, equipments which work in better condition won't cause abrupt halts as their maintenance are regularly carried out.

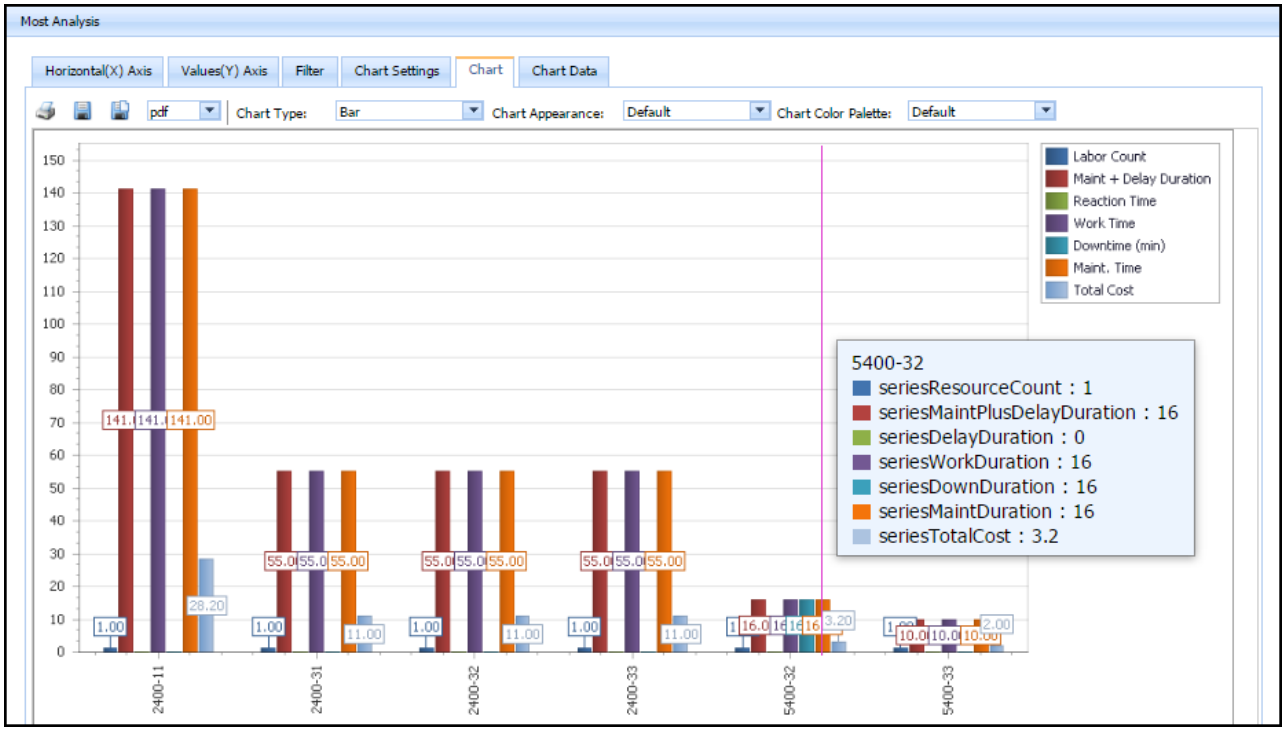



**Figure 16.** Graphics of Control Forms used in terms of draw-off points (consumption location)

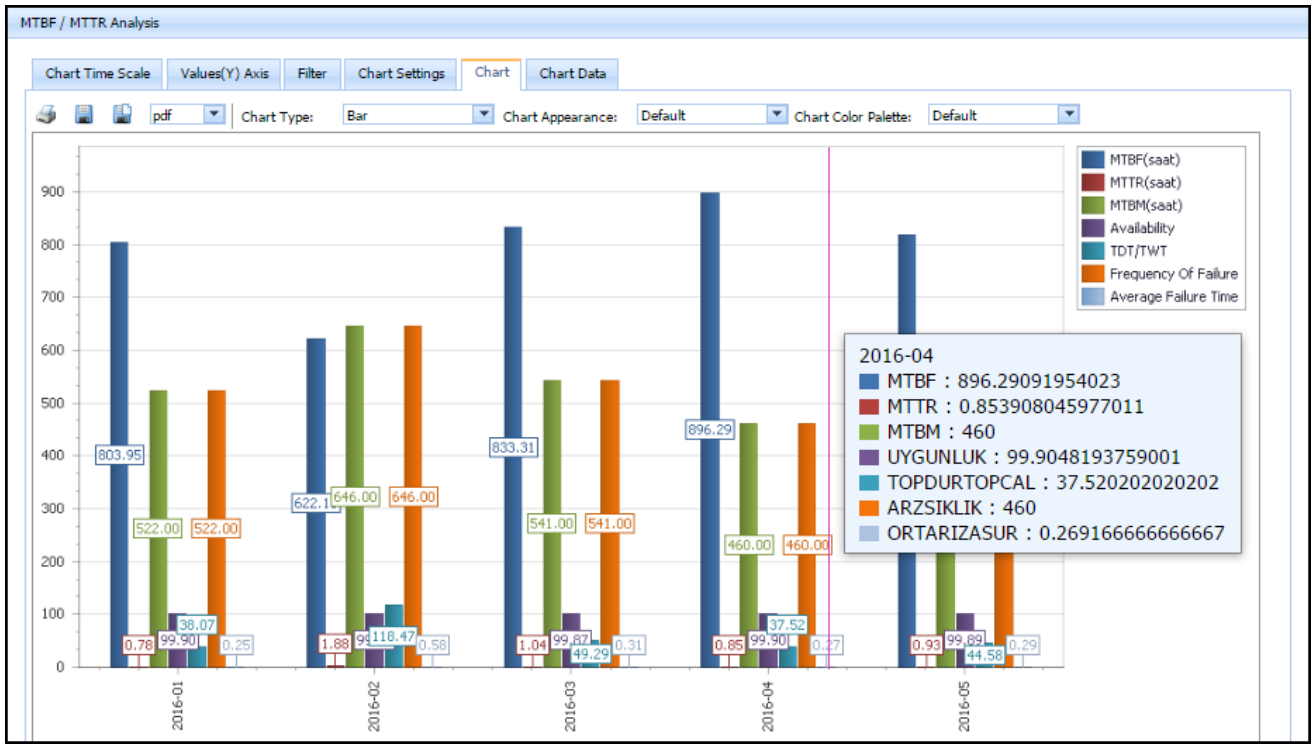



**Figure 17.** Montly MTBF-MTTR Distribution Graphic

## 5. Conclusion

Company's maintenance management work processes have been improved as a result of development that was made. Standardization in maintenance management has been achieved together with newly developed work processes. Before this module, there had been disconnection between operators and maintenance personnel from time to time.

Thanks to the new system, disconnection has been avoided. As a result of the study, critical equipment has been identified. Work steps that will be applied regularly in the maintenance have been defined. The measurements necessary for the maintenance of thee equipment and their locations have been recorded.

In this way, all these information is integrated under a systematic structure. For any personnel responsible for the maintenance, it is possible o obtain the required data about any asset in a fast and proper way. Moreover daily maintenance definitions are made by standardizing and transferring data on work steps, maintenance plans, measurement standards, measurement packages.

It is also possible to create a common language between Operator and maintenance personnel when failures are notified. Scheduled maintenance for which time has arrived has been notified to the responsible managers with e-mails. When time has arrived for scheduled maintenance, automatic work order has been generated.

Management of the measurements has been facilitated and has become manageable with the automatic transfer of maintenance measurement data into the work order under the new management system. Hereby, the problems of non-execution/negligence of scheduled maintenances, which showed up during ISO controls, have been averted

With the costs analysis made on the basis of maintenance/failure codes and failure reasons, it is possible to determine the areas where highest cost incurred due to failures. In this way, cost calculation (accounting), which is of critical importance for the enterprise is also clarified.

With assets history report, it is possible to obtain information on daily controls and maintenance plans previously applied to the asset. Moreover, information on the measurement packages and the high value measurement locations are obtained.

It could be possible to get the list of work steps where problems are identified. Hence, it is possible to make cost calculations for any equipment in accordance with the reason of failure. The time period during which a breakdown/failure is repaired is calculated. When the course of action to repair the failure is identified, important information for improvements can be reported.

It is planned to add new modules and features to BOYS in line with the ideas expressed by the customers. For example, there are work request and work order modules in the mobile version of BOYS.

In these modules, users can generate work requests in order to notify the operators of the failures, which they notice, over their mobile devices without using computers. Maintenance operators, who will repair the breakdown and carry out the maintenance, on the other hand, can close the work orders without having access to computers.

They can submit to the system information on work steps, labor and material costs by using their mobile devices. However, users cannot manage the materials over the mobile version.

They can neither see data, the number of warehouses, types and quantities of materials left in the warehouse, quantities of materials used, pieces of material used and left etc. nor make any management decision via mobile devices.

To enable material management via the mobile device without entering the computer environment, "Materials "management and counting modules will be added to

mobile version. With inclusion of these modules, users will be able to use their cameras on mobile devices as barcode readers. They can enter the warehouse and make their cameras read the barcodes of the materials to speed up the stocktaking process.

Via mobile devices, materials will be transferred to work order. The entry commands for the diminishing material and the exit commands for the materials to be transferred to the work order will be executed via mobile devices. User will be able to execute material transfer commands for the transfer of materials between warehouses.

Customers who are using Purchase Module in the BOYS system demand new materials for diminishing stocks. Requested materials are approved by inventory managers. Price offers (quotations) are requested from these companies from which these materials are to be purchased. Incoming proposals are collected on a screen and sent to the approval of the purchasing specialist.

Purchasing specialists evaluate and approve these offers and transform them into purchase orders. Inventory managers complete the purchase flow by placing the materials in the warehouses according to location-shelf-section information and by giving the final approval via BOYS. Companies that use BOYS want to ensure that these approvals have some legal value and they want to know when these approvals are made in the related process by making use of the print-outs whenever it is required. In this direction, BOYS will be provided with electronic signature and timestamp feature in line with this requests. Thus, since the E-signature has the same legal validity as the signed signature, all approvals will become official.

Total Productive Maintenance is an all-inclusive, efficient asset management system which is fully supported by the company's top management and which is realized by the involvement and activities of employees, especially those at the operator level, and by the improvement groups created for this purpose. Companies using BOYS demand that an autonomous maintenance module should be added to the system in order to realize Total Productive Maintenance. Therefore, an autonomous module for this purpose will be added to the system in the future. BOYS will continue to develop new modules, functions and features in order to enable companies to manage all of their activities related to maintenance processes under a single system.

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