21ST INTERNATIONAL CONFERENCE ON PRODUCTION RESEARCH

ICPR 21

CONFERENCE PROCEEDINGS

INNOVATION IN PRODUCT AND PRODUCTION

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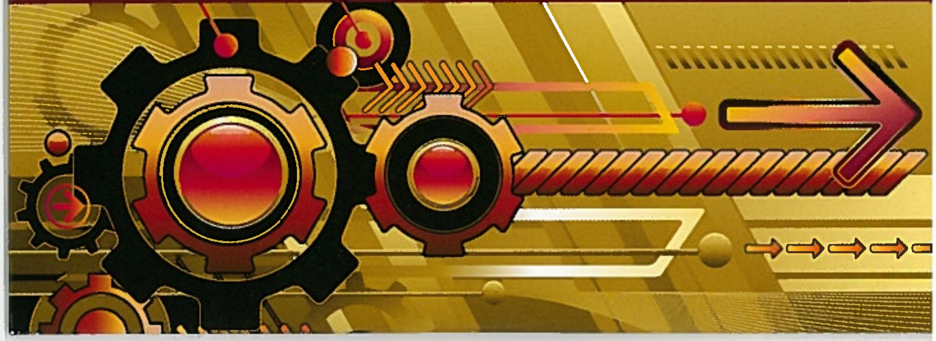

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The ICPR is regarded worldwide as one of the leading conferences promoting research in the fields of production research and industrial engineering. At the 21st ICPR, scientists from over 35 countries presented and discussed new and innovative ideas in more than 400 contributions. One of the main themes of the 21st ICPR concentrated on methods for promoting the development and growth of innovative products and innovations in the manufacturing industry.

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STANDARDIZATION AND OPTIMIZATION OF MAINTENANCE PROCESSES IN LEAN MANUFACTURING SYSTEMS

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Abstract

Efficient maintenance processes are necessary in lean manufacturing systems to ensure high productivity in order to stay competitive. In this paper the development of a two-step-approach for maintenance process optimization is presented. The first step is the development of a standard for the sequence of process steps for various maintenance tasks. With this logical design, key figures can be generated and areas of improvement become visible. Based on that standard and on the method Value Stream Mapping, a new approach to analyze and optimize maintenance processes is presented. Shorter lead times and more efficient maintenance processes are the result.

Keywords:

Maintenance, Optimization, Process Management

1 INTRODUCTION

In modern manufacturing systems with reduced inventory and short production lead times, the emphasis on equipment availability has become even more critical for the companies in order to successfully implement and sustain lean principles [1]. A lean manufacturing system is more sensitive, for example in the case of machine failures the entire production line could be affected.

The result of a survey about comparison of maintenance operations in lean vs. non-lean production systems by F. A. Moayed [7] shows that in the process of transferring from non-lean to lean production system the maintenance operation would need some modifications accordingly. The most important factors in this modification, in no certain order, are training of maintenance personnel, level of inventory and work-in-process including maintenance parts/material, reduction in the lag time between down-time and repair request, and reduction in the ratio of down-time to production time.

The first two factors can be influenced by changes in maintenance management and maintenance strategy published in several papers lik 'The maintenance management framework - A practical view to maintenance management' by Crespo Marquez et al [6], whereas the last two factors will be influenced by the maintenance process itself. Therefore maintenance processes should be more effective and the lead time of the maintenance process should be as short as possible to bring back the equipment to its normal working condition to reduce the lag time between down-time and repair request, and to reduce the ratio of down-time to production time.

Traditional methods of process management and process optimization do not consider the specific criteria that constitute an 'optimal' maintenance process. The purpose of this research work is to provide a new view on maintenance processes and to develop a process standard that describes maintenance in a transparent way. Based on the process standard, the 'maintenance value stream' can be visualized to identify and to evaluate the non-value added activities of the maintenance processes. Expected effects are the reduction of maintenance lead time and the creation of lean maintenance processes.

2 DEVELOPMENT OF A PROCESS STANDARD FOR MAINTENANCE

The first part of the presented method is the development of a standard to describe the sequence of process steps in the implementation of various maintenance tasks. This standard makes it easy to understand the logical structure of maintenance processes and allows a uniform approach in planning and executing different maintenance tasks.

The maintenance standard process should have an adequate level of abstraction. If it is too detailed, it cannot be applied to all problems. On the opposite, if it is too general it would be very little support for the optimization. Furthermore the standard process should be robust in case of real world changes.

Any maintenance task (from simple cleaning to complex repairs) should be described. Basis for the development of the standard definition was a significant portfolio of different possible maintenance tasks [2] that had been mapped in several industrial projects.

Due to standardization, key indicators can be collected, which can be applied to individual process steps in order to make comparisons with other maintenance areas. The most important key indicator 'Mean-Time-To-Repair' (MTTR) is clearly visible through this kind of process description. The maintenance process should be designed to be able to generate the favored indicators with particular focus on the MTTR. Value-adding and supporting process steps should be clearly separated.

An overview of the process standard environment is shown in Figure 1.

In the following section, each process step will be briefly introduced. MTTRp stands for 'Mean Time to Repair' for planned maintenance whereas MTTRc is the 'Mean Time to Repair' for corrective maintenance.

The 'maintenance standard process' consists of eight steps: Identify, plan, prepare, execute, restart, functionality check, approve, close. Documentation spans across all eight steps as a supporting process. It should be noted that the implementation rate of the respective process steps depends on the complexity of the maintenance tasks on the one side and on the importance of the equipment that has to be maintained on the other side.

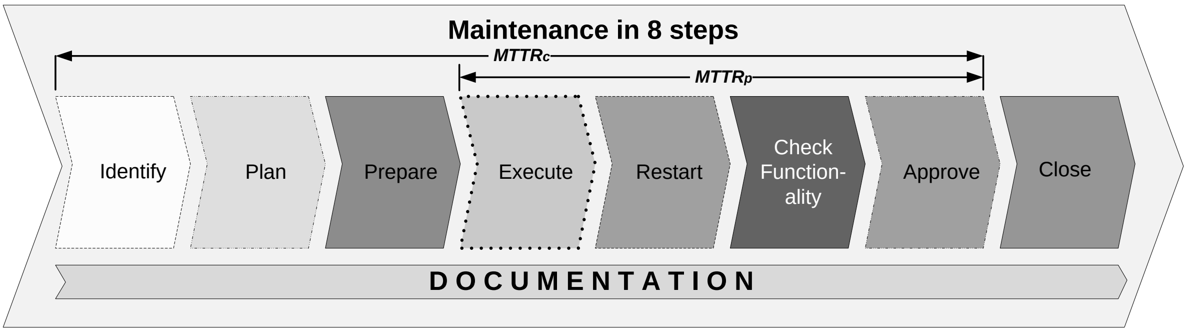

Figure 1: Process standard “Maintenance in eight steps” [2]

Identify:

The starting event of this process step is either a failure or a planned maintenance activity. If the starting event is a failure, this process step is the start time of the key Figure ‘Mean Time to Repair’ (MTTR). For optimal planning and execution, all necessary information has to be collected and appropriate activities have to be set. The end event of this activity is ‘Known activities which can be accomplished’ that is the starting event of the next process step as well.

Plan:

With the former information, human resources, material, equipment and execution date is scheduled. With the fixing of execution date, process planning is finished. The end event of this activity is ‘Readily planned work order’.

Prepare:

In this process step equipment, tools and spare parts are prepared and obstructive parts are disassembled so that maintenance can be performed unhindered. If the system is ready for the actual maintenance activity, the schedule is completed. In this case, this is also the end event of this step.

Execute:

Planned activities from the work order (planned maintenance activity) or the activities derived from the process step ‘Identify’ are processed. ‘Execute’ is the only step seen as a value adding process. The event ‘Planned maintenance activities finished’ ends this step.

Restart:

The restarting operation consists of the evaluation of system engineering, building services and safety related components as well as the actual start-up of maintenance objects. Operable equipment is the end event of this step.

Check Functionality:

In this process step, the performed actions are evaluated based on quality standards. The results are recorded in a supplied maintenance-document. The end event could be either ‘Functionality Check passed’ or ‘functionality check not passed’.

Approve:

With ‘Approve’ the maintenance object is passed back to the user’s responsibility. The MTTR ends with this process step. The two possibilities for the end event are ‘approved’ or ‘not approved’.

Close:

The last process step contains reporting (employees/departments), logging (validation protocol), returning and disposing of the commodities and finally closing of the work order. Also, future activities can be deduced and maintenance plans are updated as a result of the finished maintenance activities.

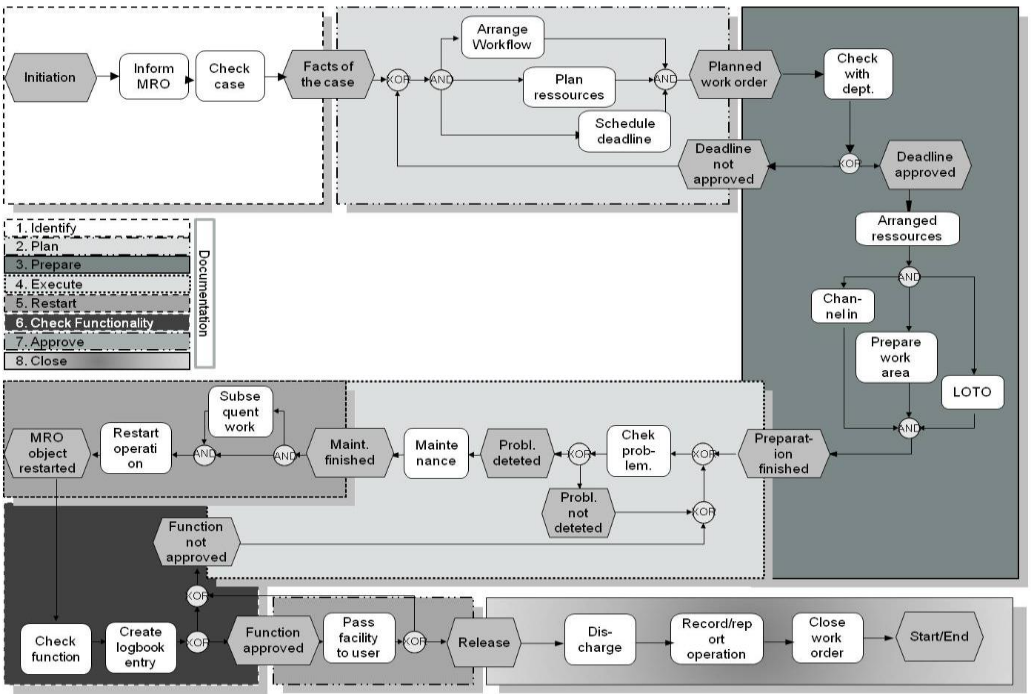

Figure 2: Clustering of a maintenance process based on the 8 steps

Further possible process-visualization methods are swim lanes. First of all, they depict particular interfaces between transitions. Secondly, flowcharts that are commonly used to document processes within a quality management system are possible. The third option would be the event-driven process chain, which is used in Figure 2 applied to the clustering of process steps. By extending the diagram to a detail level that is a step higher, the so-called 'extended Event-driven Process Chains (eEPC)' the interfaces and responsibilities with possible improvement potential become evident (Figure 4).

3 NEW APPROACH TO ANALYZE AND OPTIMIZE MAINTENANCE PROCESSES BASED ON THE METHOD 'VALUE STREAM MAPPING'

A lean maintenance system is a concept that combines both, the approved approaches and principles of 'Lean Thinking' with the modern versatile concepts and tools of maintenance, with the central goal, avoiding waste.

A value stream includes all activities, i.e. value-adding, non-value-adding and supporting activities that are necessary to create a product (or to render a service) and to make it available to the customer. This includes the operational processes, the flow of material between the processes, all control and steering activities and also the flow of information [8].

With the adaptation of the method 'Value Stream Mapping' for the maintenance area the value creation process of maintenance becomes visible. This is important for production purpose, since maintenance processes are generally not seen as value adding processes.

This approach is sub-divided into three phases and based on the new developed process standard 'maintenance in eight steps' (Figure 3).

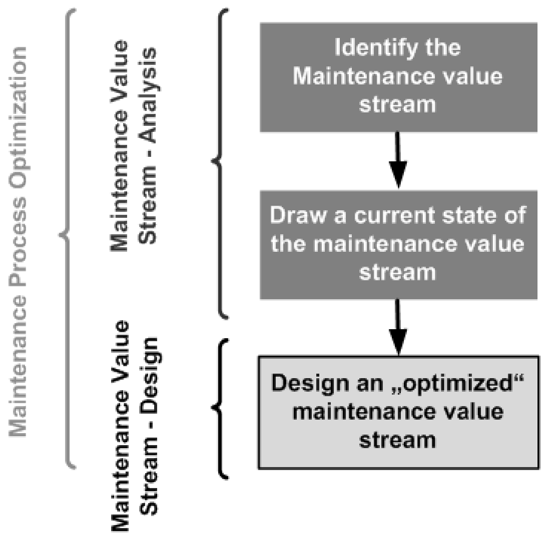

Figure 3 : Three Steps of Maintenance Process Optimization

3.1 Identification of the maintenance value stream

The first step is to categorize the different maintenance tasks reasonably (for example corrective or preventive maintenance tasks, failure, repairing, planned maintenance) in order to receive a meaningful value stream mapping. Due to highly different tasks in the maintenance area, this is essential and needs to be done carefully [3].

The realization grade of the individual process steps within the 'maintenance in eight steps' model depends significantly on the time available, complexity, closeness to production and the task itself.

3.2 Draw a current state of the maintenance value stream map

Data acquisition

In order to obtain the necessary information for data acquisition, a large, tailored data acquisition sheet is created, which is subsequently used to monitoring the maintenance tasks of the selected category for a certain period of time. The collected data are the basis for further analysis, e.g., the detailed process visualization in an 'extended event-driven process chain' (eEPC). After selecting the value stream, the process chain is outlined as eEPC for every process step of the maintenance standard process [2]. An example of an eEPC for the second process step 'Plan' is shown in Figure 4.

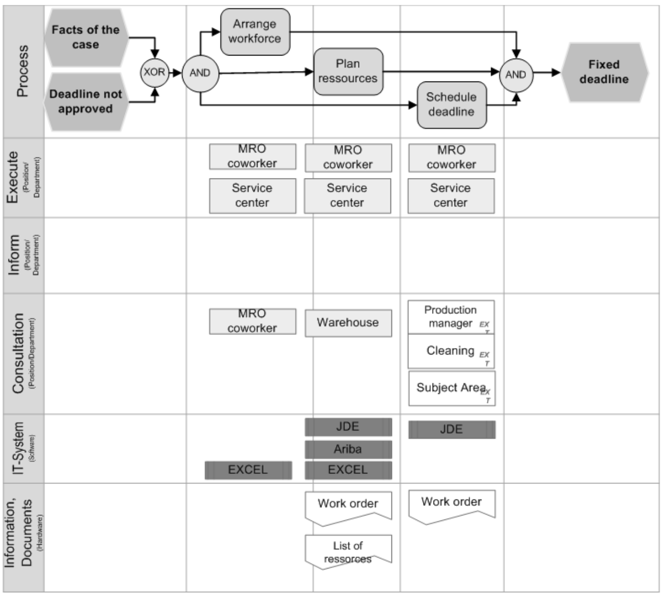

Figure 4: Example for an eEPC of the second process stepp 'Plan'

Creation of a maintenance value stream

The procedure of creating a maintenance value stream consists of eight steps. First of all, the relationship between the customer and the maintenance process is detected and visualized. Afterwards the eight process steps of the 'maintenance standard process" are extended by data frames and process parameters from data recordings. An example for a data frame is shown in Figure 5.

TT	16 min
PLT	20 min
HR	100 %
Ins. Time	----- min

TT: Transition Time

PLT: Process step Lead Time

HR: Hit Rate (key Figure for the efficiency of data acquisition)

Ins. time: Inspection time in the case of unclear circumstances

Figure 5: Example for a data frame

It should be noted that for an examination of the process steps on a higher level of detail, the sequences of activities are visualized as eEPCs that do not appear on the value stream map (Figure 4 and Figure 6).

The third step consists of an analysis and documentation of the supporting systems' interfaces, e.g. what documents will be necessary and what kind of EDP system will be used.

In the fourth step the transition time between the process steps is detected.

Next, the so-called 'inquiry loops' in the value stream should be detected, quantified and visualized. Thereby, those process steps with inefficient information search become evident and can be improved.

In the sixth step control and transition are being analyzed. Furthermore the questions of how the process steps are organized, how the connection between the process steps looks like and how the work orders are processed (Push, pull, FIFO) are answered.

Underneath the developed scheme, a timeline is drawn in the seventh step to show the transition times, process step cycle times and process lead times. Now, key figures like MTTO (mean time to organize – time period from the identification to the execution of the maintenance task), MTTR and MTTC (mean time to complete) can be easily determined.

Possible improvements will be outlined by KAIZEN-Flashes at the maintenance value stream's last analysis step. An example for the analysis of a maintenance process with 'maintenance value stream analysis' is depicted in Figure 6.

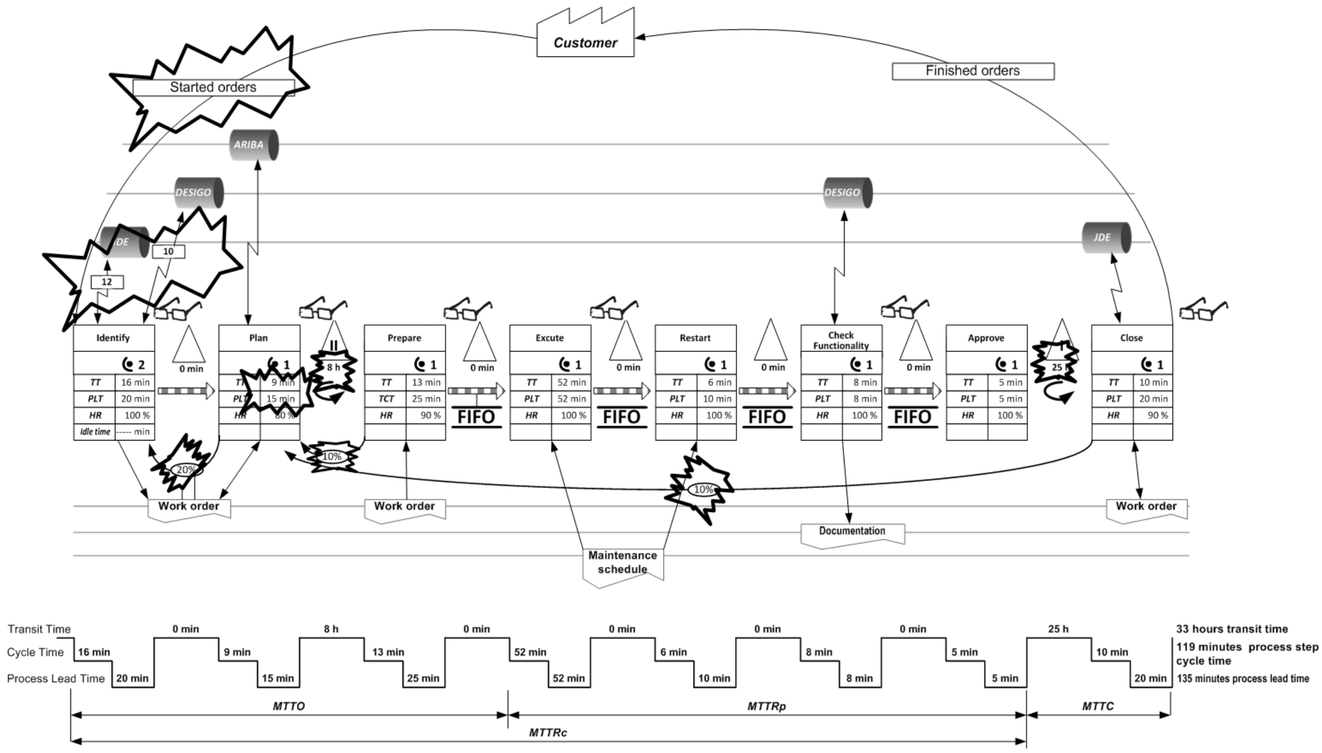

Figure 6: Analysis of a maintenance process with "Value Stream Mapping"

3.3 Optimization of the maintenance process by creating a target state

Based on the current status of the maintenance value stream under consideration of the areas of influence and principles of value stream design, a target state for the maintenance process is created [5].

Rhythm and flow:

In this area of influence a rhythm for the maintenance tasks has to be found according to the customer needs. These maintenance tasks should be executed flow-oriented in a continuous and balanced way.

Control and sequence:

The target is to control as few processes as possible at a maximum flexibility. Themes like transfer between process steps and the sequence of activities are analyzed in this area.

Process and support:

Also, the activities within the process steps have to be questioned to perform the maintenance tasks with high efficiency.

Based on these areas of influence and on underlying principles the following guidelines for the creation of a target state value stream are deduced [4]:

Customer requirements:

What are the customer's requirements for the maintenance value stream in terms of quality and quantity? As far as quantitative requirements are concerned, they are the basis for a very important key figure in the maintenance value stream, namely the customer tact time. Also, the consideration of how frequent maintenance orders are triggered is of vital importance. The customer tact time is the reference value for the process step lead times. If the latter is too long, it is necessary to analyze the process and to find out whether improvements are possible.

Classification of the process steps (value adding, support, waste):

For this classification, the process cycle is being analyzed and categorized based on the maintenance standard process. In the course of this step it is necessary to change to the next more detailed level of the maintenance value stream analysis - to the eEPCs - and analyze the activities of the 8 process steps in order to identify their value adding rates. The goal is to execute the value-adding activities in the maintenance process amid maintaining a high level of quality and to reduce the non-value-adding process steps. On the one hand, this is achieved by the elimination of waste, on the other hand, by increasing the efficiency of organizational activities.

Where can continuous flow been used?

The process steps need to be processed successively, without interruption, thus, resulting in a reduction of interface losses, shortened transport, idle time etc.

Pull-System:

In case it is not possible to integrate a continuous flow between the process steps, a Pull-System is a possible way to connect the single process steps to each other.

Process improvement:

The identification and elimination of large deviations between cycle time and lead time takes place at this point. It has to be identified where and why there are poor hit rates and therefore large differences between process time and lead time. Here, once again, the already mentioned eEPCs, with which process steps and necessary supporting systems and documents are being visualized, are analyzed.

Flexibility:

It has to be checked, whether it is manageable to adjust the extent of work in the course of planned maintenance, e.g. by splitting tasks, thus increasing the ability to react more flexibly in case errors should appear.

Work content:

Oftentimes, maintenance workers assume indirect activities such as transportation or inventory control besides their maintenance activities. By clearly separating the work contents (specialists) and their subsequent optimization, waiting time should be minimized.

4 SUMMARY

Taking a value stream view means considering the general picture of a process and not just individual aspects. With the method ‘value stream mapping’ extensive and complex activities can be visualized in a clear and meaningful way. Not only areas of improvement are getting visible, it is also possible to base decisions on facts and figures, not to forget the material- and information flow, which is becoming more transparent. All this helps to make informed decisions that are comprehensible and assessable.
The method also shows the correlation between material flow and information flow with the focus on customer orientation, reduction of lead times and elimination of waste.

The application and adaptation of the method ‘Value stream design’ in the maintenance area has become possible by developing the eight-step maintenance standard process. Thus, maintenance processes can be presented and optimized in reference to the value adding activities.

The standardization of maintenance processes and the adaptation of the Value Stream Mapping method for maintenance procedures contribute both to the reduction of lead-time of maintenance processes and to the increase of availability of machines and assets as well.

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