

High performance workplace design model

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Received 4 December 2012, in revised form 22 January 2013

Abstract. Processes are very fast in contemporary dynamic, turbulent and continually changing world. Systems supporting these processes become more and more complicated and are in mutual interaction. Design of high performance workplaces becomes more and more important for achieving competitiveness. In the current article workplace capability, formed by capability of technological resources and human resources, as well as lean manufacturing principles are analysed with an aim to design high performance workplaces.

Key words: workplace, technological resources, lean manufacturing, critical success factors, key performance indicators, process improvement, e-manufacturing.

1. INTRODUCTION

System is a set of interacting or interdependent entities that have certain functions and objectives. Workplaces are the elements that form systems in organizations. Workplaces have important role in every company and therefore the development and raising the performance of workplaces are critical for every company [1].

Traditionally a company is characterized by its structure, processes and technological possibilities of machine tools [2,3]. Entire view is more complicated, every level of industrial world [4] has its own place and role in creating a full image of the industry as well as in formation of objectives and increasing the rate of fulfilment of these objectives of an organization and its units. In Fig. 1, structural levels of the industrial world and general estimation criteria as well as conditional time delay between action and expected result are shown.

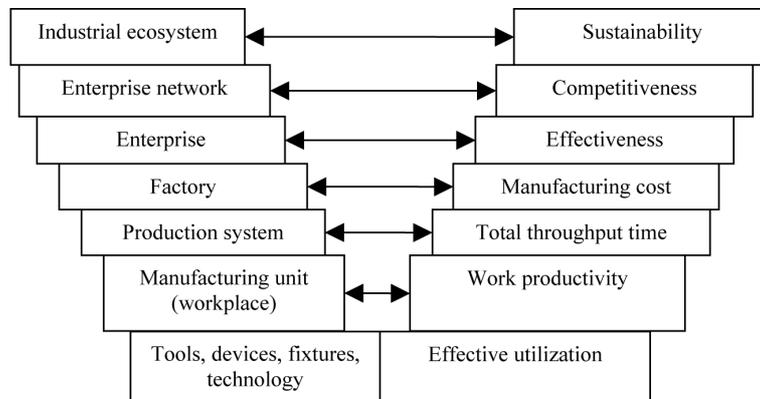


Fig. 1. Event–result interaction in practical structuring of a product – process levels towards intelligent network manufacturing.

In Fig. 1, only general (traditional) indicators [5] are presented, certain result indicators are connected with them. Indicators that are relevant for the strategy are called critical success factors (CSF). CSFs present the success of the company, business, project, process, etc. They monitor the achievement of the mission (Fig. 2). Company's strategic objectives are based on the mission that describes the company's main reason of existence [6]. Strategy is developed, based on the analysis of the operating environment of the company that allows describing the current situation and forecasting the future. One instrument for strategic communication is balanced scorecard (BSC) [6] that links performance metrics, derived from the enterprise strategy with the company's vision and strategic critical success factors, objectives and resources (Fig. 2).

Once the CSFs for each perspective are identified, it is important to identify the key performance indicators (KPI). KPIs quantify the objectives and reflect strategic performance and success of a company (or a process or a workplace). The application of KPIs provides executives with a high-level (company level) or real-time view about the progress in a process or workplace level. The main groups of KPIs are described in [7].

Production performance design matrix in a company and the general picture of a production performance monitoring system is presented in [8]. Starting from [8] and taking into consideration [9,10], the performance description model is given in Fig. 2. The model consists of three related parts:

- phase of forming company's objectives and tasks;
- phase of planning activities (for subunits, processes, workplaces etc);
- phase of estimating the results (results of simple events and actions as well as processes, projects or company as a whole).

The aim of the model is to consider a company as a system that is a part of the economic environment and to connect clearly different levels of company activities and theories used for estimating their performance.

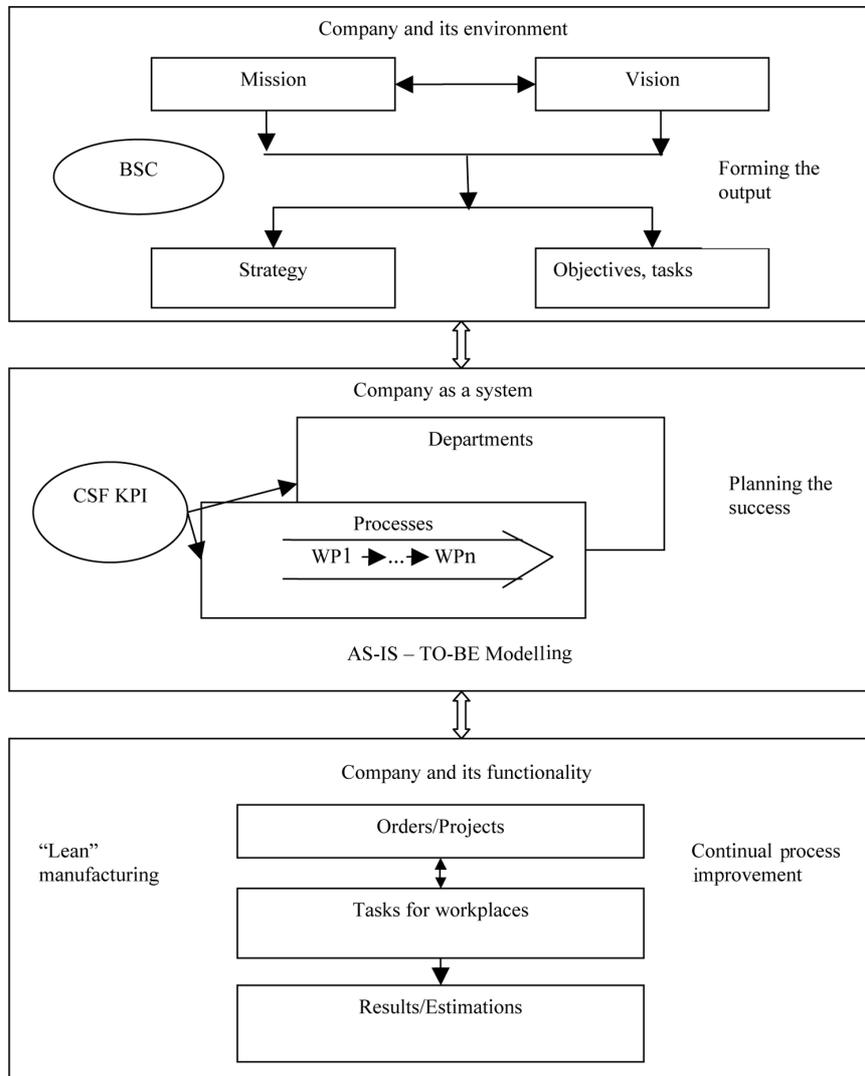


Fig. 2. Performance description model on the company level.

Cluster, company, manufacturing unit, and workplace – all these are complex and multifunctional systems and different indicators are used for the measurement of their performance and success. Performance and development are integrated with the aim to develop the system. Systems’ engineering is an interdisciplinary process that ensures that the customers’ needs are satisfied throughout the system’s entire life-cycle [11–13].

Functional development of the connection between management and workplaces is an important challenge and objective of intelligent manufacturing. To achieve effective and flexible connection between management and workplaces,

well-functioning model for estimating performance of workplaces has to be developed. At the same time, effective performance of workplaces is possible only when all requirements to the workplace are fulfilled.

2. MAIN PRINCIPLES OF WORKPLACE DESIGN

Workplace is an important part of the company, business process or production system. Workplace is designed for carrying out certain tasks. Essence of the workplace is described in [14]. Describing workplace in a production system, the important characteristics are its location, place in the production system, functionality and technological capabilities. Technological possibilities [15] of a machine tool and competences of its operator [16] determine the workplace capability. Workplace capability forms the basis for determining which details it is possible to process at this workplace, and creates preconditions for efficient performance (productivity, products' quality, expedient use of work time, accuracy of fulfilling work tasks, etc).

Activity–result relationship is general. Better results, compared with competitors, create preconditions for greater success in global market. Management theories [17] refer to the effectiveness of teamwork; quality management is based on the Deming's Plan (P) – Do (D) – Check (C) – Act (A) circle and process management principles [18,19]. According to these theories and practical experience with implementing quality management systems in different companies, it is clear that role and importance of every workplace performance plays more and more important role in the effectiveness of a manufacturing company (Fig. 3).

Leadership, formation of strategies, providing resources and assuring competitiveness are tasks of the management. Activities for continuous improvement that assure quality and ensure productivity, take place at the workplace. Performance of workplaces makes basis for the whole company's success and effectiveness. Therefore critical success factors or global achievement results are not enough. Processes have to be managed on the basis on actions taking place in workplaces, and their evaluation, analysis and decisions.

Workplace is part of a system that belongs to some unit (e.g. production unit, production system). Thus hierarchy of systems is formed in every company that has certain capability (technological possibilities and competence) and results that enable to estimate their success (depending on the hierarchy of the system in economic environment). Description of the capability and effectiveness of a workplace is presented in [1]. Workplace is a very important part of a production system or production process, because in a manufacturing process the workplace is a part of a chain of organizational-technical activities and fulfils functional tasks prescribed by production technology. Workplace has to enable manufacturing products that meet the quality requirements and to operate successfully. Workplace productivity is usually used for estimating workplace success [14]. Although productivity measurement is important, it does not allow to estimate

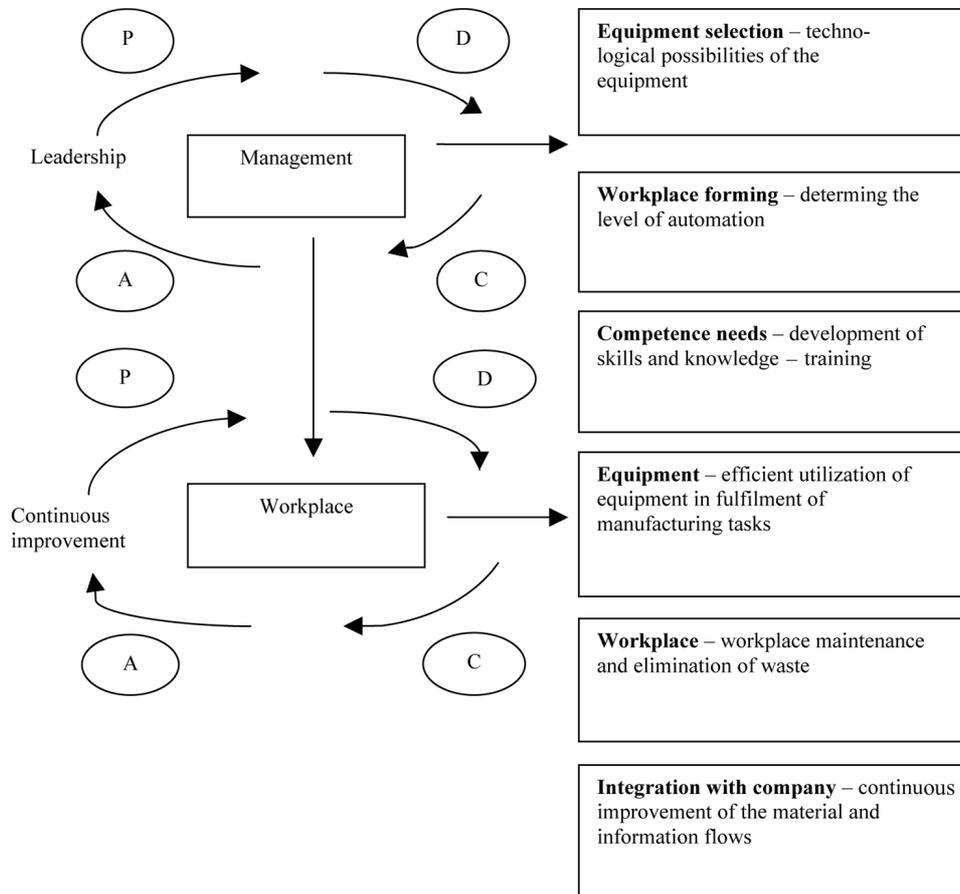


Fig. 3. Steps in workplace development.

adequately the capability of the workplace. The complexity of relations, related to the fulfilment of work tasks and groups of factors having influence to workplace performance, is illustrated in Fig. 4.

In Fig. 4 there are presented influence factors that could be divided into four groups:

- work preconditions;
- workplace specifications;
- source factors;
- impact factors.

As important as the essence of a workplace is its place in the order handling process. Essence and role of the workplace in the order handling process (Fig. 5) is based on the model of ontology of a production system [7].

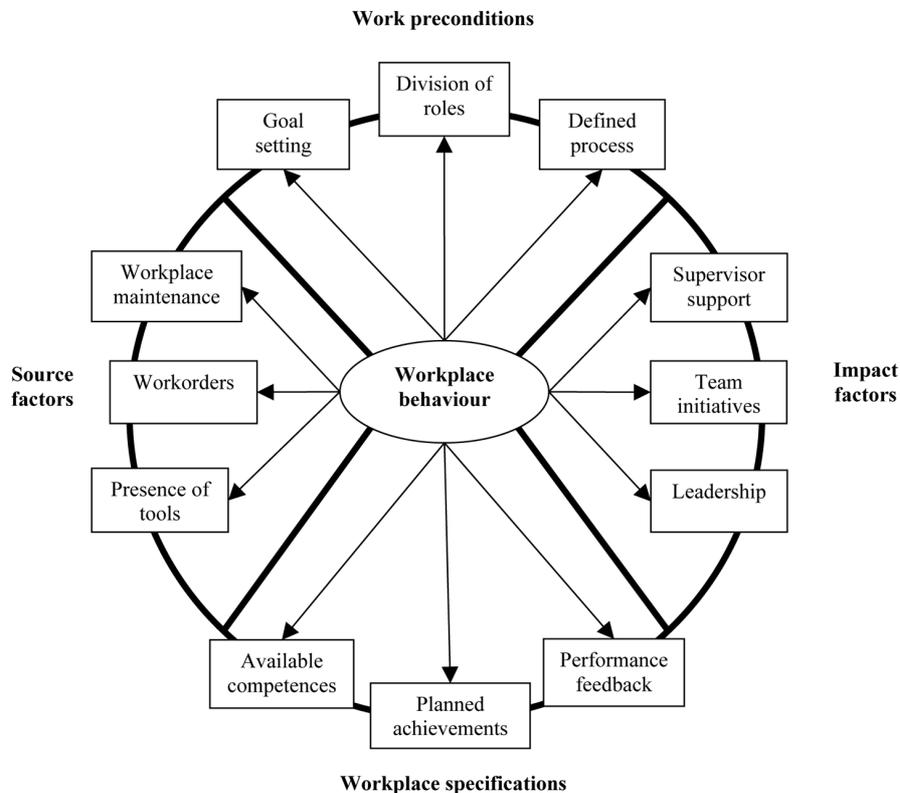


Fig. 4. Factors having influence on workplace effectiveness.

3. MODEL FOR WORKPLACE PERFORMANCE ESTIMATION

Order and order handling is viewed as a complex activity. Effectiveness of this activity forms the basis for the company's effectiveness and profitability. How effectively are workplaces organized and how effectively they fulfil work orders, influences directly effectiveness of order fulfilment. Machine time (main time with support time) rate to the duration of the production cycle in a workplace should be as high as possible. To achieve this, workplace centred methods to raise effectiveness should be used (Fig. 5).

In Fig. 5, the following abbreviations are used 5S – workplace organization method, including sorting, setting in order, sweeping, standardizing and sustaining the practice; JIT – just-in-time; 7waste – seven wastes of lean philosophy that do not add value (transportation, inventory, motion, waiting, overproduction, overprocessing, defects – the Kaizen methodology for continual improvement); Kanban – a scheduling system for lean and just-in-time production.

Production system is a number of workplaces that are used to perform certain manufacturing operations according to the manufacturing process and technology. Structure of the manufacturing process (Fig. 6) creates basis for company's

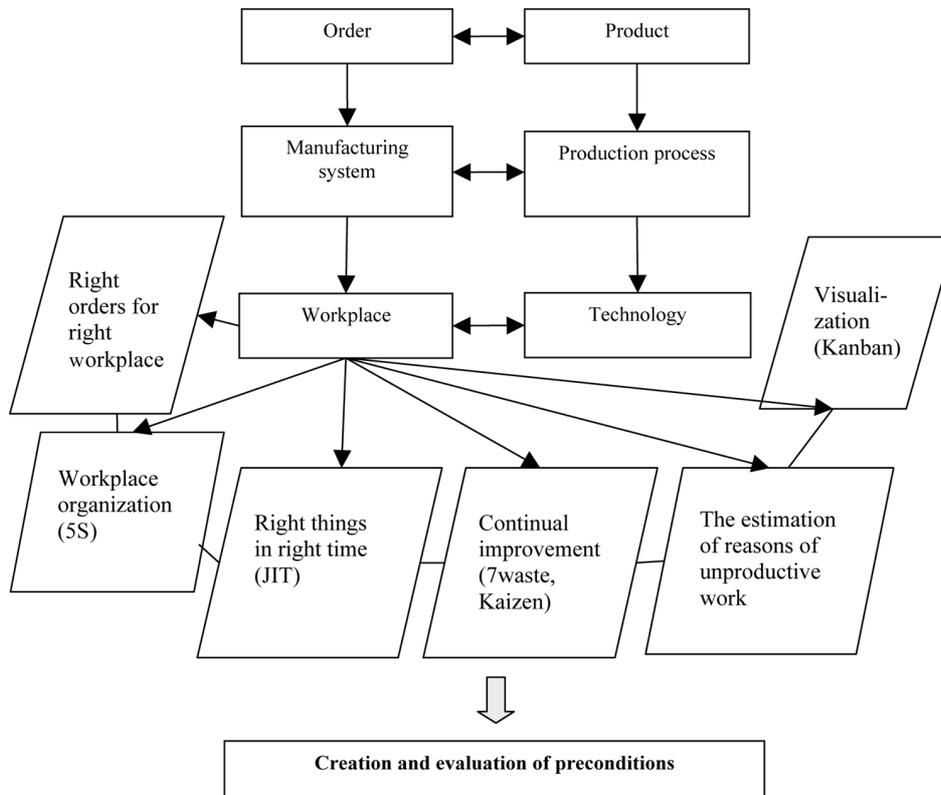


Fig. 5. Success factors of a workplace.

technological capability and possibilities to raise productivity by using rational technologies.

Technological improvements are usually expensive and their influence is considerable only by implementing cost-effective work organization at the same time. Main elements used in cost-effective work organization, related to the workplace, are presented in Fig. 5.

Technological preparation, related to product manufacturing and production planning, creates prerequisites for effective work at the workplace. Preparation should not be underestimated because it creates preconditions for zero defects manufacturing, achievement of planned productivity, etc (optimization of manufacturing routes, use of resources, etc).

Elaborating operation technology, one aim is to minimize product manufacturing costs at the workplace (Fig. 6). As usually different products have to be manufactured that requires different resources, use of alternative routes should be considered, with an aim to minimize throughput time at the same time. From here arises a task of modelling uncertainties and variability in the manufacturing environment [20]. Network manufacturing possibilities should be also considered for achieving the best results.

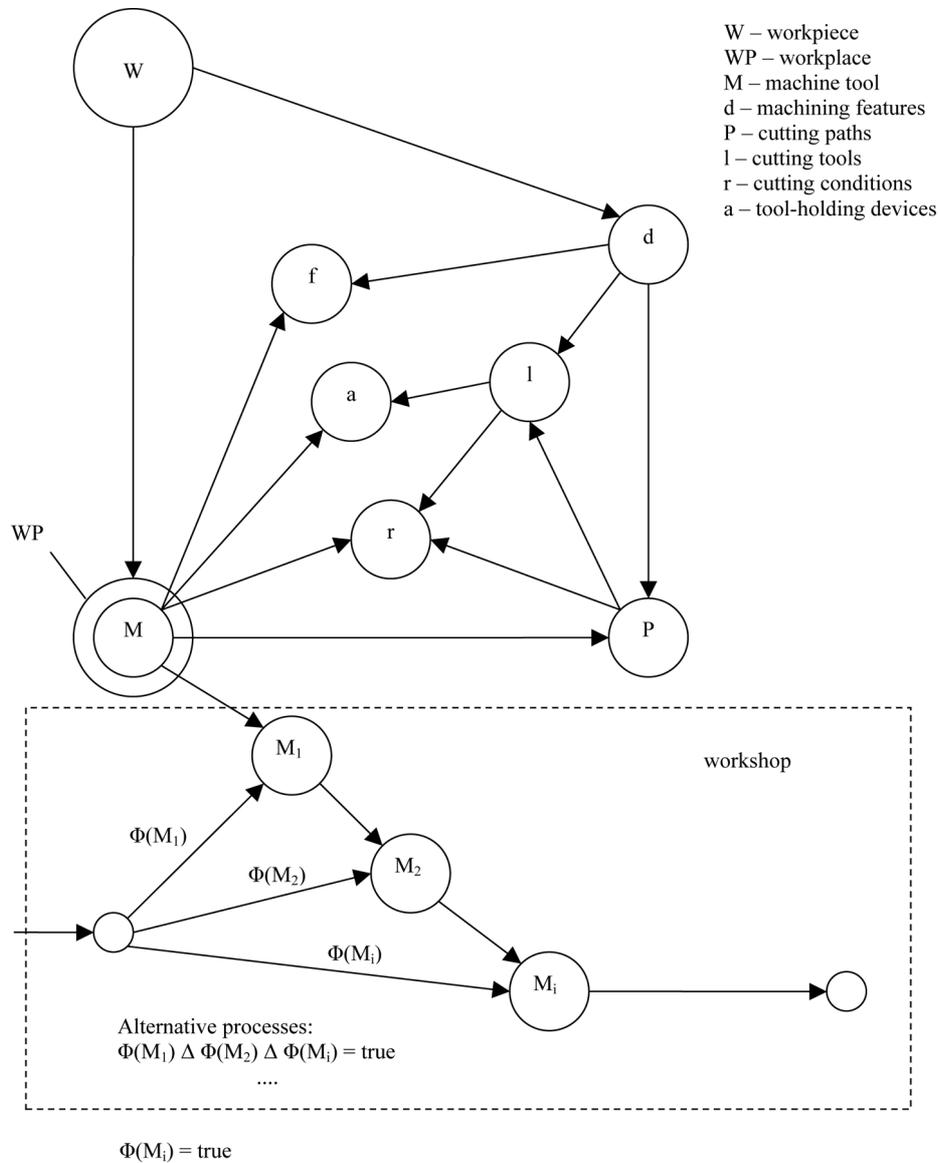


Fig. 6. Structure of the production process.

Use of planning models creates preconditions for minimizing operation cost and shortening the cycle time of product batch, but does not assure elimination of possible waste and fulfilment of planned tasks. Therefore the implementation of a complete model of performance is important.

Important is to pay attention to implementation principles of cost-effective manufacturing (eliminate waste). Hence, important criteria for evaluating workplace performance are:

- evaluation of the conformity of technical realization to the requirements;
- evaluation of preconditions for effective manufacturing.

Every workplace and department, participating in the order handling process, should know its tasks and seek for maximum efficiency and effectiveness in accomplishment of its tasks. Results are seen after the tasks (activities according to work order) are finished (Behaviour loop). Monitoring the results and comparing them with planned results is an important action in estimating the workplace performance.

Conceptual model of a high performance workplace is presented in Fig. 7. The model enables the following procedures:

- estimation of the suitability and readiness of the workplace for carrying out planned tasks;
- estimation of the workplace performance;
- comparison of the planned and actual results and presenting main non-conformities;
- risk assessment and determination of its importance;
- finding inputs for improvement the process and analysis for raising effectiveness.

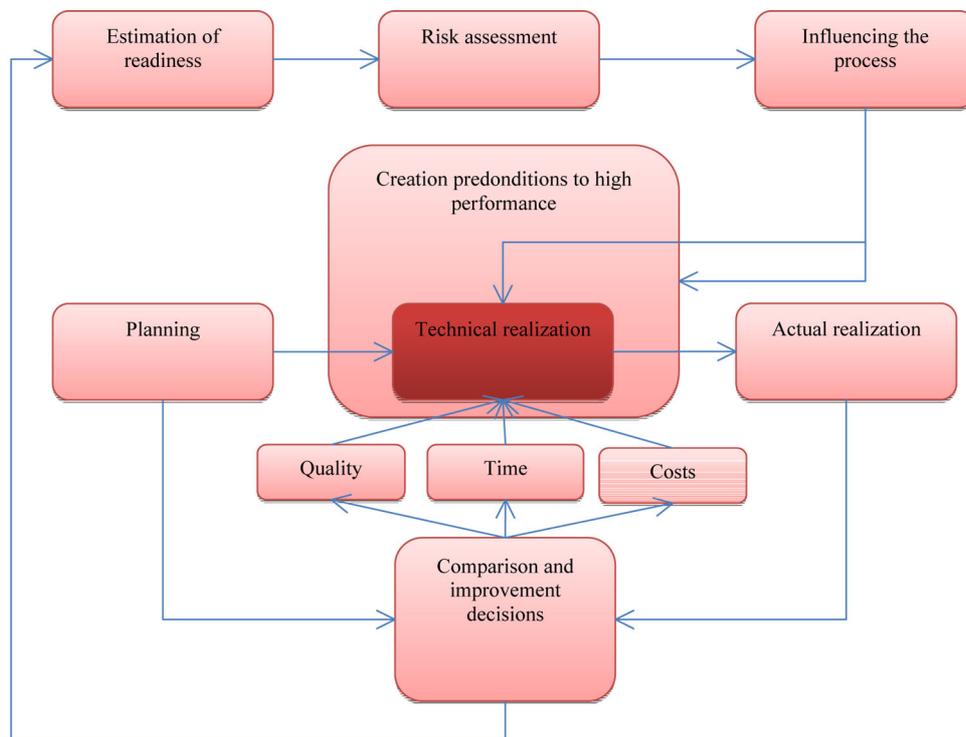


Fig. 7. Conceptual model of workplace effectiveness.

Estimation of the technical realization could be viewed from three viewpoints.

1. Quality of technical realization Q depends on the ratio of high-quality products to the total number of manufactured products:

$$Q = \frac{K_k}{K_s} \times 100\%, \quad (1)$$

where K_k is the number of high quality products and K_s is total number of manufactured products.

2. Estimation of the realization time (time spent for realization) T :

$$T = \frac{T_t}{F} \times 100\%, \quad (2)$$

where T_t is the time, needed for fulfilling the orders and F is the work time fund

$$T = \frac{\Sigma T_H}{F_s}, \quad (3)$$

where T_H is total time spent for order handling and F_s is the shift's work time fund.

3. Estimation of costs related to technical realization K is calculated as

$$K = 1 - \left| \frac{K_t - K_p}{K_t} \right|, \quad (4)$$

where K_t is actual costs and K_p is planned costs.

Index of efficiency of technical realization of a workplace can be calculated as

$$I = QTK. \quad (5)$$

Quantitative assessments are made possible by the estimation of technical realization level, while evaluations of the creating preconditions for efficient manufacturing are rather qualitative [21,22]. Such evaluations are comparative, e.g. 20 keys (20 focus areas that will help the organization to build a sustainable continuous improvement culture), EFQM (European Foundation of Quality Management Excellence model), SPICE (Software Process Improvement and Capability Determination), etc. By evaluating creation of preconditions for efficient manufacturing, the following aspects are important:

- maintenance of the work environment – 5S;
- preventive maintenance and repair of manufacturing equipment;
- work organization and motivation system;
- management and information flows.

Effectiveness of order handling, effectiveness and competitiveness of a company are based on the performance of workplaces. Order handling is a

complex activity that comprises the whole company. All employees have to give their dedication to fulfil their tasks in time and with high quality.

Every company seeks continual improvement. Main characteristics of effectiveness (evaluation factors based only on time) are presented in Table 1.

Explanation of the notations used in Table 1 is the following.

T_{TH} is the order fulfilment time, i.e., time for completing the whole order handling process, starting from receiving an order from the customer until the delivery of the product to the customer. In broader sense, order fulfilment time reflects the time it takes to respond to customer orders. Sometimes a more narrow approach is also used, which is the time period from the receipt of the order and until it is available for packing or shipment. This is also called as the production lead time.

T_{TS} is manufacturing throughput time (also known as throughput time) – the period required for a material, part or subassembly to pass through the manufacturing process. Throughput time could be expressed as the sum of the cycle time, transportation time, final control time and idle time:

$$T_{TS} = T_{SM} + \sum_{i=1}^r T_{R_i} + \sum_{i=1}^c T_{C_i} + \sum_{i=1}^x T_{X_i}, \quad (6)$$

where T_{SM} is the cycle time, T_{R_i} is the summarized transportation time in the manufacturing process, r is the number of transportation operations, T_{C_i} is the summarized final control time, c is the number of final control actions, T_{X_i} is the summarized idle time and x is the number of different types of the idle time.

Table 1. Analysis of effectiveness of a workplace and process

Elements of evaluations	Elements of analysis
Order fulfilment time (T_{TH})	Use of working time (importance of value creating time in production process)
Importance of manufacturing in order fulfilment process, % (T_{TS}/T_{SM})	Main reasons of non-productive work
Importance of cycle time in throughput time, % (T_{SM}/T_{TS})	Level of achieving the objectives Index of employee satisfaction
Importance of machining time in cycle time, % (T_m/T_{SM})	Contribution of a employee as a team-member
Importance of loading and unloading time in cycle time, % (T_p/T_{SM})	Dynamics of effectiveness (changes and improvements in production process)
Importance of setup time in cycle time, % (T_s/T_{SM})	Cost factors and their dynamics in production process
Importance of machining time in cycle time, % (T_m/T_{SM})	Quality assurance
Importance of idle time in throughput time, % (T_X/T_{TS}) and in order fulfilment time, % (T_X/T_{TH})	

T_{SM} , the cycle time, is the period required to complete an operation or a job from start to finish. Cycle time consists of different times:

$$T_{SM} = \sum_{i=1}^m (T_{m_i} + T_{p_i} + T_{s_i} + T_{k_i}), \quad (7)$$

where m is the number of machine tools used to manufacture the product, T_m is the machining time, T_p is the workpiece loading and unloading time in the machine tool, T_s is the machine tool setup time (a period required to make a machine tool ready to fulfil an operation) and T_k is the measurement and control time of the machine tool during fulfilling an operation.

Machining time directly creates value to the product. Workpiece loading and unloading time depends highly on the automation rate. Typically workpiece loading and unloading time is minimized, using, for example, two-position working tables (at one side machining takes place, at the other side loading or unloading of the workpiece). Machine tool setup time depends on the operator's competences but also on technological possibilities of the machine tool. Idle time is non-productive time (during which an employee is still paid) of employees or machine tools or both, due to work stoppage from any cause. Reasons of idle time could be different, e.g., waiting for materials or instructions, waiting previous operation to be finished, walking from one department to another but also power failure, waste of time by the operator (laziness, no motivation). Idle time could be divided into normal idle time and abnormal idle time. Some idle time always remains, but it should be kept as low as possible. Therefore especially roots of abnormal idle time should be found out and eliminated.

4. INTEGRATION OF A WORKPLACE WITH THE PROCESS AND THE SYSTEM

The process organization in a company is the central part of the process-oriented corporate design [23]. While the organizational structure divides the company into partial systems (departments, workshops, units, etc) with their determined capabilities [1], the process orientation deals with the execution of orders (in the company level) and tasks (in the workplace level) in the timely oriented sequence with the flow of simple events.

Process is a sequence of simple events that are in chronological, spatial and logical order that makes inputs into outputs for purpose in the best possible way. System is a set of processes or processes realized in a certain system on the basis of workplaces. The more different are orders, the more flexible has to be the system and the more complicated is fulfilling the work orders at workplaces. Workplace has a leading role in the manufacturing process because it is the executor of a simple event or manufacturing operation according to the planned manufacturing technology (Fig. 6). Planning is based on production volumes (objectives) and uses mathematical methods for optimizing theoretical results of a process (routes and tasks to workplaces for a day, shift, etc).

Table 2. An example of the system–process–workplace integration

Goals	Activities
System goal	The evaluation of the suitability of producing certain products in a certain production system, rational use of technological capabilities
Process goal	The evaluation of alternative routes based on the net cost of the product and more effective use of resources
Workplace goal	Reducing idle time by analysing and eliminating the reasons of its occurrence
Personal goal	Improving competences and making suggestions to create preconditions for productive work (see Fig. 5)

The objectives of the company under review must be determined in order to evaluate the analysed as-is model [23–25]. As-is models could be supported by the reference models and/or benchmarking. The primary goal of as-is modelling is the presentation of existing structures and processes in a company. Using an as-is model, the existing process and its planned outputs, depending on the determined inputs, form the basis. As-is model is a structured reflection of reality. Process is described by a flow-chart, connecting simple events, their executors and expected (planned) results. Additional important goal of the as-is analysis is to create a list of weaknesses and potential improvements as completely and consistently as possible, based on collected models. Processes are bearers of simple events and generate measurable outputs. The most important reference point of the to-be modelling is definition of the performance of the process. The to-be models must achieve an operable degree of detailing to be able to evaluate in detail the resulting effects on the organization, the activities to be carried out, and the communication links between them with respect to different core parameters [23].

As-is and to-be modelling makes the connections between the objective and the result. Process plays central role in modelling, and connections of the process with the system and workplaces are analysed. The system creates preconditions for planned realization of a process and workplaces have to assure efficient fulfilment of the tasks. Improvement activities begin from employees, who carry out their tasks at workplaces. An example of system–process–workplace integration for improving the organization’s effectiveness and competitiveness is presented in Table 2.

5. CONCLUSIONS

The key factors that can influence the company’s workplace performance have been investigated. Workplaces play an important role in the organization’s competitiveness. Connections between the system, processes and workplaces and a framework of the workplace performance model with the aim to optimize the efficiency of workplaces and competitiveness of the company have been presented.

ACKNOWLEDGEMENTS

This research was partially supported by Innovative Manufacturing Engineering Systems Competence Centre IMECC (supported by Enterprise Estonia and co-financed by the European Union Regional Development Fund, project EU30006), by Estonian Ministry of Education (Research Project SF0140113Bs08) and Estonian Science Foundation (grant F7852).

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Suure jõudlusega töökoha loomise mudel

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Tänapäeva dünaamilises, turbulentses ja pidevalt muutuv maailmas toimuvad protsessid väga kiiresti. Neid toetavad süsteemid muutuvad järjest keerukamateks, põimuvad üksteisega ja mõjutavad üksteist vahetult. Seetõttu muutub suure jõudlusega töökohtade loomine ettevõtete konkurentsivõime saavutamise seisukohalt üha olulisemaks. Käesolevas artiklis on analüüsitud tehnoloogiliste ja inimressursside koostoides tekkiva tehnoloogilise efektiivsuse ning kulusäästliku juhtimise põhimõtteid eesmärgiga kujundada suure jõudlusega töökohti.