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Reengineering the Port Equipment Maintenance Process

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Abstract

For the river port, the equipment maintenance is very important process because it directly influences the operational efficiency. Efficient equipment maintenance process demands accurate equipment data collection, clearly defined tasks, work order management, inventory control and reporting. This paper shows how equipment data can be collected and the analysis and reengineering of the equipment maintenance process. The result is the reengineered equipment maintenance process which is presented in the form of the process model with defined key performance indicators. This model and performance indicators can then serve as a basis for the integration of the maintenance process with other port processes and into the port management information system.

Key words: *business process, maintenance, model, performance indicators*

1. INTRODUCTION

River ports provide goods storage services in open and closed air storage facilities, and goods manipulation from and to all kinds of transport vehicles (for example ships, railway, trucks). These basic port services present processes composed of activities, with its inputs and outputs (in the form of a material and information flows). As business processes they are not isolated, but connected with other processes such as financial services, procurement services, human-resource management services etc. These processes are often supported with the management information system, which provides information to process participants. The management information system also connects the inner ports processes with its environment composed of business partners, agencies and government institutions.

Based on the changes in the business environment of the port, the ports operations must be carefully planned. River ports operational efficiency mostly depends on the adequately maintained equipment (cranes, forklifts, wheel loaders etc.).

Everyday operating tasks can cause malfunctions of these machines and extend the time of service, whether it is a storage operation or reloading operation in question.

Accurate equipment data collection and management enables that maintenance services can be planned and executed within the shortest possible time. It is

important that the maintenance services be integrated with the other processes.

This paper presents equipment data collection method and a model of port equipment maintenance process which is created after the analysis of the port maintenance activities. The process model includes data collection activity and other activities concerning the maintenance services. Section 2 presents theoretical background for the business processes and port maintenance process. Section 3 presents the case study of river port, its equipment and the functionality of port management information system. This section also presents the maintenance process analysis. Section 4 presents the data organization method, data collection method from strain/stress and vibration measurement, and the reengineered process model with defined process performance indicators and automation suggestions. Last section presents conclusion.

2. THEORETICAL BACKGROUND

2.1 Business Processes

Business process presents a set of connected activities which jointly create the output which has value for the customer [1]. Process activities as the elements of the business processes are realized by the process participants. Process participants can be divided into process owners which do the process planning, organization and monitoring, and into participants who carry out the process tasks [2]. Processes can be carried out within an organization, but also can spread across multiple organizations. Usually processes involve participants from more than one organizational department.

Another element of the business process is the event, which represents the result of the activity and also it can be the cause for beginning the certain activity. Every process can have its performance indicators exemplified in different forms, such as number of occurrences of certain event, time for activity execution, number of errors in the process, costs etc.[2]. To define a process, to analyse it, improve it and implement it in organization, the whole set of techniques and methods can be used, and they are unified under the paradigm of Business Process Management (BPM) [1]. Business process management can be implemented with appropriate software support. This software is called Business Process Management System (BPMS) and it is often closely connected to the Enterprise Resource Planning System [2].

2.2 Maintenance as a Business Process

Processes in organizations can be divided into primary processes, supporting processes and management processes. Maintenance belongs to the supporting process group and has the great impact on organizational performance [3]. To monitor the condition of the equipment, the equipment data needs to be collected and processed, providing basis for the planning and decisions [4]. Data collection can include data about vibrations, temperature, flow rates, contamination, speed and power [5]. To manage the collected data efficiently, the maintenance process requires the certain level of computer support [6]. The computerized maintenance process includes the organization of maintenance data, work order planning and scheduling, labour information, reporting and analysis, and inventory management [7-8].

One of the first steps in the maintenance process automation is to define a business process model with all its elements. Business process modelling can be done in several different modelling languages. The Business Process Modelling Notation (BPMN)[9] is a process modelling language already used for the maintenance process improvement [10]. After the model is made, the performance indicators should be defined. Key performance indicators should be based on standards which enables sustainability of maintenance process quality like presented in [10].

3. MAINTENANCE PROCESS IN THE PORT

3.1 Port of Novi Sad

Port of Novi Sad is located on the river Danube, in the province of Vojvodina, Northern Serbia. It is located on the intersection of the river corridor 7 and road corridor 10[I]. The port enables multimodal transport (by river, railway and road). It is connected with the ports in EU countries (Hungary, Austria, Germany, and Slovakia) [I]. Different types of cargo can be handled like the containers, liquid material, bulk materials and etc [I]. The port equipment is diverse, and consists of portal cranes of different capacities, forklifts also of different capacities, wheel loaders, skid steer loaders, weighbridges, telescopic funnels, machines for bags packing and oil products pump with its own storage capacity[II]. Ports management information system, developed under the EU project named DaHar [III], covers several port processes. It enables information for the ships movement records (entering the port, staying in the port and exiting the port). It provides information about the weight measurement of the trucks, storage operations and reloading operations. Information system also provides data management for accounting department, human resources department, and sales and procurement department. Information system does not cover the equipment maintenance process.

3.2 Equipment Maintenance Process Analysis

The machines which are used in operating tasks are the subject of various disturbance effects, which cause the malfunctions and the need to maintain these machines. The maintenance activities apply on all the equipment used in the everyday operational tasks (reloading, transport, weight measurement, and warehouse tasks). Maintenance in the port contains the procedures and activities to prevent the equipment failure or to bring the equipment back to its operational state, with the goal of minimal investments in time and minimal costs. Maintenance of the port equipment implies methods for the three kinds of the maintenance (preventive, corrective and combined). Maintenance also includes the control of the spare parts inventories, in a way that the port can provide its services continuously.

The observation and analysis of the maintenance process activities in the port resulted with the conclusion that the application of the information technology solutions for the port maintenance process is not at the very high level. The maintenance activities and data flows between them are not fully defined. There is no systematic approach to planning and carrying out the maintenance procedures. Documentation is managed manually and thus prone to incompleteness and errors. The existing maintenance process has no defined performance indicators.
For the maintenance process automation there should be done several points of maintenance process improvement. First, all the data about types of equipment, locations, types of stored materials and equipment spare parts, types of malfunctions, workers and business partners, needs to be organized. Next is the equipment data collection method development, which would enable equipment parameters tracking (very important for the preventive maintenance tasks). Finally, the business process model needs to be created to define maintenance activities and how they are connected. Performance indicators should also be defined to enable process analysis and improvement.

4. REENGINEERING OF THE PORT EQUIPMENT MAINTENANCE PROCESS

4.1 Data Organization

Data organization means that there should exist the record of all elements of the maintenance process (equipment, locations, inventory items, human resources, business partners, malfunctions). All the elements should be identified with its identification number and organized into groups. The record should be maintained regularly as changes occur. The record should help the data collection for the equipment parameters tracking. Maintenance log should be created for the status tracking of occurred malfunctions.

4.2 Collecting Information from Equipment – an Example of Strain and Stress Measurements on the Crane

Predictive and proactive maintenance of the equipment is based on continuous and systematic data acquisition. Acquired data is directly related to the operating condition of the equipment. By trending and analysing the data from the equipment we can monitor the health of the equipment and react before the failure occur. Parameter which is directly related to the state of the equipment is mechanical vibration acquired on the equipment bearing housing. However the level of vibration and the content of the vibration time waveforms and frequency spectra is highly dependent on the loading of the crane. Therefore the loading of the crane should be monitored and the vibration signal analysis must be correlated to the existing load. Figure 1 shows the basic architecture of the monitoring system. Acquired data are stored locally with the possibility for remote access through VPN access.

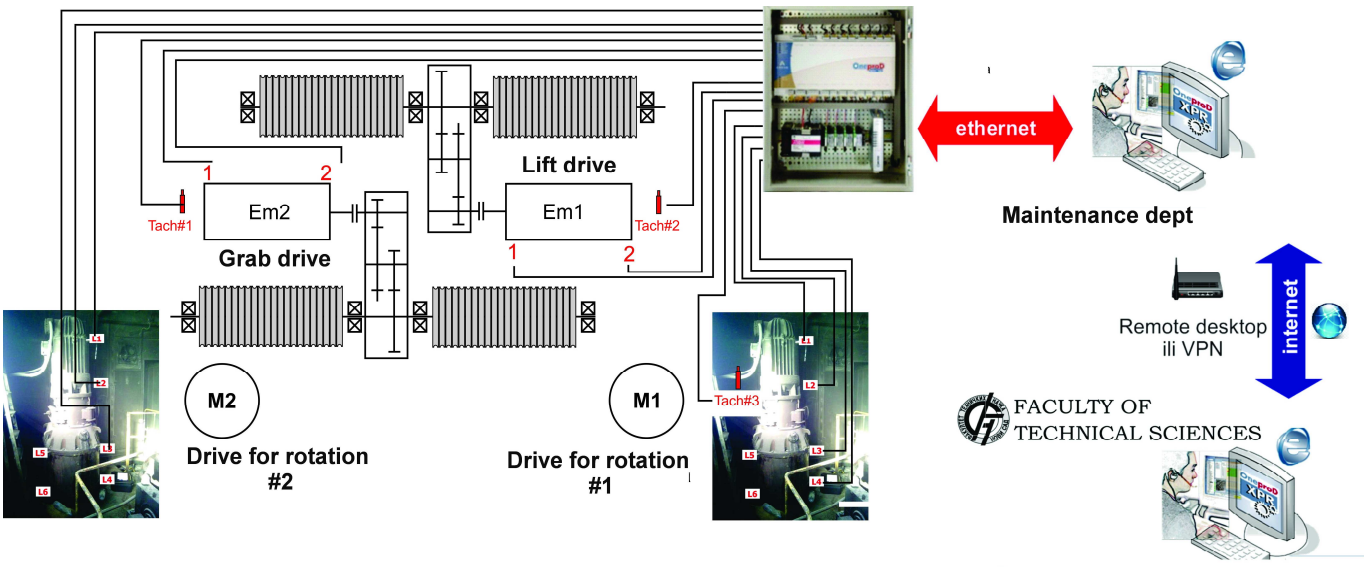

Figure 1. Architecture of the vibration monitoring system of the crane

The loading of the crane from could be measured by using the force transducers, strain gauges and telemetric equipment for wireless signal transmission.
The complete measurement chain includes strain gauges in half Wheatstone bridge configuration, industrial accelerometers for vibration measurements, rotary encoder for rotation angle measurement, industrial inclinometer for luffing angle measurement, PC based digital measuring amplifiers with TCP/IP based communication protocols for stress and vibration measurements and telemetry system for force measurement. The proposed number of measuring points is four, located at the place of acceptance of vertical forces from the crane rotating superstructure, at

the support structure of the lower portal, or alternatively at the portal legs (Figures 2, 3 and 4). The other points for the signal reception from the force transducer are at the steel ropes for lifting and opening of the crane grab (Figure 5). For the reliable force measurement at the grab steel ropes, it is necessary to set the force transducers as close as possible to the crane grab. But, in the order to avoid large lengths of the cables and to avoid the tearing of the cables, the force transducers are put on the connection points as shown in Figure 5.

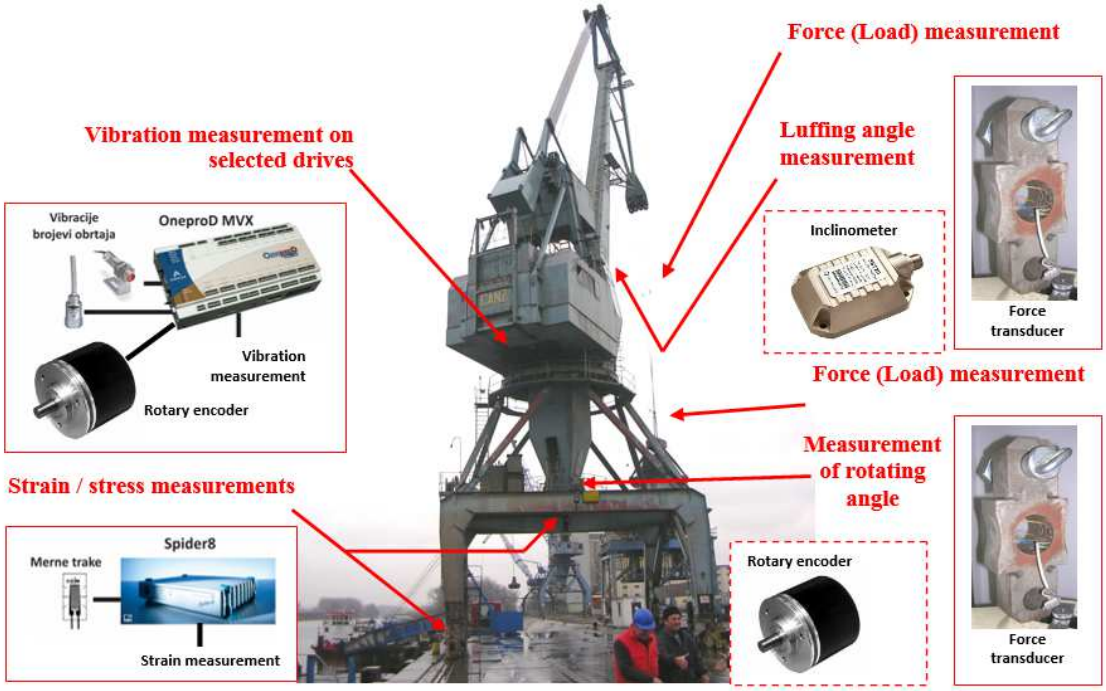

Figure 2. Measurement points at the crane

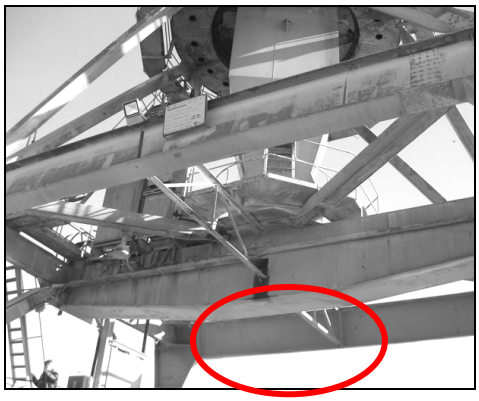

Figure 3. Place for setting up the strain gauges at the supporting structure

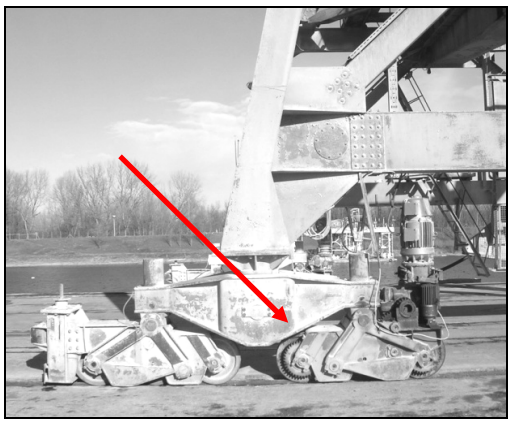

Figure 4. Recommended instrumentation (putting the measuring shaft instead of the rocker arm shaft with wheels)

Three bodies of the force transducers are made, with the strain gauges applied within the openings located at the middle of the body. The force transducers are calibrated in the accredited laboratory for the force measurement (Figure 6). The side of the force transducer which contains the antenna and telemetric units is correctly mechanically protected (the protection does not influence the measurement capabilities).

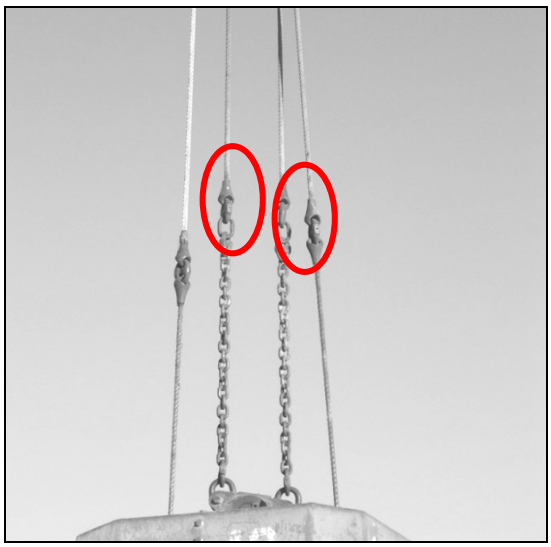

Figure 5. Points for putting the force transducers for the force measurement in the steel ropes of the grab

By analysing the data collection activities the next observations are made:

- The existing measuring equipment is not complete. In order to track all the relevant parameters concerning safety and availability of the crane the measuring equipment needs to be completed.
- The crane contains the alarm systems for certain situations like engine overload, or transgression of the highest allowed working speed (although they are not connected to the ports computer network). This is the potential point of improvement.
- There is large number of points which are relevant for tracking the crane state, and with existing measurement equipment this is not feasible. So as mentioned above, the additional measuring equipment is needed.
- The calculation of the fatigue of vital parts of the crane demands much of input data, so it is decided that these data should be tracked and be available for occasional computational verification.

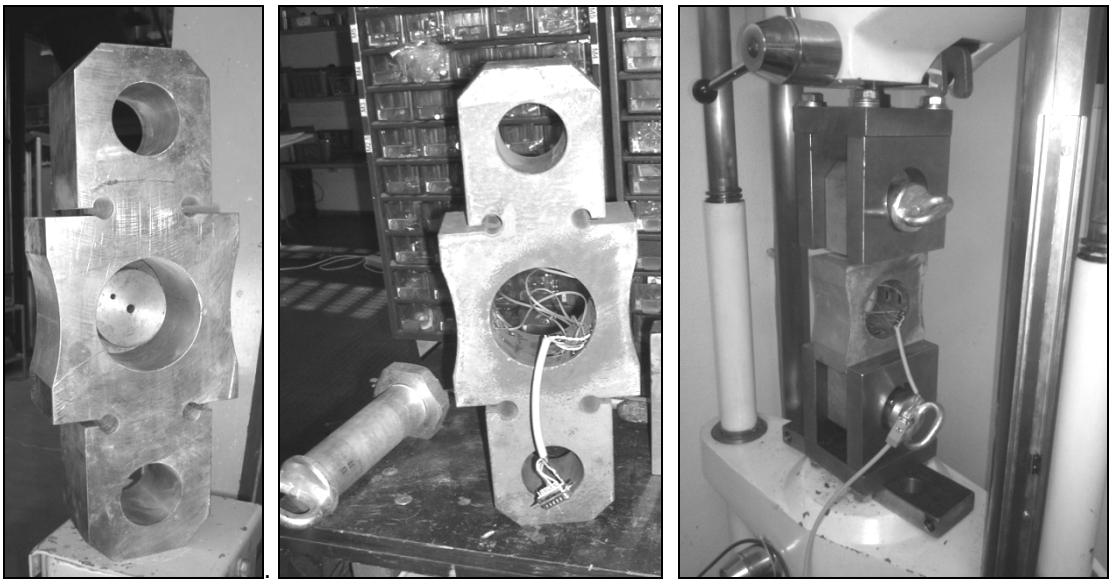

Figure 6. Body (left), strain gauges (middle) calibration (right) of the force transducer

4.3 **Process Modelling**

In order to enable integration of maintenance process with other processes and thus its integration within the information system it is necessary to create the business process model, to define the key performance indicators and automate the process.

The BPMN modelling language is chosen for process modelling. Process model is presented on Figure 7. There are five process participants identified:

- manager of the maintenance department (also has the role of the process owner),
- equipment operator,
- maintenance worker,
- service company,
- accounting department.

The process starts with two events where the first one is the *Equipment parameters need to be measured* and the other one is named *Equipment malfunction is noted*. The first event triggers the equipment data collection activity, which produces the collected measurement data. The other event triggers the activity of recording the malfunction which produces malfunction identification note and the new maintenance log entry. Either of these two activities can further trigger the activity where the manager of the maintenance department needs to make the decision about the type of malfunction. Besides equipment documentation, the needed data for the decision activity is the equipment measurement data (collected from the data collection activity), or in other case it is the data that is read from the maintenance log entry (collected from the malfunction recording activity). The decision is realised through the creation of maintenance order form. The maintenance could be done from the side of maintenance worker or from the side of the external company which does the maintenance service. If one or more maintenance workers do the maintenance activities, the procurement order is created for the necessary materials and/or equipment parts (procurement can be done internally from the inventory of externally from the suppliers). If the external company does the maintenance service then the service order is also created. The next process activity refers to performing the maintenance tasks and can be done as explained above. When the maintenance is done the unused equipment parts are returned to inventory and the return form is completed from the side of the maintenance worker, or if the maintenance did the service company, then the service report is created. Manager of the maintenance department signs the created documents and the maintenance log is updated again. Also the equipment data is updated. The accounting department processes the signed documents and the maintenance manager creates report for the purpose of further analysis. The report includes information about the malfunction, on caused damage (if any), on what is the reason for the caused malfunction, on

what is done to treat the malfunction, and what is used from the materials or equipment parts in the maintenance process.

4.4 **Key Performance Indicators and Process Automation**

With the process modelled the key performance indicators could be defined. There are several performance indicators which could be measured in this case. First there is the time of the equipment uptime and the time that is necessary to bring the equipment into operational condition. Next, there is the number of occurrences of the event in the process, for example measuring the number of occurrences for the certain type of malfunction on the equipment. The number of malfunction occurrences should be sorted by the type of the equipment. Also, indicators for the number of times the maintenance workers are used, or the number of times the external service maintenance company is used, and the costs for these engagements, could be useful.

These key performance indicators show useful information to decision makers in various ways. The maintenance process analysis could be done. They can show if the investment into maintenance workers training was useful, if the equipment is operated correctly by the operators, under which circumstances the equipment is not reliable, whether it is worth to use the external maintenance services or train the internal stuff based on the maintenance time and costs.

Another point of improvement is the maintenance process automation and integration with other port processes. This could be achieved in two ways, either through the information system, or through the business process management software.

If the automation is done through the information system then the software application should be made and integrated with other applications. For this case the created BPMN model and its defined performance indicators can serve as a blueprint for the software application development planning. The business process management systems are the other way to automate the process and to measure its performance in the real time. There are many software products which enable the mapping of the process and the data it is using, the simulation and analysis of the process, and the automation of the process activities.

There is also a possibility to use both the business process management system and the information system connected. The certain functionalities of the information systems can be mapped to the activities in the process management software.

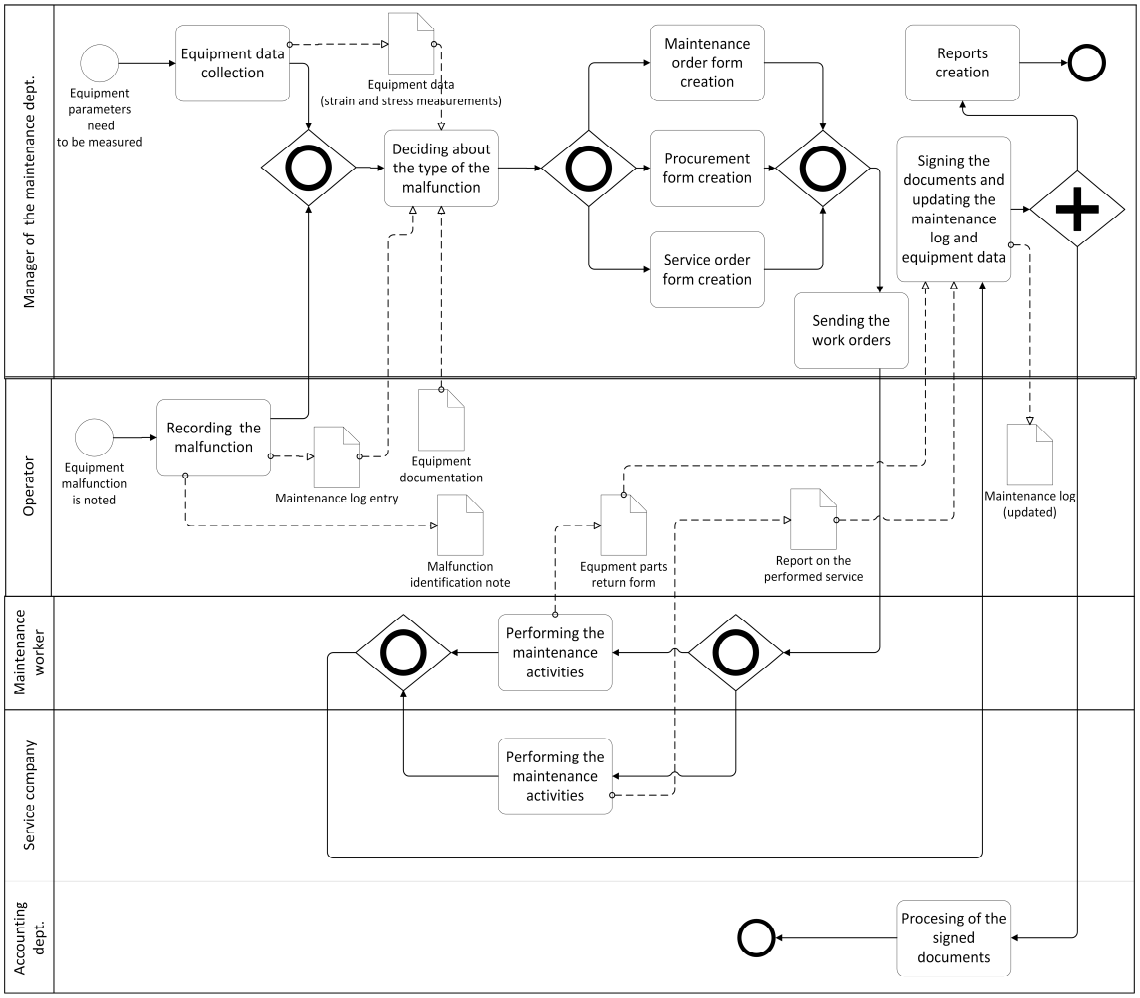

Figure 7. BPMN process model

4. CONCLUSION

The research presented in this paper presented the points of improvement in one of the main supporting processes in the river port. Measurement of equipment parameters, business process model and defined key performance indicators present the basis for the process improvement.

The potential points of improvement are made:

- integration of alarm and measurement systems into monitoring system,
- developing software applications based on the defined process model,
- integration of developed software applications into information system.

Future research work could encompass the implementation automatic detection of the equipment state, and the implementation of business process management software to automate the process. Also it would be interesting to investigate how the application of discrete-event simulation software connected to equipment data collection system could help predict potential failures and problems, and enable appropriate maintenance activities in a timely manner and thus achieving operational efficiency.

ACKNOWLEDGEMENT

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Reinženjering procesa održavanja opreme u luci

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Apstrakt

Proces održavanja opreme predstavlja veoma bitan proces za poslovanje rečne luke iz razloga što direktno utiče na operativnu efikasnost. Efikasan proces održavanja zahteva tačna merenja i akviziciju podataka, jasno definisane aktivnosti, upravljanje radnim nalozima, upravljanje zalihama i izveštavanje o procesu. U radu je prikazana metoda prikupljanja podataka o stanju lučke opreme, kao i analiza i reinženjering procesa održavanja. Rezultat istraživanja je model procesa održavanja sa definisanim indikatorima performansi. Model i indikatori performansi mogu biti osnova za integraciju procesa održavanja sa ostalim poslovnim procesima u luci i integraciju u lučki informacioni sistem.

Ključne reči: *poslovni proces, održavanje, model, indikatori performansi*