

## THE FUNCTIONING OF E-MAINTENANCE SERVICES IN SELECTED DEVICES OF THE BUILDING INDUSTRY

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### **Abstract:**

In this article the existing solutions within the scope of e-maintenance services for machines used in the construction industry have been presented. The major factors influencing the quality of e-maintenance services from the point of view of the service recipient, i.e. the user of a machine, have been identified. Owing to the conducted analysis, it was also possible to formulate auxiliary assumptions for creating and modifying a technology for equipment remote diagnosis and monitoring.

**Key words:** *maintenance, diagnostics, digging machine, prevention, repair, network, ICT*

### **INTRODUCTION**

The correct and stable functioning of machines and equipment is undoubtedly one of the major elements in properly operating production enterprises [6]. Over many years in the 20th century, the increasing costs and enhanced competition forced continuous development of theories, methods, technologies and techniques used to ensure the unreliable functioning of machines and devices in a plant. Currently, three main approaches to maintenance can be distinguished [4]:

- reactive maintenance,
- preventive maintenance,
- predictive (proactive) maintenance.

In the reactive approach, appropriate measures of maintenance teams are undertaken in a reaction to disturbances in production processes. This approach is the oldest one, and at present it is not frequently applied. The preventive approach goes back to the 1940s [2]. In this approach, the centre of gravity was shifted from repair activities to preventive ones. Preventive activities include chiefly inspections, maintenance works and overhauls, which are carried out according to an established schedule. Particular tasks are carried out according to a schedule fixed at the beginning, so numerous activities may be undertaken whether or not they are really necessary. This problem has been solved in the predictive approach, which has been developing since the 1970s. This approach is aimed at forecasting potential problems in production processes. It is based on appropriate algorithms and certain parameters of the technical facilities used. On the basis of forecasts, measures are taken in the right place and at the right time [5].

The development of the applied maintenance concepts is accompanied by a growing number of information that needs to be processed. The correct course of maintenance processes may require integration and access to a large amount of data. At this point, the e-maintenance concept can help. This concept combines the development of operating technologies with the fast development of communi-

cation and information technologies [2]. It might be said that e-maintenance is „a concept of maintenance in which particular activities are undertaken on the basis of updated information about the resources, which is systematically obtained via the Internet” [1].

E-maintenance services are provided mainly in situations when the technical means are scattered over a large area or access to them is difficult [3].

In Poland the market of building machines is developing dynamically as the demand for construction services grows. A large number of building investments is caused mainly by the influx of European funds to Poland as well as by new commercial investments. It is not only domestic producers that are visible on this market, but chiefly representatives of the biggest global concerns engaged in the construction of machines. Modern building machines available on the primary and secondary markets are equipped with increasingly advanced management support systems and employ hi-tech ICT technologies.

### **AN OVERVIEW OF SELECTED SOLUTIONS APPLIED IN BUILDING BRANCH MACHINES**

#### *Global e-service by Hitachi*

One of the companies which offer continuous monitoring of work parameters for their products is Hitachi. The above mentioned services include such products as: digging machines, fork-lifts, wheel loaders and tipper trucks.

The solution proposed by the company is named Global E-Service and allows managing the possessed equipment by means of any computer, in any location and at any time. Within the framework of this system's functioning, particular devices send data on selected aspects of their work to the server. Communication with the server takes place via satellites or GSM (Global System for Mobile Communications). The system operation diagram has been presented in Fig. 1.

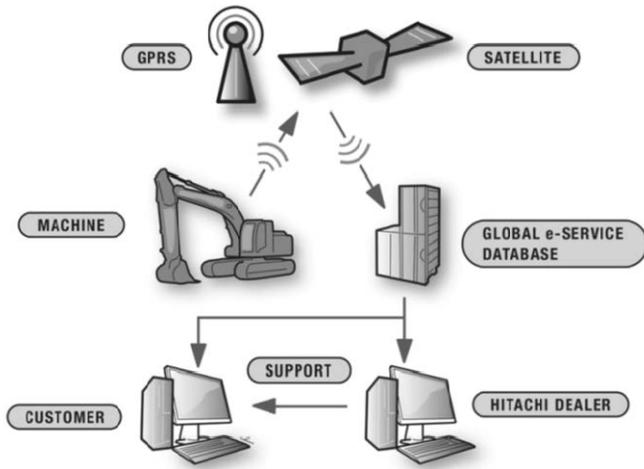


Fig. 1 The flow of information in an e-service [7]

The machine sends all the information through satellite links or GSM (GPRS – General Packet Radio Service) to the central server. The company dealer taking care of a particular machine has access to this information via an internet connection. Selected information is also sent to the machine user's account. In the event additional data is necessary, the customer can communicate with the service team.

Having been processed, the transmitted data is made available to the customer through a relevant website. The available data includes among others:

- hours of the machine's work,
- engine's work temperature,
- pressure in the hydraulic system,
- consumption and level of fuel,
- CO<sub>2</sub> emissions,
- recommended terms of inspections and service works,
- geographical data concerning the work of particular machines.

The customer does not have to incur additional costs for global e-services in the guarantee and post-guarantee period. The whole cost of the service is included in the initial price of a purchased machine. Within the framework of this service, Hitachi service teams in a given country have a possibility of monitoring the machines purchased or allocated to work in this country. Each machine is equipped with an appropriate communication module, which sends data related to its work to the server. In general, data transmitted within the system can be divided into two groups:

- data systematically relayed in real time,
- data transmitted once every 24 hours.

Real-time data includes information on the machine's geographical location as well as codes of „fatal errors”. All the other data, in a form of a cumulative update package, is sent via automatic connection during night hours. The instantly reported error codes allow the service team to immediately assess the situation as soon as a failure appears. However, the service team employees do not read the codes or undertake any action on their own. According to the procedure, in the event of a failure, the customer should contact a relevant service team, which only then can, by means of the possessed software, initially diagnose the machine on a remotely controlled basis and next, take further steps.

Two types of communication modules are used for communication:

- module based on satellite communication,
- module based on GSM systems.

The module based on a GSM system is a newer solution, in line with the current tendency to replace older satellite modules with the latest GSM ones. Solutions based on satellite communication are not only more expensive, but their use involves the following problems:

- problems with communication reliability,
- problems with limited capacity of the buffer collecting data to be sent to the server.

The first of the above listed problems occurs if a machine works in the so-called dead point or in closed production halls. Ideal communication is ensured only in an open area. In the event there is no communication, the machine continues to collect data in a special buffer and sends it after connecting to the server. However, thus obtained data can only be viewed with a considerable delay. Failure to communicate with the server for a few days results in the data buffer overload and suspension of the whole communication system. In such a case it is necessary to reset the module, which can only be done by a specialized service team that must be provided with direct, physical access to the machine.

Despite the fact that a large amount of data is gathered in the system, customers have access only to its small part via the website. In particular, this is data concerning the geographical aspects of work (workplace location, mileage) and general parameters of the machine's work (engine's work time, percentage time of the machine's relocation in the overall time of its work, fuel consumption, level of fuel in the tank etc.). More detailed data is available only to the service team employees. Although the values of many parameters are collected by the producer, they are not analysed with regard to symptoms which might herald a failure. Also, no predictive solutions which enable forecasting a failure or taking preventive measures are applied. However, the collected data is viewed and analysed by the service team members before scheduled inspections of particular machines. This allows the scope of service activities to be properly planned.

The global e-service system also plays the role of a guard making sure that the machine is used by the customer in a proper way. Any work undertaken in the case of signalled irregularities is recorded and can be thoroughly analysed so as to identify damage which could have been avoided thanks to an immediate response and stopping the machine's work.

#### CareTrack firmy Volvo

All the machines manufactured by this producer, such as: wheel loaders, digging machines, articulated haulers and power graders, provide a possibility of using CareTrack service. This service is available free-of-charge for a period of 3 years from the date of purchasing a new machine. It is provided via satellite communication and GPRS, and data readout is enabled through the internet. Owing to the service, it is possible to monitor such information as: machine's location, fuel consumption, time of work, distance covered by a machine as well as reports on failures, warnings about the improper use or remote diagnostics of machines. A diagram of CareTrack functioning has been presented in Fig. 2.

A machine (B) connects to a navigation satellite (A) in order to pinpoint its location. At the same time, it transmits operational data via GSM/GPRS (C), and if it is not possible,

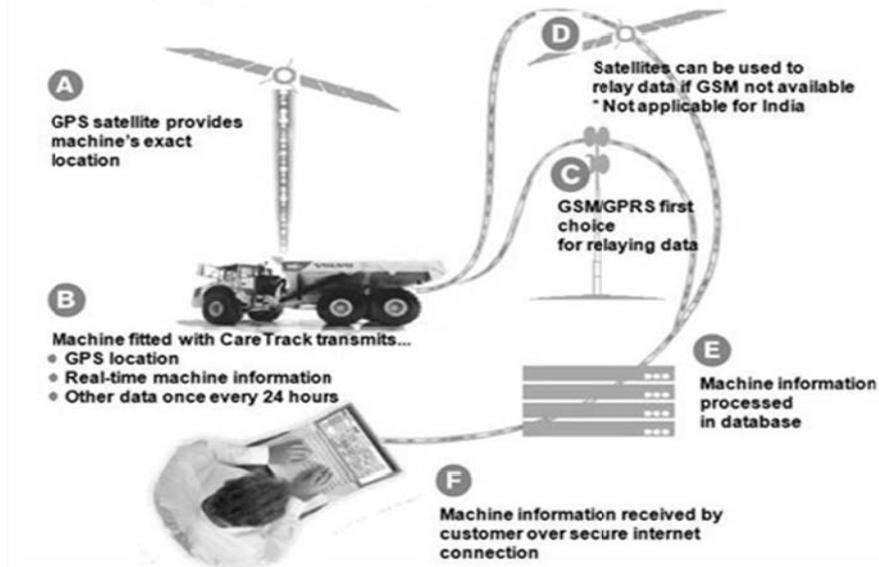


Fig. 2 The principle of operation of the CareTrack service [10]

it makes use of satellite links (D). A part of data is transmitted in real time and less important data – once every 24 hours. The information is stored on Volvo servers (E). It can be available to service teams and users via the Internet (F).

As after a period of 3 years the service is chargeable, it is possible to buy a subscription including 2 different levels of monitoring: CareTrack Basic – which is a basic version of the system, and CareTrack Advanced – having all possible functions. The basic version is recommended for simpler, smaller machines.

The basic package includes the following functions:

- machine’s location relayed in real time,
- machine’s work time, transmitted in a form of daily, weekly or monthly reports,
- alarm warnings in a form of e-mails or SMS messages, if the machine leaves the established work area or if it works beyond the pre-set time,
- a reminder of necessary inspections in a form of e-mail or SMS messages and website access to the records on inspections,
- support for spare parts purchase planning in a form of reminders of their replacement.

The advanced package contains the basic package functions as well as:

- information on fuel consumption transmitted in real time, which is available in a graphic form on the website,

- daily, weekly or monthly reports on the use, efficiency and productivity of a machine, sent electronically or available on the website,
- transmission of alarm warnings about serious machine’s failures in a form of e-mails and sms messages,
- remote readout of machine’s parameters by the service team, which allows more effective planning of inspections and repairs of the machine at the place of its work,
- periodical reports by the service team, containing remarks on the machine’s use.

*Komtrax Plus by Komatsu*

Komtrax system produced by Komatsu consists of typical elements, such as: establishing and tracking of the machine’s position by means of GPS and GIS systems, monitoring of fuel amount and the time of machine’s work [11]. Apart from these standard functions, the Komtrax service also contains a very advanced system for vehicle health monitoring – VHMS.

VHMS (Vehicle Health Monitoring System) is aimed at maintaining the machines and vehicles in proper condition via satellite links as well as a wireless network and the Internet. The service operation diagram has been presented in Fig. 3.

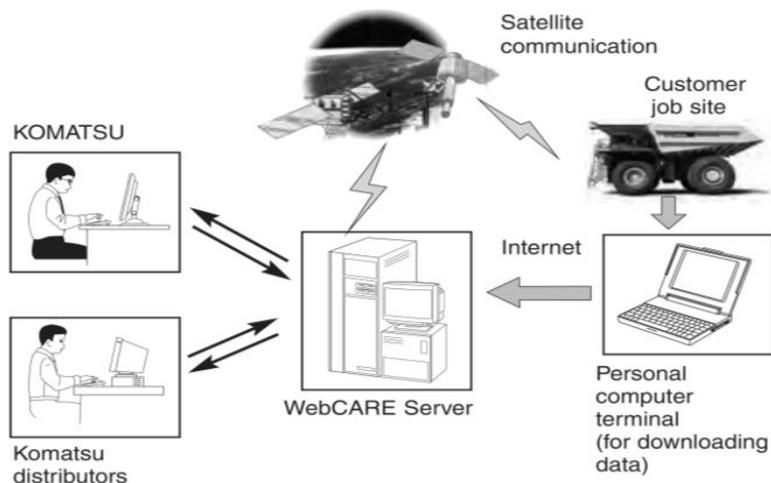


Fig. 3 An ideographic presentation of VHMS operation [8]

Data from a machine is transmitted to the server via a satellite, from where it is sent by the Internet to the service team and users. It is also possible to send data directly to the user's computer by a wireless Hi-Fi network, owing to which it is not necessary to come up to the machine in order to connect the computer with the machine's interface. From a personal computer the data can be sent via the Internet to the central database server.

Fig. 4 presents a simplified diagram of WHMS operation, in which the following modules have been distinguished: a monitoring system on the machine's board (1), a communication system (2) and a WebCARE database system (3).

The monitoring system collects data from sensors located in machine's crucial subassemblies. The data contains among others: engine's work parameters, transmission system's parameters, vehicle body data, error codes, payload data. Data gathered by the sensors is stored in the VHMS controller, from where it can be transmitted to WebCARE servers via satellite communication or to the computer by means of a Wi-Fi network.

The system enables applying the proactive and predictive approach to machine maintenance. The controller systematically collects and transmits information concerning e.g. cooling water temperature or the maximum, minimum and average temperature of oil. Even if the parameters keep normal levels and cannot cause the engine's overheating, it is possible to detect non-typical symptoms by comparing them with reference parameters in a control group, by means of statistical tests. Moreover, the archival and latest data make it possible to predict the terms of inspections and repairs. This allows preparing the necessary parts before the fixed time. Owing to the collected data, it is possible among others to determine the lifetime of particular subassemblies and to plan their inspections on the basis of work, and not time parameters. For example, it was possible to extend the time of engine's work from 12000 to 20 000 hours between inspections. Similar measures are taken

for the transmission system, where the load of clutch and gearbox is measured on the basis of the frequency of changes as well as the real time of their work, and not the work of the whole machine.

**EVALUATION OF SOLUTIONS**

Currently, many companies offer their products with e-maintenance services, which are required to provide necessary information on the machine's location, work and malfunctioning of particular components. However, the most important function of e-maintenance is to provide information on the machine's condition and enable its analysis by service teams in order to predict failures, which in turn will allow taking preventive measures.

The presented e-maintenance systems, which are used by leading companies engaged in construction materials production, have a similar scope of offered services, but a detailed analysis and interviews with service teams managers reveal considerable differences between them. Table 1 contains the collected information on Hitachi, Volvo and Komatsu.

The analysis of the way a machine communicates with the server allows stating that all the systems make use of satellite communication. However, it should be stressed that this manner of communication depends on the satellite's location in relation to the machine, which means that the flow of information is not continuous. At present, only the CareTrack system offers a GSM connection, which enables continuous communication with the machine. On the other hand, Komatsu makes it possible to communicate via Wi-Fi, which ensures greater freedom in the obtaining of machine's work characteristics.

All the companies subjected to analysis enable users to download information they need by logging in a special system. Volvo and Komatsu also inform the customer of the machine's significant parameters by sending an SMS message and an e-mail. This is definitely a more reliable and

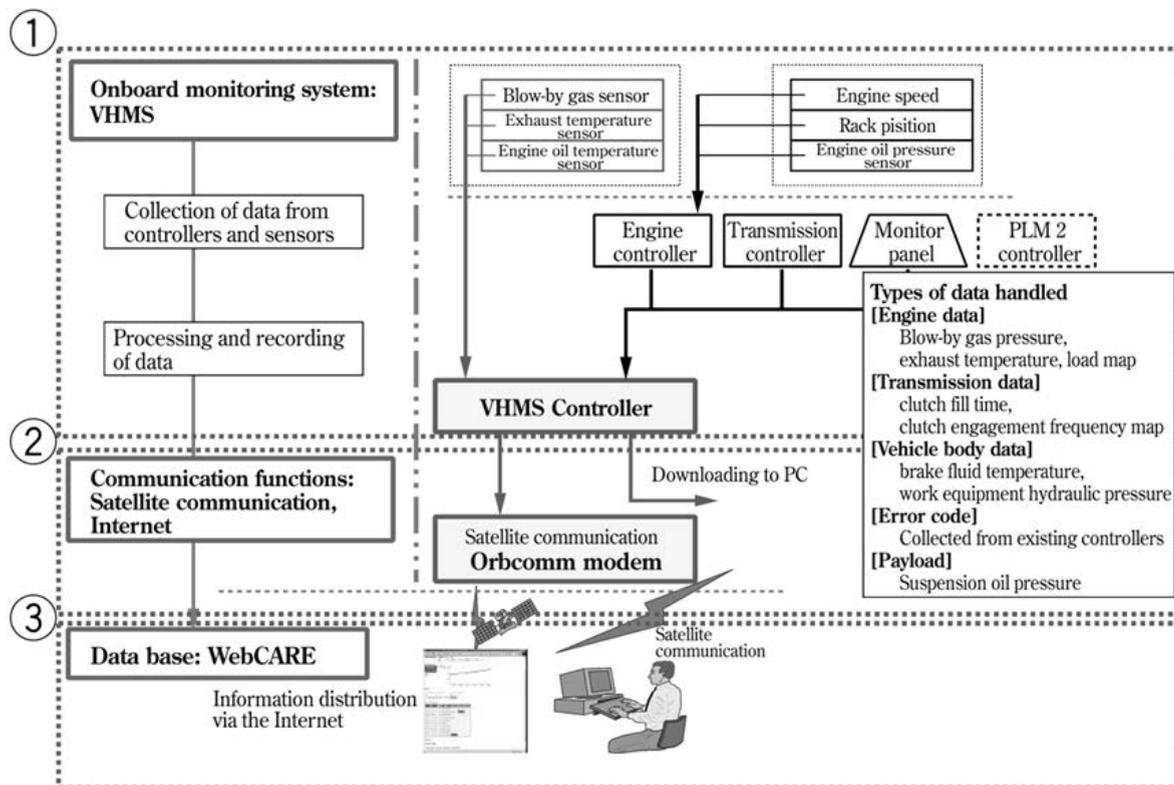


Fig. 4 VHMS conceptual diagram [9]

**Table 1.**  
**A list of e-maintenance services provided Hitachi, Volvo and Komatsu**

Activity	Method	Hitachi	Volvo	Komatsu
Communication with machine	GSM	0	1	0
	Satellite	1	1	1
	Radio	0	0	0
	Wireless (Wi-Fi)	0	0	1
Manner of information transmission to the user/service team	SMS	0	1	1
	e-mail	0	1	1
	logging in the system	1	1	1
	Telephone	0	0	0
Type of transmitted data	Location	1	1	1
	Vehicle route	1	1	1
	Speed of moving	0	0	0
	Road travel time	1	0	1
	Fuel consumption	1	1	1
	Protection against fuel loss	1	1	1
	Error codes	1	1	1
	Engine work time	1	1	1
	Engine work parameters	1	1	1
	Parameters of hydraulic assembly work	1	1	1
	Parameters of wheels and steering system work	1	1	1
	Use of data for the forecasting of failures	0	0	1
Data analysis for prediction and prevention of problems	Use of data for the forecasting of preventive measures	0	0	1
	Use of data for the purposes of inspections	1	1	1
	Use of data for failure removal	1	1	1
	Location	1	1	1
	Route	1	1	1
	Speed of moving	0	0	0
	Road travel time	1	0	0
	Fuel consumption	1	1	1
Customer's access to data	Protection against fuel loss	1	1	1
	Error codes	0	1	1
	Engine work time	0	1	1
	Engine work parameters	0	1	0
	Parameters of working assembly work	0	1	0
	Parameters of wheels and steering system work	0	1	0
	Message by means of mobile devices	0	0	1
	Information on failures and anomalies available to service teams	Pop-up alarms in the system	0	0
Other ways of automatic messages	0	0	0	
Free-of-charge service	Reported by customer	1	1	1
		1	1	1

effective transmission of information to the customer, providing the user with a possibility to immediately react to a problem with the machine.

The type of data transmitted from a machine to the service team in all the analysed systems is very similar. This is information about a broad spectrum of the machine's functioning, starting with the machine's location and movement or fuel loss and finishing with the work of particular machine systems. According to the e-maintenance concept, such detailed information should be used by service teams to forecast failures and, in consequence, to take measures preventing serious damage of the machine. However, it is only Komatsu that undertakes such analysis and measures in its system. The remaining companies limit themselves to reacting to the occurrence of a failure and to analysis of the machine's condition before an inspection. However, it should be stressed at this point that the vast majority of customers are interested in information about the machine's location and fuel consumption. From reports prepared by service teams it may be concluded that the remaining information, i.e. data on the parameters of engine work, wheels and steering system or hydraulic system, is seldom analysed by customers.

A very important element of e-service functioning is the manner of providing the service team with information on the existing failures and malfunctions of machines' work. Only Komatsu offers messages on the malfunctioning of machines by means of mobile devices, which enables a quick reaction of the service team. In the remaining cases it is a message from the customer that sends a signal about the machine's malfunctioning to the service team.

It should also be emphasised that e-service is included in the price in the case of all the analysed companies and, depending on the customer's interest, it can be provided until the machine is taken out of service.

#### SUMMARY

Summing up, it can be stated that the analysed companies engaged in the production of specialist building machines offer their products together with a service which allows machine's work monitoring in a quick and detailed way. The most versatile service is provided by Komatsu. Its system makes it possible to forecast the occurrence of failures, which allows taking preventive measures, considerably reducing the machine's maintenance costs. Alarm warnings about the malfunctioning of a machine, which are

available to service teams in this system, enable them to take immediate steps.

On the basis of the conducted studies, the following detailed conclusions can be drawn:

1. The analysed systems of building machines allow collecting information about a wide spectrum of the functioning of a machine, starting with its location and relocation or fuel loss and finishing with the work of the machine's particular systems.
2. Among all the companies subjected to analysis, only the system proposed by Komatsu allows fully proactive measures to be taken. The system enables continuous monitoring of machine's different parameters and (by forecasting the occurrence of failures or a necessity to carry out an inspection) undertaking proper preventive measures in due time.
3. Within the framework of the e-maintenance service provided by Hitachi and Volvo, information stored in the e-service system is used to analyse a machine before an inspection and to make an initial diagnosis of the failure causes. These measures are mainly reactive.
4. Major recommendations concerning the functionality of the systems in the investigated solutions include:
  - a wider use of e-maintenance system possibilities enabled by more sophisticated diagnostics of technical means and, in consequence, a broader range of predictive and proactive measures,
  - employment of wireless technologies for direct communication with machines,
  - employment of satellite as well as GPRS complementary communication between machines and servers, due to range limitations of both technologies ,
  - a more extended system of informing the equipment users and service (maintenance) team employees of the existing problems with machines, by

means of the latest technologies (GSM, satellite telephone communication and Internet),

- integration of the existing systems with technologies supporting maintenance and repair activities, such as: virtual or augmented reality.

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