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PRODUCTION MANAGEMENT

Workplace performance analysis: methods and a system

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Abstract. A web-based workplace performance improvement system was developed for managing real-time manufacturing processes and the level of execution of the production tasks at workplaces. The system's web aspect provides significant advantages, as the system is distributed through inter-operable, cross-platform, and highly pluggable web-service components. It is possible to estimate the effectiveness of the production process at the workplace through different key performance indicators. The main objective is to eliminate excessive idle time, but also to analyse possibilities of reducing various times involved in the manufacturing process, such as the setup time, quality control time, etc. The system was developed in cooperation with Fujitsu Services Estonia, and it is possible to integrate it with the human resources managing system PERSONA (Fujitsu Services).

Key words: workplace performance, key performance indicators, information exchange, data management, web services, performance analysis, information system.

1. INTRODUCTION

Principles of improving workplace and production system performance are tightly connected to the company's competitiveness. Optimization of workplace activities is an integral factor for achieving the expected performance and improving results. The factors influencing the performance of the workplace are described in [1]. A conceptual model of workplace performance improvement was also designed. An important task is to indicate the most suitable set of key performance indicators (KPIs). The KPIs must adequately represent the metrics, focusing on aspects of the organizational, technical, and individual performance of the workplace in carrying out the manufacturing task. Monitoring the KPIs should be a repetitive action, and trends should be monitored and evaluated continually, taking into consideration the estimated (planned) and achieved results. The results are gathered over a specific time period so that it is possible to determine if the results are acceptable. KPIs and their achievement or non-achievement should be communicated understandably to each workplace operator as well as to the shop-floor and top management. A general overview of the KPIs is presented in [2,3].

The workplace is connected to different information flows. Through the material flows the workplace is horizontally connected to other workplaces. Vertically, the workplace is connected to the information flows, the aim of which is to describe the tasks at the workplace as well as the data concerning the results of the analysis (quality, productivity, energy efficiency, cost, etc.).

The main challenge is to quickly and effectively manage information at the workplace and in real time on-site (at work) so that the company can obtain the required information at all selected places (different positions). Making the right decisions and managing the timely launch of improvement activities are possible on time only if adequate information is available. Furthermore, the specific procedures that can, according to the need, respond to emerging situations must be prepared.

Workplace performance can improve the results based on the needs of the respective model, the management of information flows, data collection and analysis

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systems, and the corresponding development of the information system.

2. WORKPLACE INFORMATION MANAGEMENT AND PERFORMANCE OBJECTIVES

The workplace is a single unit of a production system that is organized on the basis of a machine tool (or a group of machine tools), serviced by an operator (robot) and additional servicing equipment if needed. Workplaces are integrated into the production system. The production system belongs to a company, which can be part of an industrial network or cluster. In [1,4] it was described in detail how the workplace is connected to the system, but also how it is related to the process (i.e. to the manufacturing process). The workplace integration with systems and processes can take place through material and information flows. In the current article we are focusing on the information flows and on the analysis of the performance problems of a workplace.

A general description of the main information flows connected to the workplace is given in Fig. 1. There are four main information flows connected to the workplace in a company:

- personnel information, operated by any human resources management system;
- manufacturing information, which is described more thoroughly in the relevant manufacturing documentation;
- performance information;
- financial information.

Information management is the collection and management of information from one or more sources and the distribution of that information to one or more audiences. Our information management system was developed for organizing e-manufacturing. E-manufacturing is a responsive manufacturing model that optimizes the use of production assets based on information exchange from shop-floor operations throughout the enterprise and the extended supply chain [5,6].

The general objectives regarding the productivity are the following:

- order fulfilment time (min) – the time period from signing the order to the shipment of the manufactured product. The process is running over the extended supply chain;
- total throughput time (min) – the period required for a material, part, or sub-assembly to go through the manufacturing system. The process is running in the production unit (workshop(s)), and workplaces are a part of the process;
- cycle time (min) – the time period to complete an operation or job on a machine tool or workplace. Workplace is the main unit for executing certain parts of the process.

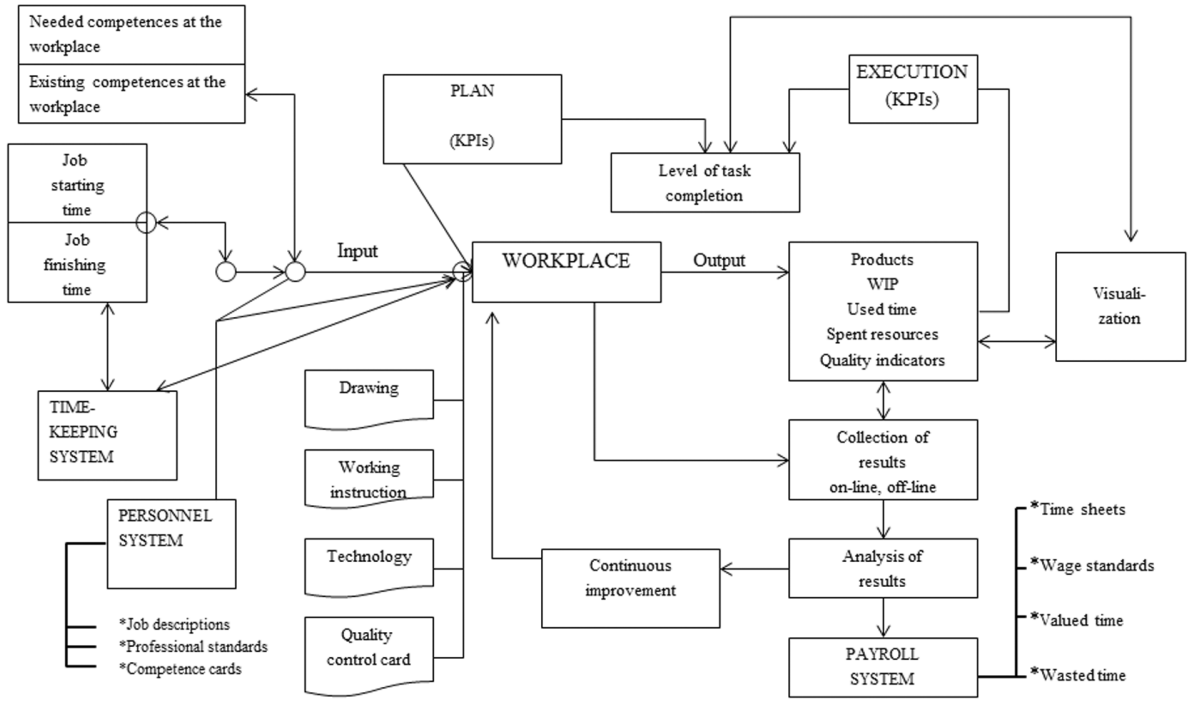

Fig. 1. Main information flows connected to a workplace. WIP – works in process.

3. PERFORMANCE ESTIMATION AND ANALYSIS

Companies may use a variety of alternative ways to achieve their targets. The evaluation criteria of methods are based on the enterprise goals [7,8]. Analysis of the strategic objectives of small and medium-sized enterprises (SMEs) would show that manufacturing enterprises use similar methodologies for achieving their goals. This allowed us to create an optimized model for all production-based SMEs. This model can simplify not only discovering bottlenecks and analysis of processes, but also the choice of improvement activities. Sector-specific strategic objectives are used to better understand a company's goals [9–11]. In order to get the right understanding of a company's objectives and to obtain a comprehensive overview of the critical success factors for the process (in other words, what should be done by the management to be successful in reaching their goals), the sector-based objectives should be divided into process-based aspects reflecting different targets of the primary process. The model for improving the company's productivity and efficiency is presented in [9].

A picture on the company level, i.e. strategic level [9], is different from that on the workplace level, i.e. operating level. The workplace is generally the elementary unit in the corresponding process. In the workshop we have different workplaces with their own tasks, which are regularly described in the work instructions. The integration and interaction of different systems and processes in the manufacturing process are described in previous studies [1,4,12]. Manufacturing operation functions (Fig. 2) are described in detail in [13], a US standard that presents activity models of manufacturing. These models provide a framework for establishing the boundary between the planning phase (carried out by enterprise resource planning (ERP) and product life-cycle management (PLM) systems) and the execution phase (carried out by the manufacturing execution system (MES)).

The MES [14,15] provides real-time data collection to ensure that all the work tasks, including quality inspection, are completed. The MES ensures that the company/workshop/workplace always has the direction required to manufacture the products and load the equipment and that the data are captured to meet the enterprise's data needs. By streaming data acquisition and execution for workshop managers, technicians, and mechanics on the shop floor, the MES also creates efficient processes that consist only of value-added activities. The shop-floor MES activities connected to the workplace are represented in Fig. 3.

Within the manufacturing domain, the developed application is able to meet the specific shop-floor needs to increase productivity through a better use of the available information. An important factor in the improvement process is the estimation mechanism based on the selected criteria.

The results must be measurable and assessible. It is necessary to assess the scale and to make decisions on a graduated scale that can assess the outcome (e.g. as good, fair, poor). Further, the reaction mechanism provides guidance on behaviour: good, moderate, or poor.

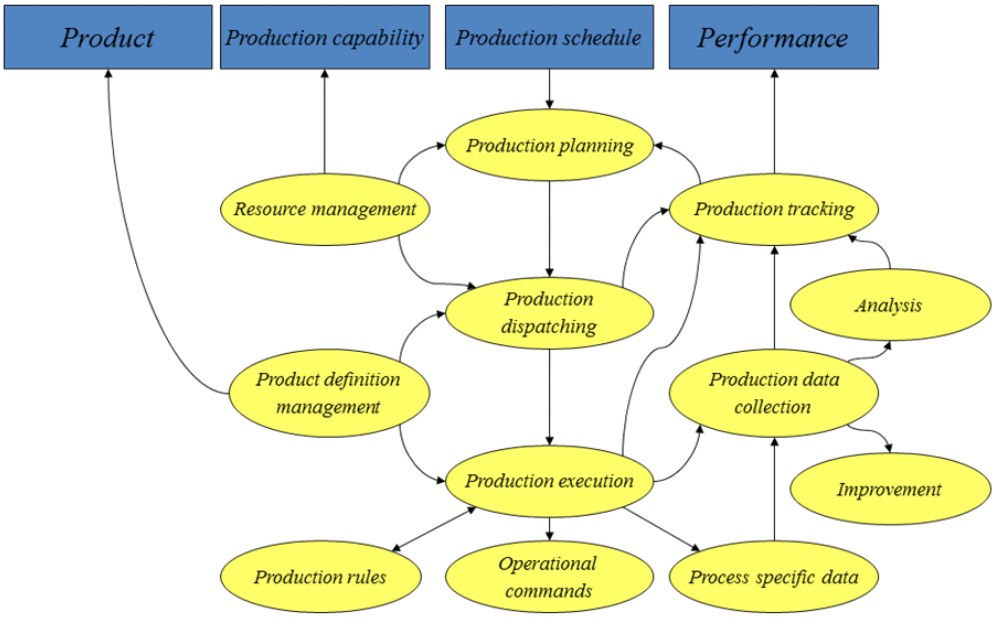

Fig. 2. Information flows in the manufacturing process [13].

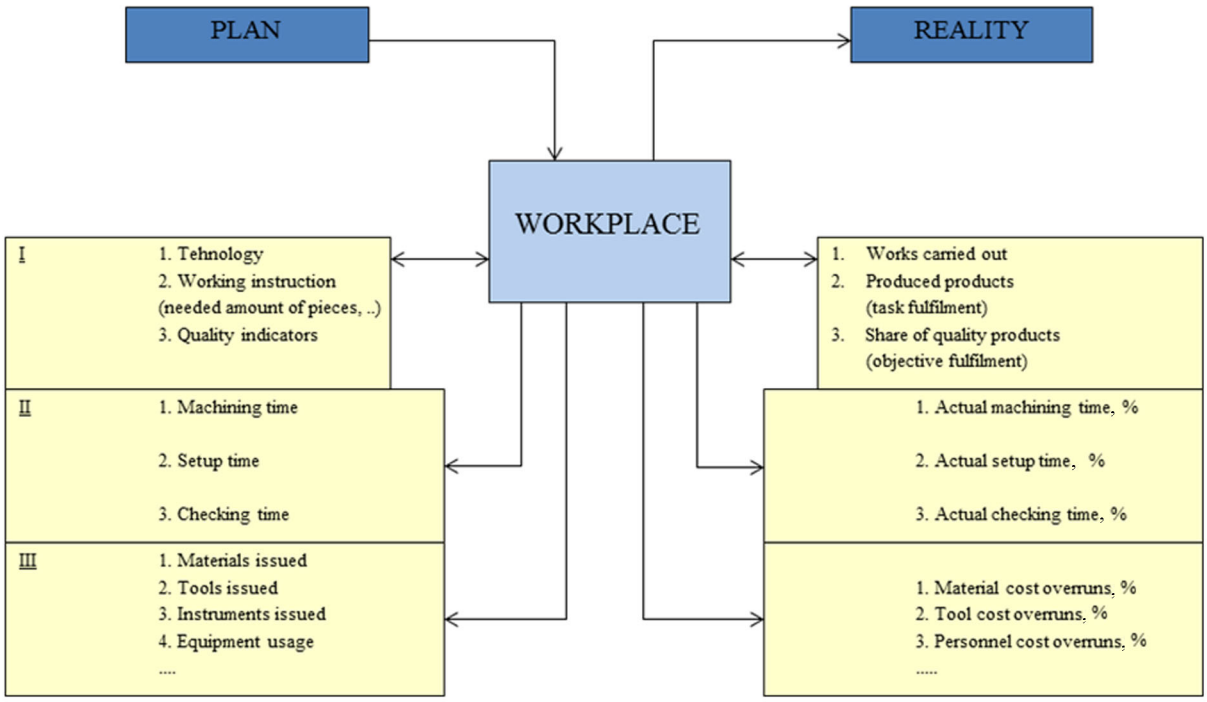

Fig. 3. Planning and execution process at a workplace.

4. DEVELOPING PERFORMANCE MEASUREMENT AT A WORKPLACE

The workplace is part of the production system, which is important for its technological capacity and job performance. The effective use of the entire workforce at a workplace is a very important task for which both the employer and the employees are equally responsible. The following four aspects are involved in the performance measurement process at a workplace:

1. Approach to the achievements. The top-down cascading approach is the most widespread, and the process is started with the definition of high-level issues (global criteria). These indicators are then broken down into increasingly more detailed indicators through a cascading process according to the formal organizational hierarchy. The opposite way is the bottom-up process, which is based on personal responsibility and suited for designing a system for which every member of the organization is responsible. Every employee is responsible for contributing to the definition of performance indicators covering their process or area.

Production management and organization take continuously place on two levels: (1) the employee level, based on the job description and carrying out of work orders and instructions given by self-control, plays an important role in achieving the specific work-related endpoints; (2) the management level, which is based on the management's judgment, production plans, etc., and constant checking of the set objectives.

Better performance is generally a prerequisite for achieving better results. Better results compared to one's competitors, in turn, create preconditions for successful coping in the global market. Achieving great results in a company starts from the results of the workplace.

2. Plan and the reality. The two basic loops in the planning and execution of manufacturing as described in [16] are

- requirement loop, which defines technological possibilities/competences needed for order fulfilling and associates these with the existing possibilities/ competences and production system's technological capabilities; and
- behaviour loop, which observes performance level (activities) according to order fulfilment measures of efficiency and compares outputs with expert estimations of system capability.

The requirement loop is a tool for planning. It determines requirements for performing a certain operation at a workplace and also the needed (planned) outputs (pieces, quality, time, etc.).

The behaviour loop is for measuring work efficiency and for realizing continual improvement principles.

KPIs are planned for workplaces taking into account the competences of the operator and technological possibilities of the machine tool of this workplace. In reality, deviations may occur. This means that planned outputs are not always achieved: quality non-conformances, time overlapping, resource overlapping, etc.

These losses have a negative impact on the performance; for example, non-conforming quality means an increase in costs due to the need of re-processing or producing new products and/or exceeding time limits. Therefore, estimating the performance and analysing the results are very important.

3. Achievement fields. There are different global criteria in a company that are of key importance for its success and competitiveness. These are mainly connected to time, cost, and quality. It is very important for companies to specify pertinent indicators, make clear how they are linked to the company's goals, and what impact they have on the company's activity [17]. In our approach we took into consideration the quality issue. Typically, quality is assessed according to the outcome (i.e. at the end of the production process) and compared to the planned outcome.

The KPIs help a company to indicate and later evaluate how successful and efficient the company is. Every company that decides to improve its performance through KPIs should assess what indicators are crucial for its business and manufacturing processes. However, the main problem that managers are faced with during the identification of the right metrics is the number of indicators [14,18]. In addition, metrics that can be used in one company need not be successful in other companies. Furthermore, managers should understand not only the *common* problems that may appear in manufacturing processes in different fields, but exactly the main questions that come out in *their* firms [12].

It is necessary to have knowledge on the formation of the KPIs (see Fig. 4). On the other hand, it is equally important to have an understanding of the whole data acquisition and measurement system in the determined field. When there is a clear connection between the enterprise's goals, activities, and KPIs, then the results/profit can be seen by everyone [19].

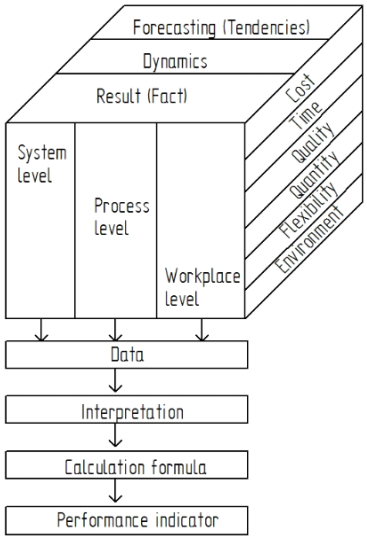

Fig. 4. The process of forming KPIs for various activity levels according to different objectives.

4. Measurement system. The results of designing and implementing the performance measurement system will become an important part of a company's activity as they will have an impact on the shop level but also on the whole company. Measurements are important because they will show the managers the problematic areas and will help to solve different issues [12]. In addition, metrics can provide the managers with the necessary information and action plan as well as help them to determine what should be done first. It is comparable to driving: you should decide which direction to take to achieve the final destination. If you do not have maps or suggestions where the road will take you, you can never cross the finish line. One recommendation is that the company should roughly split the problematic domain into smaller areas, which can be better handled, prioritized, and processed by the team of the company.From this standpoint, performance measurement has certain vital steps.

- Determine the area or object (Fig. 4). In our case quality was chosen. Determine the field inside the area (quality management, quality assurance, quality control). Quality assurance involves planning preventive actions that grant that quality objectives are achieved.
- Determine the KPIs that are connected to the activity level in the company. For the company it is very important that any damage related to the production of defective products is detected and accounted for. Damages leading to a break may cause the company unpredictable spending. If there is no accounting practice, the extent of the actual damage is not clear. The aim of all businesses is to reduce the harm associated with the production of defective products. Damage control for break process can be, for example, the following:

(a) setting a goal; this year's goal is to reduce scrap losses by 10% compared to the last year:

$$\text{Goal} = \frac{\text{Last year's losses defective (EUR)}}{\text{Last year's turnover (EUR)}} \times 90\%; \quad (1)$$

(b) finding this year's actual defective damage; this year's actual damage taking into consideration reject losses:

$$\text{Defective damage} = \frac{\text{Sum defective damage per year (EUR)}}{\text{Last year's turnover (EUR)}} \times 100\%; \quad (2)$$

(c) finding physical damage due to reject losses in comparison with the target. The actual damage

due to the reject losses as well as the visualization of reject losses on a monthly basis to provide one graph:

$$\text{Fulfilling the goal} = \text{Goal} - \text{Defective damage}. \quad (3)$$

The employees' quality management-related criteria may include the following:

- the percentage of the defective products throughout the production shift;
- product quality control cycle, part of the prescribed time of the cycle.

5. PERFORMANCE MODELLING

In reality, deviations may occur, which means that planned outputs are not always achieved: quality non-conformances, time overlapping, resource overlapping, etc. may occur. These losses have a negative impact on the performance; for example, non-conforming quality means an increase in costs because of re-processing or producing a new product and/or exceeding the time limits. Therefore, estimating the performance and analysing the results are very important.

According to Fig. 4, the results would be obtained on different integration levels (workplace, process, system) by different criteria (time, cost, quality, etc.). On the basis of Fig. 2, we can determine that periodically or in real time we have to compare the expected figures (planning phase) with the achievements (execution phase). The determination of the current situation is the basis for identifying weaknesses and for localizing potential improvements. As-is modelling gives an overview of the current situation of the activity running at a workplace, process, or system. To-be modelling is carried out on the basis of the as-is models and the weaknesses analysis that originates from the as-is modelling. The results of to-be modelling are linked with the objectives fixed on the management or the operating level. These could be cost savings, shortening of processing times, minimization of idle time, etc.

Figure 5 presents an example of the shortening of the processing time considered in the quality control process.

The above principles were developed based on a job performance monitoring system. The main principles of this system are presented in the next section.

The MES provides the opportunity to quickly identify deviations from the planned course and to immediately implement corrective action. Such real-time monitoring of production processes is based on its capacity and flexibility. It is important to fix the areas that need more strategic attention, because the production of a central volume is extremely high. In addition to the areas, it is necessary to select the most important KPIs, which give all necessary information to solve the problem. Data collection has to be carried out, if possible, automatically using integrated measuring and monitoring systems, barcode readers, RFID tags, etc. through the use of appropriate interfaces. The data are collected semi-automatically from workers with the help of MES terminals.

6. A CASE STUDY OF A WORKPLACE PERFORMANCE MONITORING SYSTEM

The system was developed following the above principles. The system's IT solution leader has been Fujitsu Services AS, which has also been the creator of the staff management system PERSONA. The workplace performance monitoring system is easy to manage, user-friendly, and cost-efficient. It gives an overview of the time loss, and it is possible to analyse the reasons of the problems. The system works on the principles presented in Fig. 6. It is possible to analyse the time of each cycle or the process time component separately. It is possible to insert the input manually or on the basis of different sensors or from other systems that could be linked to the workplace performance monitoring system.

According to the proposed approach, IMECC OÜ, Estonia, is currently developing a workplace information system in cooperation with our partners. The aim of the workplace information system is to manage tasks for workplaces, collect data from the workplace, and analyse the collected data according to the initial plans.

The workplace information system includes the following web services for standard integration:

- getting task lists with nominated time estimations from the ERP system;
- sensor inputs from workplace devices and workers (RFID) for detecting working time;
- configuration and downtime;
- output of data (including raw data, consolidated data, reports).

The workplace information system is customizable for every company according to their needs and business processes. It is possible to use a company's own workplace software for the user interface layer. The system can be used also with mobile devices or tablet PCs. For both views – workplace and production manager – there is an especially adaptable design to offer maximal usability. The main functionality blocks for the system are the workers' or workplace's task lists and task reporting.

The system consists of the following components:

- workplace monitor,
- production manager's module,

- reporting module,
- setup module.

The key functionality in the system is to monitor the performance of the workplace. From the viewpoint of the workplace there is also a historical graph of workplace performance. The production master is able to see the performance of all the workplaces.

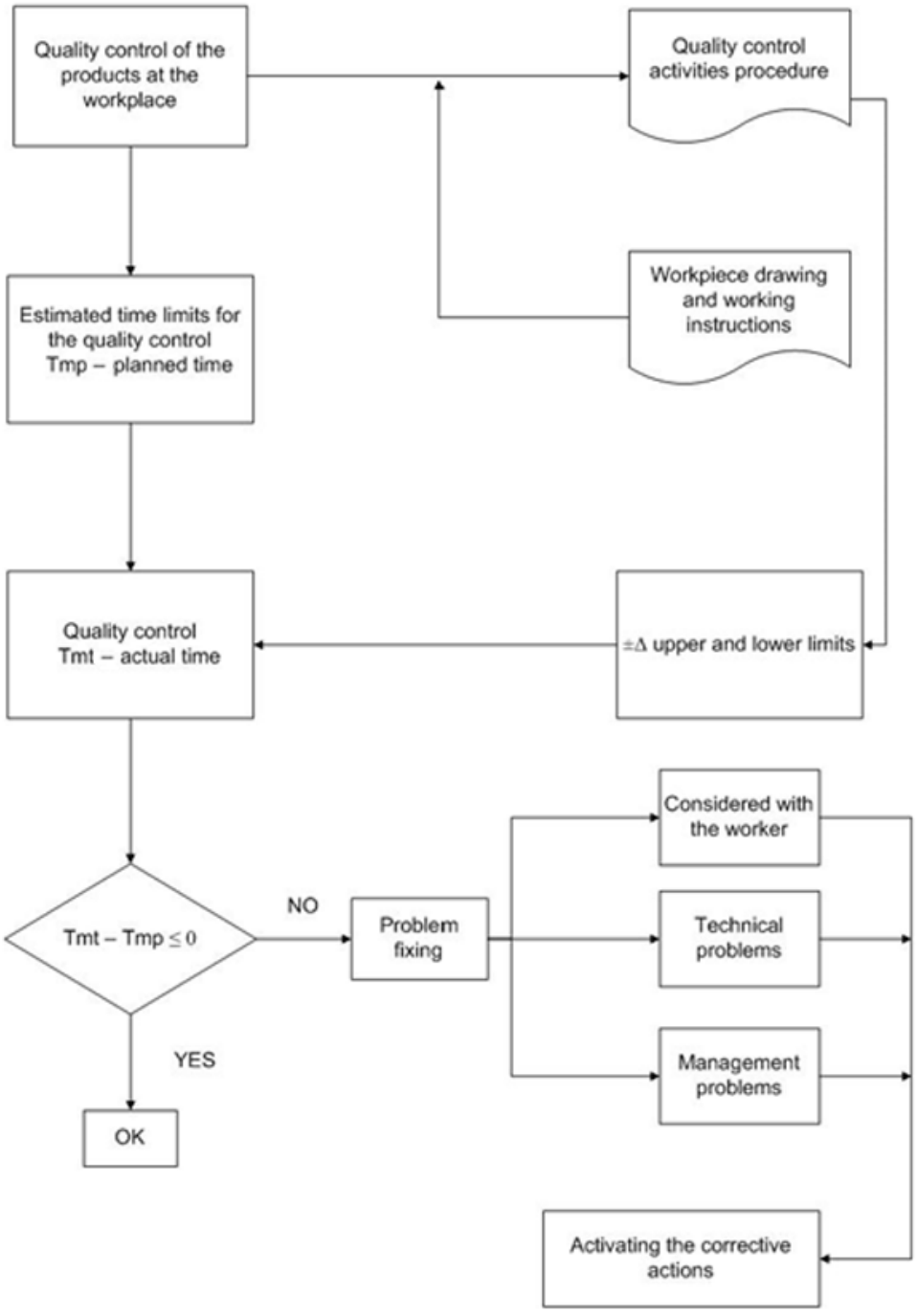

Fig. 5. Kanban signal delay for the quality control process. Tmp – total message processing time, Tmt – total message transfer time.

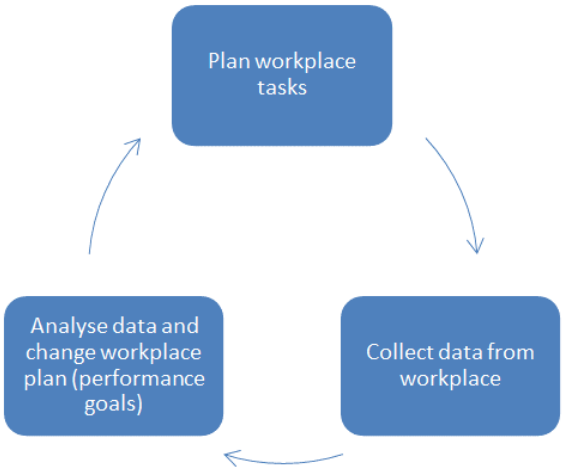

Fig. 6. Workplace information system's main domains.

7. CONCLUSIONS

The workplace is a significant unit of a production system (a company). The competitiveness of a company starts from the performance of its individual workplaces. The performance is measured through different key performance indicators, the real determination of which is very important. The current article describes performance analysis methods and the improvement process on the basis of an example. For minimizing the cycle time or total throughput time, the corresponding time-forming components have to be determined and the rules for optimization declared. This provides the possibility of developing a workplace performance monitoring system with the degree of automatically gathered information appropriate for the company. A prototype has been developed; its testing and improvement are underway. Our experiences in the companies have shown that the model can give possibilities of significantly increasing the efficiency (min 40–50%).

ACKNOWLEDGEMENTS

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Töökoha tulemuslikkuse analüüsi meetodid ja mudelid

Jaak Lavin, Jüri Riives, Sergei Kaganski, Rivo Lemmik, Marko Paavel ja Kaspar Koov

Töökoht on oluline nii tootmissüsteemis kui ka ettevõttes tervikuna. Ettevõtte konkurentsivõime aluseks on töökoha tulemuslikkus. Seda mõõdetakse erinevate tegevuse võtmenäitajate kaudu. Käesolevas artiklis on kirjeldatud töökoha tulemuslikkuse analüüsi, mis põhineb konkreetsel näitel. Toote läbivusaja või siis tootmistsükli aja vähendamiseks tuleb neid mõjutavad tegurid kindlaks määrata ja välja töötada optimeerimise reeglid. See loob eeldused ettevõtte-keskse töökoha tulemuslikkuse jälgimise automatiseeritud süsteemi loomiseks. On välja töötatud veebipõhine töökoha tulemuslikkuse jälgimise lahenduse prototüüp.