View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

ISSN 1846-6168 (Print), ISSN 1848-5588 (Online)
ID: TG-20170124193850

Preliminary communication

THE IMPACT OF WORKPLACE SUPPLY ON PRODUCTIVITY IN FUNCTIONALLY ORGANIZED LAYOUTS

Grega KOSTANJŠEK, Brigita GAJŠEK

Abstract: In practice, way of supply of workplaces often affects production process realization. This is particularly true in the majority of small and medium enterprises in non-automotive sector, where production is functionally organized. Literature review confirms that production processes and their logistics support are organizationally and operationally connected to each other and in most cases even inseparable, performed by the same employees. The latter restricts efforts to determine the impact of supply on overall equipment effectiveness (OEE) and on productivity in a broader sense. Assessed impact of supply on OEE indicator forms an excellent starting point for decision making and planning of investments in production and inbound logistics. Practice shows that investments in production machines prevail over investments in inbound logistics. Why to invest in logistics is constantly recurring question between production managers, especially in nonautomotive sector. Operation and flow process charts are upgraded and used in combination with the equation for OEE indicator to determine the impact of supply (logistics) on Availability and on productivity in a broader sense.

Keywords: OEE; functional layout; productivity; inbound logistics; workplace; supply

1 INTRODUCTION

Productivity is a term that constantly hovers between employees and management, especially in automotive industry [3], where experts and researchers are not focused only on the production lines but also on logistics. Logistics can be seen as a key competitive factor in the automotive industry due to the rising number of model variants and options [1]. With the increasing importance of logistics [2], the evaluation of logistics effectiveness and efficiency is gaining increased attention. While the most advanced automobile industry develops and implements logistics performance management (LPM) [1], many other production companies are even unable to distinguish between logistics and technological operations. Nowadays, picking and sequencing of parts are not everywhere a core logistics activity, although from the perspective of the automotive industry this would be highly expected.

From the perspective of managers, at first sight, the easiest ways toward increased output are increasing overtime, increasing number of shifts [17], the introduction of machines with higher capacity, and the transition from manual to automated production. Less frequently, companies approach to productivity improvement progressively, with separation of logistics and technological operations on workstations with low value of Overall Equipment Effectiveness (OEE). Generally, it is difficult for companies to link supply of workstations (logistics) with productivity, especially since the same workers are performing alternately logistic and technological activities. It has been a known fact that the productivity of work system depends on the number of installed workplaces and logistics needed to produce a defined amount of units: the more wastes of time, such as walkways, idle times or non-value-adding handling operations a work system includes, the higher is the number of required employees and lower is the productivity [3,15].

Production companies are mostly familiar with OEE, which measures the gap between the actual performance and the potential performance of a manufacturing unit. OEE shows how well a company is utilizing its resources, which include equipment, labor and the ability to satisfy the customer. The OEE can be recognized as a tool that helps companies to determine the workstations with potential for improvements. An OEE score of 60 % is fairly typical for discrete manufacturers, but indicates there is substantial room for improvement [17].

Productivity focused managers can orient using several indicators. Three of them are OEE, Single Resource Productivity (SRP), and Total Resource Productivity (TRP). They all evaluate how effectively companies utilize production operations and the trend. However, OEE does not demarcate the logistics impact from technological one. For this purpose it is necessary to combine OEE with an additional methodology to explain indicator OEE on an analytical level. Distinction between two types of influences is important, because it indicates where to invest to improve productivity, in logistics or in technology.

In this paper we focus on the non-automotive sector, discrete manufacturing and SME type of company in order to develop a simple methodology that will help described companies make the first step towards defining the boundaries between logistics and technological activities and start with continuous improvements. Practice in automotive industry shows that it is necessary and possible to increase productivity. For this reason, a kind of process analysis was developed for a systematic approach to seeking time reserves in production processes organized on functional layout in SMEs. The fundamental contribution of the proposed procedure is firstly to determine the share of non-value added and logistics activities in production processes, and secondly to point on root causes for time inefficiency and connect them with the responsible persons/departments. In production companies, times and types of necessary logistics activities are often not recorded in databases of business information systems. Generally, the formal technological procedures or routings define only preparatory closing times and piece times. Times of delays and transports between workstations are not planned. This situation is problematic in cases when someone is looking for areas with potential for improvement in terms of saving time. The latter is nowadays essential for business survival.

Improved analytical approach for distinguishing logistics and technological activities at any kind of workplaces serves us as base for defining the share of supply of workstation in OEE on a selected case in practice. Additionally, the relation between OEE and productivity will be discussed.

2 THEORETICAL FRAMEWORK

2.1 Productivity

The term productivity was probably first mentioned by French mathematician Quesnay in an article in 1766 [4]. In 1883, another Frenchman, Littre, defined productivity as "faculty to produce". In 1950, the Organisation for European Economic Cooperation (OEEC) issued a formal definition [16]: "Productivity is the quotient obtained by dividing output by one of the factors of production. In this way, it is possible to speak of the productivity of capital, investment, or raw materials, according to whether output is being considered in relation to capital, investment or raw materials, etc." In 1979, and later in 1984, American Productivity Center (APC) offered the first three (and in 1987 the fourth) basic definitions of productivity, particularly as relevant to companies [5]:

- Partial productivity is the ratio of output to one class of input. For example, output per person-hour (a labor productivity measure) is a partial productivity concept;
- Total factor productivity is the ratio of net output to the sum of associated labor and capital (factor) inputs. The net output here is sometimes called value-added output. In this ratio, we explicitly consider only the labor in capital input factors in the dominator;
- Total productivity is the ratio of total output to the sum of all input factors. This is a holistic measure which takes into consideration the joint and simultaneous impact of all the input resources on the output, such as manpower, materials, machines, capital, energy, etc.;
- Comprehensive total productivity index is the total productivity index multiplied by the intangible factor index. This is the most sophisticated measure that extends the total productivity measure to include any user-defined qualitative factors – as many as are relevant to a company – ranging from product quality and process quality to timeliness, market share, community attitude, etc.

Most of the indicators used by companies today are non-standard and cannot be distributed to any of above four basic productivity definitions, although companies are convinced that they are measuring productivity. Labor productivity is still often set in foreground. On the other hand, scientists try to determine total productivity and the broader, holistic productivity concept. Sumanth [4] stated some misconceptions about productivity. It is applicable to know the following truths, which are antonyms of mentioned misconceptions:

- production improvement does not necessarily mean productivity improvement;
- efficiency improvement does not guarantee productivity improvement;
- improvement in sales revenue does not necessarily ensure productivity improvement;
- quality improvement does not have to be at the expense of productivity.

Partial productivity, for example labor productivity expressed as output per man-hour, is a ratio of output to one type of input. Labor productivity originates from Taylor's scientific management. Work-study specialists and industrial engineers continue to place great emphasis on the output-per-man-hour measure to set up time standards, to prepare labor efficiency reports and to do labor planning and unit labor costing. Although Sumanth [4] suggests replacement of partial productivity with total productivity measure, this is unattainable in practice. However, precisely because of that it is important to be aware of partial productivity measure limitations [4]:

- if used alone, can be very misleading;
- do not have the ability to explain over-all cost increases;
- tend to shift the blame to the wrong areas of management control;
- profit control through partial productivity measures can be a hit-and-miss approach.

In practice, despite everything, the prevailing opinion is that low labor productivity threatens the survival of the company [13]. Productivity is often linked with "time and motion" [14]. The evidence of time and motion studies was used to put pressure on workers to perform faster. Not surprisingly, these studies had a bad press as far as workers were concerned. Similarly, the image of "time and motion" does not sit well with productivity specialists.

2.2 Manufacturing performance measurement system

The leading indicators of business performance cannot be found in financial data alone. Performance measurement is the process of quantifying action, where measurement is the process of quantification and action leads to performance. Companies achieve their goals by satisfying their customers with greater efficiency and effectiveness than their competitors [18]. The terms efficiency and effectiveness are used precisely in this context. Effectiveness refers to the extent to which customer requirements are met, while efficiency is a measure of how economically the firm's resources are utilized when providing a given level of customer satisfaction. This is an important point because it not only identifies two fundamental dimensions of performance, but also highlights the fact that there can be internal as well as external reasons for pursuing specific courses of action [19]. Take, for example [20], one of the quality-related dimensions of performance – product reliability. In terms of effectiveness, achieving a higher level of product reliability might lead to greater customer satisfaction. In terms of efficiency, it might reduce the costs incurred by the business through decreased field failure and warranty claims. Hence the level of performance a company business attains is a function of the efficiency and effectiveness of the actions it undertakes, and thus:

- A performance measurement can be defined as the process of quantifying the efficiency and effectiveness of action;
- A performance measure can be defined as a metric used to quantify the efficiency and/or effectiveness of an action;
- A performance measurement system can be defined as the set of metrics used to quantify both the efficiency and the effectiveness of actions [21].

This article will focus on the issues associated with designing the process for quantifying the efficiency in general workplace.

According to [6], "Operations management literature considers throughput as a part of performance measurement." The throughput is output/machine hour or capacity utilized. TPM, a concept for corporate change, includes a way of defining OEE [7]. The definition of OEE includes downtime and other production losses, which reduces throughput. The definition of OEE does not take into account all factors that reduce the capacity utilization, e.g. planned downtime, lack of material input, lack of labor etc. OEE is just a useful component of a complete overall manufacturing performance measurement system, but it does not allow classification of observed inefficiency on technological and logistical causal areas.

The basis for implementation of any performance measurement system is trusted and quality data. In the TPM literature, collection of trusted data is something left to the inventiveness [6]. Usually several complementary systems are used, but neither of those data collection systems gives an appropriate and comprehensive picture of the losses and reasons for them. Companies can choose between manual and automatic data collection systems. Manual data collection systems are, in comparison with automatic data collection systems, cheaper, less complex, more detailed and failures can be carefully examined. Since there is no unified picture about lost productivity and reasons for it, there is also no general agreement on the magnitude of different types of losses, nor on the reasons for losses [26]. The reason for collecting data should not be to present neat figures, but to create a base for action and development of processes [27]. The set of measures should cover those aspects that indicate potential future improvements and the measure should in itself identify and generate continuous improvements, instead of working as passive control. The objective for future research of data collection should be finding a method that is not time-consuming, is at the same time precise and gives trusted data.

Performance measurement systems are often analyzed in scientific literature. Most studied companies seriously need to consider changing their performance measurements [28] because they use wrong measures or fail to use the right measures in correct ways. This was assessed as serious and therefore it seems important to identify the critical dimensions in a performance measurement system (what to measure) and the optimum characteristics of the measures (how to measure) [29]. New performance measurement systems should be dynamic and time should be important as a strategic performance measure.

Efficient flow of materials and short throughput times depend on effective manufacturing, comprising production and logistics actions; therefore we have to measure horizontal business processes instead of functional processes. This leads to flow-oriented measures. One way of switching to flow orientation is to measure times and throughput volume [30].

2.3 Process analysis based on ASME standard

The literature on tools for process analyses was reviewed with aim to find one for detecting inefficiency in production arising from logistics and separately technological activities. It should help to identify root causes for any kind of inefficiency. Frank and Lillian Gilbreth's Operation and Flow process charts have proved as good starting point and techniques of motion and process analysis, which unfortunately did not meet all our needs. They [31] defined process charts as "a device for visualizing a process as a means of improving it."

Later adopted ASME standard defines a flow process chart as a graphic representation of the sequence of all operations occurring during a process or procedure, and includes information considered desirable for analysis such as time required and distance moved. According to ASME standard, for analytical purposes and to aid in detecting and eliminating inefficiencies, it is convenient to classify the actions, which occur during a given process into five classes, known as operations (produces and accomplishes), transportation (moves), inspection (verifies), delays (interferes), and storages (keeps). Each class is represented with graphical symbol. These symbols serve as verbs, describing the actions, and provide observers with a powerful common language for describing work. They are an outstanding set of categories that are:

- mutually exclusive - each one represents a distinct type of action;
- universally applicable - they occur in all work areas (engineering, legal and other);
- comprehensive - they cover the work processes completely [19].

In the early 70s, Graham introduced additional three variations of the aforementioned operation symbol.

Symbols were later incorporated into a revised ASME Standard [32]. Two of them show "value-added" steps in information processing. Those are "origination" and "Add/Alter". "Origination" represents the creation of a record or a set of documents and "add/alter" an addition or change of information on an existing record or set of documents. The third symbol stands for "Handle" and represents make ready and put away, loading and unloading and all sorts of activities that do not involve information change.

The aim of the process chart has remained the same as in 1927. Several articles and multiple uses in practice have revealed the usefulness of Gilbreth's approach, sophisticated by Graham, for process analysis requirements. In practical part of this paper process charts were used for inefficiencies detection at production workplaces arising from logistics and to define causes for them.

2.4 Needs for customization and reuse of process charts

Implementation of manufacturing performance measurement system demands setting standards for performance measures. Setting those standards in general conflicts with continuous improvement [33] and the ability to be flexible. Carelessly set standards have effect of setting norms rather than motivating improvement. Continuous improvements and flexibility are important characteristics of SMEs in wood and metal processing sectors [34].

Logistics plays a vital role in economic systems and in everyday life. Given the significant cut of production and workforce costs, reducing logistics costs has also become an increasingly important task for managers. The latter are often hidden for identification, especially in production halls. In the face of competition, most sectors of European industry have made substantial efforts to upgrade their production infrastructures and integrate new forms of organization. One of further possibilities in reducing costs is in logistics industry as business supporting services provider. The global logistics industry is estimated at roughly 5.4 trillion euro or 13.8 % of the global GDP [22]. On average, logistics costs account for 10-15 % of the final cost of the finished product. Logistics therefore has great potential for cost reduction.

Costs of activities can be gradually reduced by eliminating activities that do not add value or by reducing their duration. Time management is extremely important also in production halls where logistics is mostly not recognized as function contributing to effectiveness. However, even in this field conditions are changing [23,24,25]. Trendy applications of lean thinking to productions companies require elimination of all types of unnecessary productivity losses that could in some cases largely fall on logistic activities. In order to eliminate wastes and improve lead-times it is certainly important to develop methodologies for searching non-value adding activities in production environments and wider.

Today companies are free to implement value stream mapping, Kaizen, any kind of performance measurement system, document their processes, and perform audits or certifications. However, not many SMEs can afford systems demanding a lot of administration, time and money. Today's companies are open to more simple solution that will help them to improve their processes faster and cheaper.

2.5 Overall Equipment Effectiveness

The equipment is a basic working tool in every production. Handling it in an inappropriate way is almost intolerable and performing preventive maintenance is a necessity. However, it happens that workers use machines and equipment until they break. Such unplanned defects decrease productivity in the absence of in-process inventory. Consequences are loss of revenue, missed deliveries, and waste of resources.

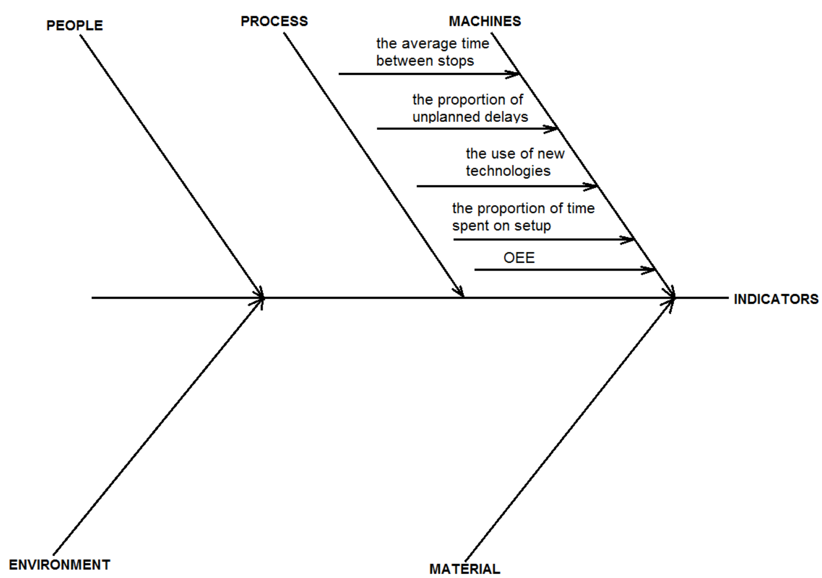

Figure 1 Indicator for "Machine" [27]

The production processes constantly repeat. Cyclicality allows the use of known methods and techniques for control and improvement. Historically, financial indicators were the most common way for operation valuation. However, over time this type of performance monitoring led average company to extremely poor performance. Companies have employed labor force, bought new machinery and equipment regardless of customer orders, rotate suppliers in order to achieve the lowest possible cost, while ignoring quality, the uncertainty of supplies and increased cost of large orders, etc.

In the last fifteen years due to the impact of total quality management implementations and Japanese manufacturers' competition on the market with short delivery times, companies slowly replace traditional cost and financial indicators with new or simply add additional ones. One of the biggest challenges in designing a system of indicators is to convince senior management and owners to satisfy with less than twenty indicators [35]. The indicators may be indexes, coefficients or shares.

Various indicators fall within different influential areas on Cause-effect diagram designed by Kaoru Ishikawa, Fig. 1. In many years of research, he discovered that causes for problems generally originate from five areas, namely process, machines, people, material, environment and measurements. OEE indicator very well covers the area "machines" on which we want to monitor the impact of supply [7].

OEE is a measurement method that is commonly used by companies on their way towards a Lean production where in specified it is a percentage number that is usually defined by multiplying the calculated availability rate, performance rate and quality rate [5]. It is a measure of equipment utilization in relation to its full potential. OEE and its individual factors give the company numbers to see where the equipment is losing time [6,5].

Availability (1) takes into account Down Time Loss. It is a percentage number that shows how often the machine is available when needed for production. It accumulates two wastes, breakdowns and setup/adjustments, which are downtimes measured at the equipment.

$$Availability = \frac{OT}{PPT} \tag{1}$$

OT – Operating Time
PPT – Planned Production Time

Performance (2) takes into account Speed Loss. It takes into account minor unplanned stops, for example idling and operation at a lower speed than the built-in.

$$Performace = \frac{ICT}{\frac{OT}{TP}} \tag{2}$$

ICT – Ideal Cycle Time
TP – Total Pieces

Quality (3) takes into account Quality Loss. The quality ratio includes losses due to ejection produced by the machine, as well as losses due to the occurrence of errors.

$$Quality = \frac{GP}{TP} \tag{3}$$

GP – Good Pieces

Improving OEE (4) should not be the only company's objective. OEE gives companies three values, which are all useful individually as situation changes from day to day. It also helps to visualize performance in simple terms.

$$OEE = Availability \cdot Performance \cdot Quality \tag{4}$$

The machines in discrete production usually have OEE rates between 45% and 65%. Companies' aim should be values from 85% to 95% [36].

3 METHODOLOGY

Inbound logistics activities are recognized as a potential for improvements to gain shorter lead times and increase productivity. Automotive industry is much ahead from other production sectors because of its specific, very work intensive environment. But competition is present in all production environments, not only in automotive one. We observed a segment of production companies that lags behind. Their employees perform alternately logistics and technological activities and achieve a low OEE indicator. Such companies need cheap, easy to use and effective methods to collect data for decision making on future improvements and investments.

Companies' needs for determining the share of non-value added and logistics activities in production processes were noticed in Slovenian wood and metal processing sectors, specifically in SME with production processes organized on functional layout. 20 selected companies mostly:

- dispose with limited financial resources to invest in development and implementation of new technologies;
- have lack of trained employees who are free to implement any kind of manufacturing performance measurement system;
- are not aware or are unwilling to admit the existence of reserves on side of logistics;
- have limited options for automation;
- did not install the mechanism of continuous improvement yet;
- are familiar with the principles of lean production, but practical implementation is weak.

Typical for functional layouts is the large amount of transportation and handling. Workstations that frequently interact with movement of material, semi products or people are located close together. Products are produced in batches and all machines performing similar type of operations are grouped at one location. Companies exploit this layout when the production volume is not sufficient to justify a product layout. Its limitations are backtracking and long movements of materials/semi products, inability of mechanized material handling, prolonged process time, lower inventory turnover, frequent set-ups, longer throughput time and work-in-process ties up space and capital [5].

Functional layout largely influences on efficiency of logistics activities, although this is not always recognizable by managers. In such production facilities, in addition to machines, there are many chaotically distributed logistics units and means of transport. In the researched branch, 5S method is usually completely unknown to managers, Fig. 2.

Figure 2 Common situation in observed companies

Firstly we improve Gilbreth's approach, sophisticated by Graham, for process analysis requirements. The goal was to develop a tool for inefficiency detection in production processes adapted to the requirements of our time.

Methodology for process analysis was spontaneously developed at the Faculty of Logistics, University of Maribor, through the last six years. At the beginning we were using original ASME standard for flow process chart. The standard was used to present information on existing and proposed processes. Because the feedback information for partner's companies was possible to present in a simple form, the methodology became immediately applicable by students and employees in observed companies before any changes in their processes whatever actually were made, so that the special knowledge and suggestions of those in positions of minor importance, skills and knowledge were fully utilized.

The idea is that qualified person follows the material flow through the production plant and records the sequence of actions, determines the type of each activity, assignees the ASME symbols, measures the duration of each activity, and travels distances for all movements. This kind of research work requires short preparation on the observation and allows participation of methodologically unskilled persons but with invaluable work experience. The use of cameras resolves dilemma with occasional uncertainty concerning the classification of certain activities.

The methodology was used in 20 SMEs with functional layout and above mentioned characteristics. Weaknesses of the basic procedure were gathered, discussed and used for development of improved methodology.

In the second phase OEE indicator was analyzed. Case study method was used to determine the impact of supply on OEE indicator.

4 RESULTS

4.1 Renewal of time study technique

Motion and time study aim to eliminate unnecessary work and design most effective methods and procedures while providing methods of measuring work to determine a performance index for an individual or group of workers, department or entire plant [5]. A group of scientists lists four time study types. Those were stopwatch, work sampling, predetermined motion time system (PMTS) and Maynard's Operation Sequencing Technique Methodology (MOST). Today, of course, we note a number of variants, which were developed according to the specific needs of the user. In this paper we used process analysis bases on ASME standard.

Frank and Lillian Gilbreth originally developed Operation and Flow process charts as techniques of motion and process analysis. They defined process charts as "a device for visualizing a process as a means of improving it. Every detail of a process is more or less affected by every other detail; therefore, the entire process must be presented in such form that it can be visualized all at once before any changes are made in any of its subdivisions. In any subdivision of the process under examination, any changes made without due consideration of all the decisions and all the motions that precede and follow that subdivision will often be found unsuited to the ultimate plan of operation" [10]. That is only one of many techniques that identify the different types of activity that take place during the process and show the flow of materials or people or information through the process. According to ASME standard, for analytical purposes and to aid in detecting and eliminating inefficiencies, it is convenient to classify the actions, which occur during a given process, into five classifications. These are known as operations (produces and accomplishes), transportation (moves), inspection (verifies), delays (interferes), and storages (keeps) [11].

Quantity unit charted	Symbols	Description of event	Distance moved [m]	Unit oper. time	Unit transp. time	Unit inspect. time	Delay time	Storage time
1 palette	○ ⇨(1) □ D ▽	Moved to delivery point	105		120 s			
1 box	○ ⇨(2) □ D ▽	Moved to machine	1		20 s			
	○ ⇨ □ D(1) ▽	Box waits for operator					2 min	

Figure 3 Example of initial flow process chart fragment for "as is" process

Group of students followed different material flows through 20 production plants and recorded the sequence of activities, determined the type of each activity, assigned the ASME symbols, measured the duration of each activity and travelled distance for all movements. They filled the data into the pre-prepared table (Fig. 3). This kind of work requires short preparation for the observation and allows participation of methodologically unskilled persons. After third cycle we started to use cameras and resolved the dilemma with occasional uncertainty concerning the classification of certain activities.

After methodology application in 20 companies, some weaknesses of the basic procedure were gathered. The most important finding was that logistics activities could not be easily separated from the production ones, excluding transportation and storage. Logistics activities, including transportation and storage, in manufacturing environments do not add value. Further finding was that delay can characterizes two types of activities with significantly different characteristics. The first type of delay activities comprises those activities that are necessary for the completion of the process and the second type of delay activities comprises those activities that are not associated with the process at all. We noticed that logistics activities in production environments do not add value for the customers who order products, but companies need to realize them for process completion. The situation is completely different in the case of logistics company selling logistics services, but this does not fall within described research. It is difficult to understand the practical value of technological and administrative activities equation under "operations" as proposes ASME standard. According to ASME an "operations" also occurred when information is given or received or when planning or calculating takes place.

To improve the approach we introduced four types of activities/times rather than just value-added and non-value-added activities/times. Those are:

- beneficial – activities/times that are directly related to a product that is the subject of the contract with company's customer (e.g. painting);
- non-beneficial - activities/time that are not directly related to a product that is the subject of the contract with company's customer (e.g. paperwork);
- necessary – activities/times that are strictly necessary for realization of customer's orders (e.g. painting and paperwork);
- unnecessary – fully redundant activities/times that are not related to the customer's order and the manufacturing process at all (e.g. coffee break, private conversation).

From the list above three meaningful pairs describing specific operation can be formed:

- beneficial - necessary (add value);
- non-beneficial - necessary (do not add value);
- non-beneficial - unnecessary (fully redundant).

Two changes of initial Gilbreth's methodology have been introduced. Firstly, the symbol for work with documentation, namely "diamond", was added. In production environments, any kind of work with documentation does not add value. Nowadays physical work with documents is becoming redundant, non-value-adding and need special attention. Secondly, in standard flow chart, initial types of time were replaced with proposed (beneficial/necessary, non-beneficial/necessary, non-beneficial/unnecessary) and a column with an additional symbol for work with documents was added (Fig. 4). In such a manner, pure technological activities were successfully separated from all other. Too many production companies still do not have any sense of how much time they spend for logistics and transport activities, downtimes or even for with the process entirely unrelated activities inside production halls. Constantly monitoring the situation is questionable for SMEs from the point of efficiency. It is advisable that companies at least occasionally monitor those processes that bring them the majority of revenues. After the renovation, the methodology was again tested and used in practice.

Quantity unit charted	Symbols						Description of event	Distance moved [m]	beneficial – necessary time	non-beneficial – necessary time	non-beneficial – unnecessary time
1 palette	○	⇨ 1	□	D	▽	◇	Moved to delivery point	105		120 s	
1 palette	○	⇨	□	D	▽	◇ 1	Confirmation of the movement from the warehouse			10 s	
1 box	○	⇨ 2	□	D	▽	◇	Moved to machine	1		20 s	
	○	⇨	□	D 1	▽	◇	Operator checks missed calls				15 s

Figure 4 Improved flow process chart

The observation of specific process was always performed several times on different shifts (night, morning), at rush hours and non-rush hours. Each time, observers made flow process chart. Normally, five repetitions were performed, preferably using the camera, without prior notice.

To combine longer and/or non-value adding times with the causes for them, the resources that are necessary for each cycle of the observed process were preliminary listed and systematically arranged in groups like material, technology, documentation, work organization and so on. Existing characteristics of each group can be a potential source of inefficiency. These groups can afterwards label categories of the cause-effect diagram. Data on the repetition frequency of individual cause and on total process time were also collected. Cause-and-effect diagrams revealed key relationships among various variables. Defined root causes provided additional insight into process behavior. The use of 5W technique to trace causes back to root causes was also encouraged on side of observers.

Companies initially wanted to shorten their process times and did not know where or how to start. They looked for the professionals who would later also be hired to design a tailored system for processes improvement.

Average cycle time in observed processes lasted 29 minutes, of which we observed in average:

- 53 % of beneficial - necessary time,
- 36 % of non-beneficial - necessary time,
- 10% of non-beneficial - unnecessary time.

Production lead-time could be on average shortening by 10 % without any investment, usually with only minor organizational changes. 36 % of non-beneficial - necessary time on average was spent on:

- logistics and transportation (22%),
- administration work (8%),
- inspection (4%),
- necessary delays (2%).

By investing in logistics and transportation it would be possible to reduce the lead-time on average by maximum of 22 %. Delays were mostly caused by long search times (logistic units, tools, documents, vehicles), not defined work organization, duplications of tasks, absence of detailed scheduling, low and basic IT support, absence of IT support, lack of prevention in the field of quality assurance, not optimal layout, disadvantageous features of workshop.

4.2 Defining the impact of supply in OEE indicator

With process flow charts collected data was used for calculating OEE indicators.

Actual time needed for supplying the workplace with materials, tools, documents and alike is incorporated in Actual Production Time (ATP) in equation for Availability. If data is collected according to previously described methodology, APT can be calculated using the equation (5) where PPT represents Planned Production Time. It is calculated in a way that the maximum available time is reduced for planned breaks (lunch) and planned maintenance works on the machine.

$$APT = PPT - \sum_{i=0}^{n} NVARS_i - \sum_{k=0}^{n} NVARO_k - \sum_{j=0}^{n} NVANR_j \qquad (5)$$

Non-value adding required supply time (NVARS) represents the sum of all supply times/operations that are not directly related to the production of products and are the objects of the contract between company and its customers. Execution of these operations is strictly necessary for realization of customesrs' orders.

Non-value adding required non-supply time (NVARO) represents the sum of all non-supply times/operations that are not directly related to the production of products that are the subjects of the contract between company and its customers. Execution of these operations is strictly necessary for realization of client orders.

Non-value adding non-required time (NVANR) represents the sum of all times/operations that are not in any way related to the customer order and are fully redundant.

Hereinafter we want to explore how OEE indicator will change if we exclude NVARS.

4.3 Case study

We chose a modern and innovative European company with several decades of experiences on development, production and marketing of superior manufactured furniture. Their activities combine flexibility of the production process, cutting-edge CNC technology and years of experience, which enable them to produce perfect construction solutions. Therefore, the results of their work are high quality and aesthetically sophisticated products that make them one of the top manufacturers of interior design for recreational vehicles, boats, mobile homes and other special furniture. The company has about 320 employees coming mainly from the local environment. Investing in new technologies requires a highly trained staff. Therefore, educational structure of employees keeps growing every year. [12]

The observation and time study was carried out in the workplace 122 4SSS Weinig. Two operators work on this machine. The main operator works at the entrance and the assistant manipulates outputs. They use floor storage places and wooden EURO pallets for storage of materials and products. Main operator sets the machine on computer. The machine operates on average 3 days per week, for one shift per day. Operator's work hour costs 10.35 €. The purchase price of the machine was 193,337.47 €. Depreciation rate is 12.5%. Each hour of this machine costs 23.38 €. Ideal machine cycle is equal to 8 seconds/piece. Operator moves in a quite big radius around the machine. The observation lasted 1 hour 15 minutes and 22 seconds.

The collected data were presented in a form of process chart. Table contains the following data types:

- name of activity;
- cumulative process time;
- duration of each activity;
- value adding / non-value adding activity;
- type of loss (eight losses in the concept of lean);
- supply / non-supply time;
- number of workers who carried out the activity.

First, the indicator of OEE was calculated by equations 1 to 4. The calculated OEE value was 0.27 (6).

$$OEE = 0.33 \cdot 0.84 \cdot 0.97 = 0.27 \qquad (6)$$

We wanted to define the influence of supply on calculated value of OEE. For the calculation, we considered the equation with the expressed proportion of times spent for supply of the workplace (5). In recalculation, we set times spent for supply of the workplace on zero. Supply times were excluded from the calculation. In general, we can say that eliminated times relate to losses. Those losses appear because necessary things (tools, documents, information, materials, and semi products) are not located in the site of technological processing and in the form that would allow immediate use in technological processing. The calculated OEE value was 0.48 (7).

$$OEE_{teo} = 0.59 \cdot 0.84 \cdot 0.97 = 0.48 \qquad (7)$$

OEE indicator can occupy any value from 0 to 1 or from 0 to 100 %. Elimination of supply times in our case resulted in change of OEE value. The impact of supply reflects in the Availability. The impact of supply on the value of the Availability was in our case 26 or 26 % of the maximum value of the Availability.

Table 1 OEE on different work places

Company	Workplace	OEE	OEE_{teo}	Difference because of supply
A	1	0.27	0.48	0.21
A	2	0.46	0.62	0.16
A	3	0.40	0.57	0.17
B	1	0.57	0.78	0.21
B	2	0.66	0.86	0.20
B	3	0.44	0.76	0.32
C	1	0.50	0.64	0.14
C	2	0.45	0.60	0.15
Average		0.47	0.66	0.19

The survey was repeated at several workplaces with similar characteristics. We present OEE values before and after the elimination of supply times in Tab. 1. Average calculated value of OEE was 0.48. After elimination of supply times, this value has risen to 0.66. Influence of supply times on OEE was 0.19 on average, more specifically; availability of machines in focused category can be raised for approximately 19 % on average by improved logistics activities.

5 CONCLUSIONS

In practice, supply of workplaces often affects the production process realization. This is particularly true in the majority of SMEs, where production is functionally organized. Production processes and logistics services are connected to each other and in most cases even inseparable. We upgraded Operation and Flow process charts and used them in combination with the equation for OEE indicator to determine the impact of supply (logistics) on Availability and on productivity in a broader sense. In the calculation, we preserved machine Performance on original level, assuming that the greater machine Availability will reflect in greater quantity of produced pieces. The impact of supply on OEE calculation would form an excellent starting point for decision making and planning of investments in equipment and logistics. Practice shows that investments in machinery prevail over investments in logistics. Constantly recurring question between managers is why to invest in logistics. We upgrade Operation and Flow process charts and OEE, hierarchy of metrics, in order to help measure the impact of workplace supply.

Data for the calculation was acquired in a modern and innovative European company with several decades of experiences on development, production and marketing of superior manufactured furniture. We observed one workplace that is very typical for most wood processing companies with functionally organized production. If it was possible to completely remove the supply operations and employees could deal only with the technological operations, Availability would increase for maximum 26 %. By raising the Availability, it is not necessary to achieve the increase of Performance. Later depends on whether the workers will really produce more pieces of the product after the change.

The survey was repeated at several workplaces with similar characteristics. Average calculated value of OEE indicator was 0.48. After elimination of supply times, this value has risen to 0.66. Influence of supply times on OEE indicator was 0.19 on average, more specifically; availability of machines in focused category can be raised for approximately 19 % on average by improved logistics activities.

We will continue the research, mostly towards estimation of the assessed metric parameters impact on productivity improvements realized by their utilization. Additional examples from real production environment will be added.

We cannot claim that the improved value of OEE indicator will raise the total productivity of the company. Production improvements do not necessarily mean any kind of productivity improvement. Most probably only partial productivity will improve, for example a labor productivity measured as the ratio of output to one class of input (output per person-hour). In order to increase holistic comprehensive productivity, it is not enough merely to remove supply operation from the set of operator's tasks, which must be done on individual workplace. However, this can be a good starting point. These efforts must continue with comprehensive package of measures, which reflect in the increase of total productivity.

6 REFERENCES

[1] Dörnhöfer, M., Schröder, F., Günthner, W.A.: Logistics performance measurement system for the automotive industry, Logistics Research, 9(2016), 1-26. doi:10.1007/s12159-016-0138-7

[2] Gunasekaran, A., Patel, C., McGaughey, R.: A framework for supply chain performance measurement, International Journal of Production Economics, 87(3), 333–347.

[3] Sternatz, J.: The joint line balancing and material supply problem, International Journal of Production Economics, 159(2015), 304-318.

[4] Sumanth, D.J.: Productivity Engineering and Management, McGraw, New York, 1984.

[5] Puvanasvaran, A.P., Mei, C.Z., Alagendran V.A.: Overall Equipment Efficiency Improvement Using Time Study in an Aerospace Industry, Procedia Engineering, 68(2013), 271–277.

[6] Hogfeldt, D.: Plant efficiency: A value stream mapping and overall equipment effectiveness study, University of Technology, Lulea, 2005.

[7] Hohnjec, M.: Measurement and evaluation of process, Master's thesis, Faculty of Logistics, University of Maribor, Celje, 2008.

[8] User manual to Key 9: maintenance of machinery and equipment, Deloitte & Touche, 2000.

[9] Thakre, A. R., Jolhe, D. A., Gawande, A. C.: Minimization of engine assembly time by elimination of unproductive activities through 'MOST', Second international conference on emerging trends in engineering and technology (ICETET), 2005.

[10]Gilbreth, F. B., Gilbreth, L. M.: Process charts, The American Society of Mechanical Engineers, New York, 1921.
[11]Gajšek, B., Lerher, T., Rosi, B.: Approach to detecting promising areas for improvement in production processes, Proceedings of ICIL, Bol, June 2014, 206-215.
[12]Kostanjšek, G.: Measuring the influence of a workplace supply on productivity in companies within the manufacturing sector, Faculty of logistics, University of Maribor, Celje, 2014.
[13]Drucker, P.: Managerski izzivi v 21. stoletju, GV Založba, Ljubljana, 2001.
[14]What is productivity? [Scott-Grant], http://www.scott-grant.co.uk/pages/what_is_productivity.php, 2015-03-16.
[15]Ohno, T.: Toyota Production System: Beyond Large Scale Production, Productivity Press, Portland, 1988.
[16]OEEC: Terminology of Productivity, Andre-Pascal, Paris, 1950.
[17]Sowmya, K., Chetan, N.: A Review on Effective Utilization of Resources Using Overall Equipment Effectiveness by Reducing Six Big Losses, International Journal of Applied Engineering and Technology, 2(2016)1, 556-562.
[18]Kotler, P.: Marketing Management Analysis, Planning and Control, Prentice-Hall, Englewood Cliffs, NJ, 1984.
[19]Slack, N.: The Manufacturing Advantage: Achieving Competitive Manufacturing Operations, Mercury, London, 1991.
[20]Neely, A., Gregory, M., Platts, K.: Performance measurement system design: A literature review and research agenda, International Journal of Operations & Production Management, 15(1995): 80-116.
[21]Neely, A.D.: Performance measurement system design – third phase, Draft of the fourth section of the “Performance Measurement System Design Workbook”, April (1994).
[22]COM, Communication from the Commission to the Council, the European parliament, the European Economic and Social Committee and the Committee of the regions: Freight Transport Logistics in Europe – the key to sustainable mobility, Brussels (2006).
[23]Kuhlang, P., Edtmayr, T., Suhn, W.: Methodical approach to increase productivity and reduce lead time in assembly and production-logistic processes, Journal of Manufacturing Science and Technology, 4(2011), 22-32.
[24]Luo, H., Wang, K., Kong, X.T.R., Lu, S., Qu, T.: Synchronized production and logistics via ubiquitous computing, Robotics and Computer-Integrated Manufacturing, 45(2017), 99-115.
[25]Bauer, W., Ganschar, O., Gerlach, S.: Development of a Method for Visualization and evaluation of production logistics in a multy-variant production, Procedia CIRP, 17(2014), 481-486.
[26]Ljungberg, Õ.: Measurement of overall equipment effectiveness as a basis for TPM activities, International Journal of Operations & Production Management, 18(1998)5, 495-507.
[27]Ishikawa, K.: Guide to Quality Control. Asian Productivity Organization, Tokyo, 1982.
[28]Schmenner, R.W., Vollmann, T.E.: Performance measures: gaps, false alarms and the 'usual suspects', International Journal of Operations and Production Management, 14(1994)12, 58-69.
[29]Jonsson, P., Lesshammar, M.: Evaluation and improvement of manufacturing performance measurement systems - the role of OEE, International Journal of Operations & Production Management, 19(1999)1, 55-78.
[30]Azzone, G., Masella, C., Bertele, U.: Design of performance measures for time-based companies, International Journal of Operations & Production Management, 11(1991)3, 77-85.
[31]Gilbreth, F.B., Gilbreth, L.M.: Process charts, The American Society of Mechanical Engineers, New York, 1921.
[32]Graham, B.B.: Rediscover Work Simplification, http://intranet.imet.gr/ Portals/0/Useful Documents/documents /03065.pdf (01.12.2014).
[33]Ghalayini, A.M., Noble, J.S.: The changing basis of performance measurement, International Journal of Operations & Production Management, 16(1996)8, 63-80.
[34]Fisher, J.: Use of non-financial performance measures, Journal of Cost Management, 6(1992), 31-8.
[35]Nakajima, S.: TPM Development Program, Productivity Press, Cambridge, MA, 1989.
[36]SCDigest editorial staff: Supply Chain Graphic of the Week: Logistics Costs as Percent of GDP by Country, 2013, URL: http://www.scdigest.com/assets/newsviews/13-06-20-2.php ?cid = 7168 (14.03.2014).

Authors' contacts:

Grega KOSTANJŠEK
3 Projekt d.o.o.
Kebetova ul. 18, 4000 Kranj, Slovenia

Assist. prof. dr. Brigita GAJŠEK
University of Maribor, Faculty of Logistics,
Mariborska 7, 3000 Celje, Slovenia
E-mail: brigita.gajsek@um.si