



THE EFFICIENCY OF THE PRODUCTION – THE ANALYSE OF PROBLEMS BASED ON THE LITERATURE RESEARCH

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ABSTRACT. Background: The production efficiency is one of the most important problems of the present-day logistics, both at operational as well as strategic levels. Increasing the level of the efficiency of the production process can be achieved in many ways.

The reason of the selection of the issues covering the problems of the production efficiency is the lack of a comprehensive model for analyzing the efficiency of the production process, both in the scientific literature and in the business practice.

Methods: The main aim of this paper is to systematize the process of obtaining input data for the assessment model of the production efficiency. The methodology for building the assessment model of production efficiency at the initial stage of the analysis was presented.

Results and conclusions: The basic goal of a preliminary analysis of the model is to coordinate decision-making targets at all levels of the management. The presented assumptions should be regarded as a preliminary analysis, indispensable for the multivariate analysis of the production process efficiency, focused on the operational level.

Key words: production efficiency, production controlling, balancing of resources, production capacity.

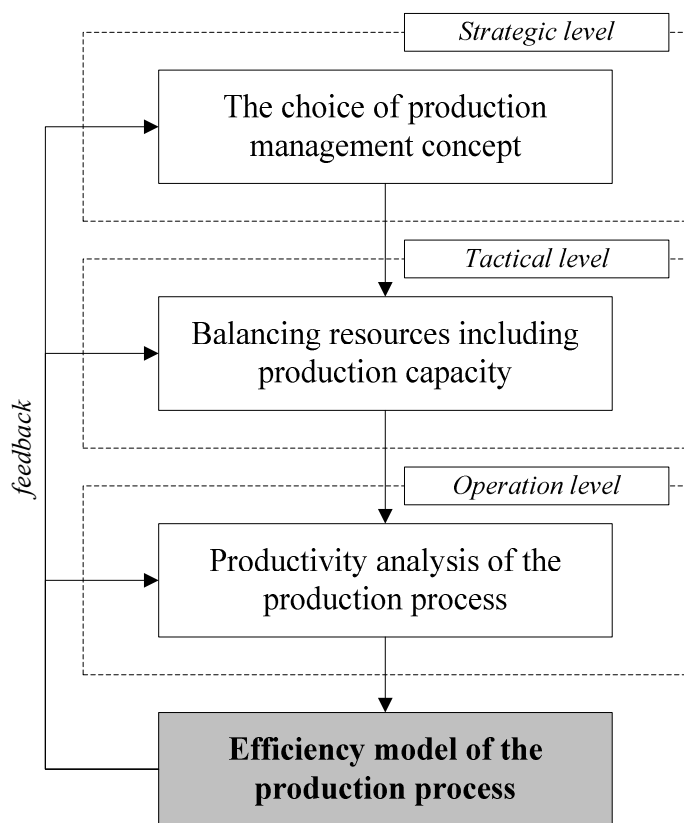
INTRODUCTION

The issue of the production efficiency, despite many efforts and attempts, has not been so far comprehensively presented and developed. At present, companies operating in the dynamically changing environment, take decisions, which have very often the negative influence on the efficiency of individual processes. The main reasons of such a situation are unclear procedures for the evaluation of the efficiency. According to the Author, the issue of the evaluation of the production process is the very important component of the effective business management, which requires the deeper analysis. The development of an effective model for the evaluation of the efficiency of the production process requires the detailed and reliable preparation of input data, which are indispensable factor of the efficiency of the further analysis.

The main aim of this paper is to prepare the algorithm of the processes of the acquirement of input data for the model of the evaluation of the production efficiency. On the basis of the literature research as well as observations in business practice of manufacturing companies, it should be noted that the basic data, necessary to create the multivariate model of the evaluation of the efficiency of the production process, should be generated from the three main ranges:

- The selection of a suitable production management concept,
- Balancing of production resources and production capacities,
- The analysis of the performance of the evaluated production process.

Deliberately structured analytical ranges can be seen as an algorithm of the preliminary analysis of the efficiency, which refers to three levels of the management: strategic, tactical and operational. For this reason, the comprehensive analysis of the evaluation of the efficiency should be supported by the preliminary researches conducted at all decision-making levels in the company. The schema of the preliminary analysis of the efficiency is shown on the Figure 1.



Source: own work

Fig. 1. The schema of the preliminary analysis of the efficiency of the production process
Rys. 1. Schemat wstępnej analizy efektywności procesu produkcyjnego

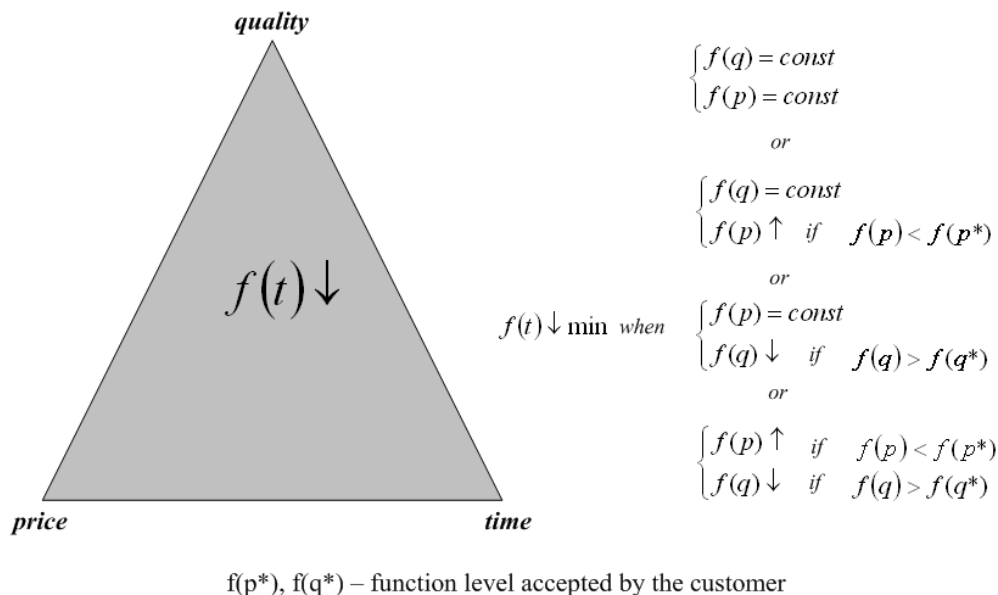
The schema of the preliminary analysis of the efficiency, presented on the Figure 1, was varied in terms of decision-making minuteness associated with the level of the management of the enterprise. The selected analytical ranges must be closely related to each other, complementary and support the realization of the fundamental aims of the company. Therefore, as presented on the figure, the use of feedbacks was proposed, which enables the reference of the analysis of the efficiency of the production process to the current organizational reality.

THE SELECTION OF CONCEPT OF THE PRODUCTION MANAGEMENT

It should be remembered during analyzing the production efficiency at the strategical level that the production company can compete on the global market basing its strategy on one of three factors:

- Time (t),
- Price (p),
- Quality (q).

The strategy of the competitiveness consists sometimes in the fulfilment of the customer order in the shortest possible time and in keeping other factors of the competitiveness at a reasonable level. The analysis of the efficiency of the production in the pricing strategy consists mainly in the evaluation the profitability of the fulfilment of the order, for which the completion time should be minimized. It should be remembered that the price strategy can be realised when simultaneously the quality and the price are maintained at the level accepted by the client. The idea of the time strategy and its impact on other factors affecting the competitiveness of the company is presented on the Figure 2.



Source: Trojanowska, Koliński 2011

Fig. 2. The time strategy
 Rys. 2. Strategia czasowa

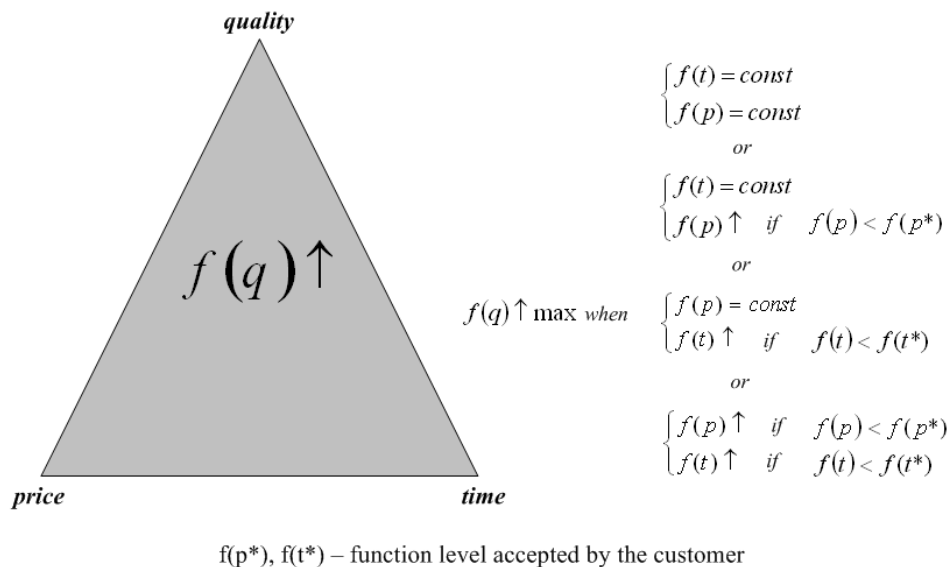
The fundamental relationships between the time function and a function of a quality and a price were presented on the figure 2. The following variants can be obtained on the assumption of minimizing of the time function:

- Minimization of the time function can be obtained while the previous level of the price function and the quality function is maintained,
- Minimization of the time function can cause a decrease of the quality function, but only to the level accepted by a client and simultaneously at the maintained level of the price function,
- Minimization of the time function can cause an increase of the price function, but only to the level accepted by a client and simultaneously at the maintained level of the quality function,
- Minimization of the time function can cause an increase of the price function, but only to the level accepted by a client and simultaneously with the decrease of the quality function, but not bigger than the level accepted by a client.

Other variants were not taken into consideration during the analysis of the time strategy, due to the fact that e.g. the increase of the quality level (assuming, that the current one is at least the accepted one) is inefficient in unchanged production conditions, because it has negative impact on the time function. It should be mentioned, that the management of a company, using the time strategy, prefers to keep other factors of the competitiveness not higher than at the level accepted by a client.

The strategy of the quality competitiveness consists in ensuring the quality, even at the expense of time or a price. The strategy of the quality competitiveness is a specific strategy, which is related to

designing for the order and based on the building a customer brand trust. The company, which wants to be quality competitive, has to have a strong brand and a well established market position. The idea of the quality strategy and its impact on other factors affecting the competitiveness of a company was shown on the Figure 3.



Source: Trojanowska, Koliński 2011

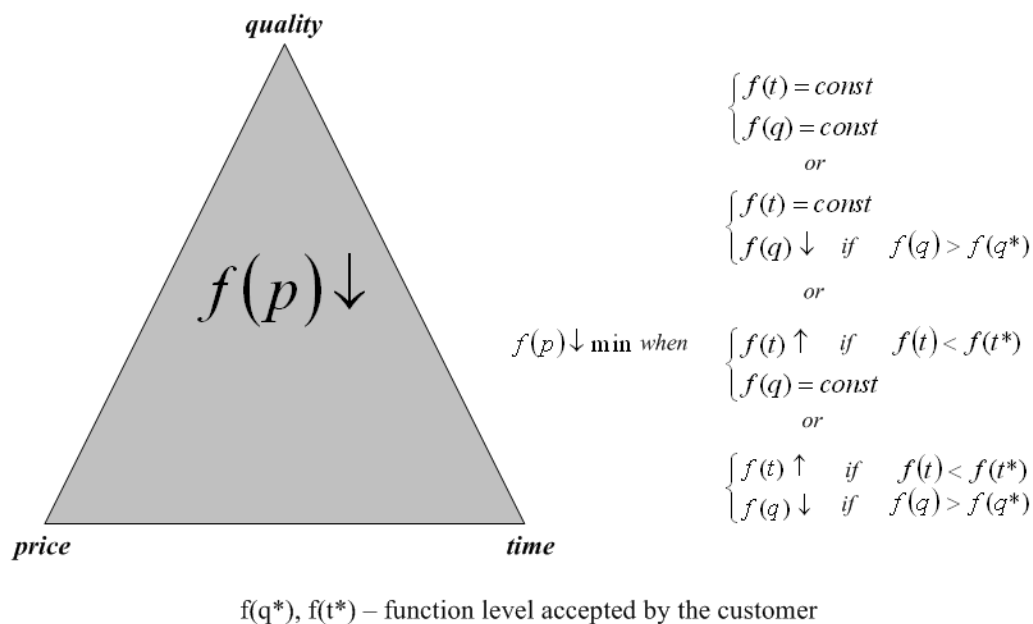
Fig. 3. The quality strategy
 Rys. 3. Strategia jakościowa

The basic relationships between the quality function and the function of time and price were presented on the Figure 3. The following variants can be distinguished, based on the assumption of the increase of the quality level, which at the same time, does not exceed the quality level expected by a client:

- Keeping the current level of the price function and time function,
- Increase of the price function and the simultaneous the increase of the time function,
- Increase of the price function and simultaneously keeping the time function at the unchanged level,
- Keeping the price function at the previous level and the simultaneous increase of the time function.

Other variants were not taken into consideration during this case, due to the fact that e.g. while assuming the maintenance of the quality level, the reduction of the price is an illogical operation and even often does not enable the realization of this strategy.

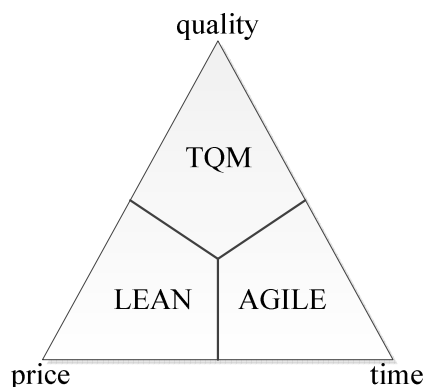
The strategy related to the price competition consists in obtaining a competitive advantage by offering attractively priced products, while keeping all other factors at an acceptable level. The price competition in production companies is possible through the appropriate, low-cost approach to the production management. The idea of a price strategy implementation and its influence on other factors of the competitiveness is shown on the Figure 4.



Source: Trojanowska, Koliński 2011

Fig. 4. The price strategy
 Rys. 4. Strategia cenowa

The choice of the right strategy has a significant impact on the operational activities of the company. The appropriate translation of the strategy into the tactical and operational levels is the key element, which has an influence on the evaluation of the efficiency of the company. The focus on the chosen strategy forces the implementation of an adequate system of indicators of efficiency assessment, according to the chosen strategy. The discussed strategies can be presented by the use of three main concepts of the production management. The proposal to use the concept of the production management in line of a particular competition strategy is shown on the Figure 5.



Source: Trojanowska, Koliński 2011

Fig. 5. The comparison of concepts of production management with strategies of the company competitiveness
 Rys. 5. Zestawienie koncepcji zarządzania produkcją ze strategiami konkurencyjności przedsiębiorstwa

The main assumption of the idea presented on the Figure 5 is the conviction, that the Lean Manufacturing concept focuses on the implementation of the price strategy by the reduction of expenditures, which can be achieved by the reduction of the level of costs. The implementation of Agile Manufacturing concept can in turn support the realization of the time strategy. This concept concentrates on the flexible adaptation of a process to the expectations of customers [Trzeciński 2007]. The quality strategy is consistent with main assumptions of TQM concept. Due to the growing importance of TQM concept, the quality has become an integral part of the strategy of companies, which obtain the business success in today's very demanding market. The production company, using the quality as an competitive advantage in the market, focuses all its efforts on providing clients the reliable goods of the high quality, even it can sometimes lead to the failure to keep the agreed terms of delivery or the need to increase the production costs.

The practices of companies shown that the management team is willing to look for alternative solutions to improve the efficiency of production process in the company. This results in many attempts of hybrid solutions of various strategies of the competitiveness [Meade, Kumar, Houshyar 2006]. The diversification of the production is one of the most effective ways of hybrid management of the production at the strategical level [Koliński 2010]. The most frequently analyzed possibilities of the improvement of the competitiveness are:

- The increase of the quality and simultaneously the reduction of a price,
- The increase of the quality and simultaneously the reduction of lead-time of an order,
- The reduction of the price level and simultaneously the reduction of lead-time of an order.

The Author's researches related to the level of the use of various management concepts in business practice [Koliński, Trojanowska, Kolińska 2011] only confirm the thesis that the management teams of companies decide to choose one of the analyzed concepts of the production management, and at the same time constantly looking for opportunities to increase the efficiency of the production process.

BALANCING OF PRODUCTION RESOURCES

The issue of balancing is an element of the efficiency analysis of wide use in the business practice. It is one of effective instruments to assess and analyze the potential possibilities to eliminate shortages of resources, bottlenecks, queues, bottlenecks in the production process, as well as surplus of resources and expenditures in relation to the particular market situation [Sliwczyński 2011]. The maintenance of unnecessary or excessive production resources (e.g. defective manufacturing equipment, excessive stocks of works in progress, low level of the utilization of production capacities) has a negative impact on the efficiency of the production process. However, it should be remembered that, the deliberate maintenance of the surplus of production resources can be caused by the strategy of the competitiveness adopted by the management of the company (e.g. flexibility and speed of the response to customer needs – the strategy consistent with the Agile Manufacturing concept).

The basic model of balancing of operational tasks and available production capacities (production potentials) in a given period of time, for a homogenous group of workstations, enabling the mutual substitution of machines during the implementation of production process, is presented on the Figure 6.

The balancing of tasks with production potential focuses on the analysis of the ratio of necessary production capacities (requirements of potential) of a specific production cell (e.g. workstation) in a given planning period and the potential of this cell in the same planning period. The basis variant of balancing the production resources is presented on the Figure 6. The detailed characterization of parameters used in this model, is presented in the Table 1.

The method of solving the problem of balancing of resources depends on possibilities to identify the structure of the production process already at the moment when the decision to realise the planned production order is undertaken. In such cases, the balancing process covers the analysis of resources, which limit the whole analyzed process, so called bottlenecks. The aggregation of orders is a method to obtain some savings associated with the minimization of production preparation time and the possibility to reduce the average load of workstation in a given planning period. Such situation allows accepting new production orders (in form of customers' orders) without changing the existing production plan [Fertsch 1998] and which has a direct impact on the efficiency of balancing of production resources. The problem arises when a company is not able to cover the market demand for manufactured goods, while the sale of each of them is profitable for a company. It must be remembered that, the critical resource (regardless of the specific character of factors, which limit the production efficiency) determines the sales value and the achieved profit as well as the level of utilization of other resources.

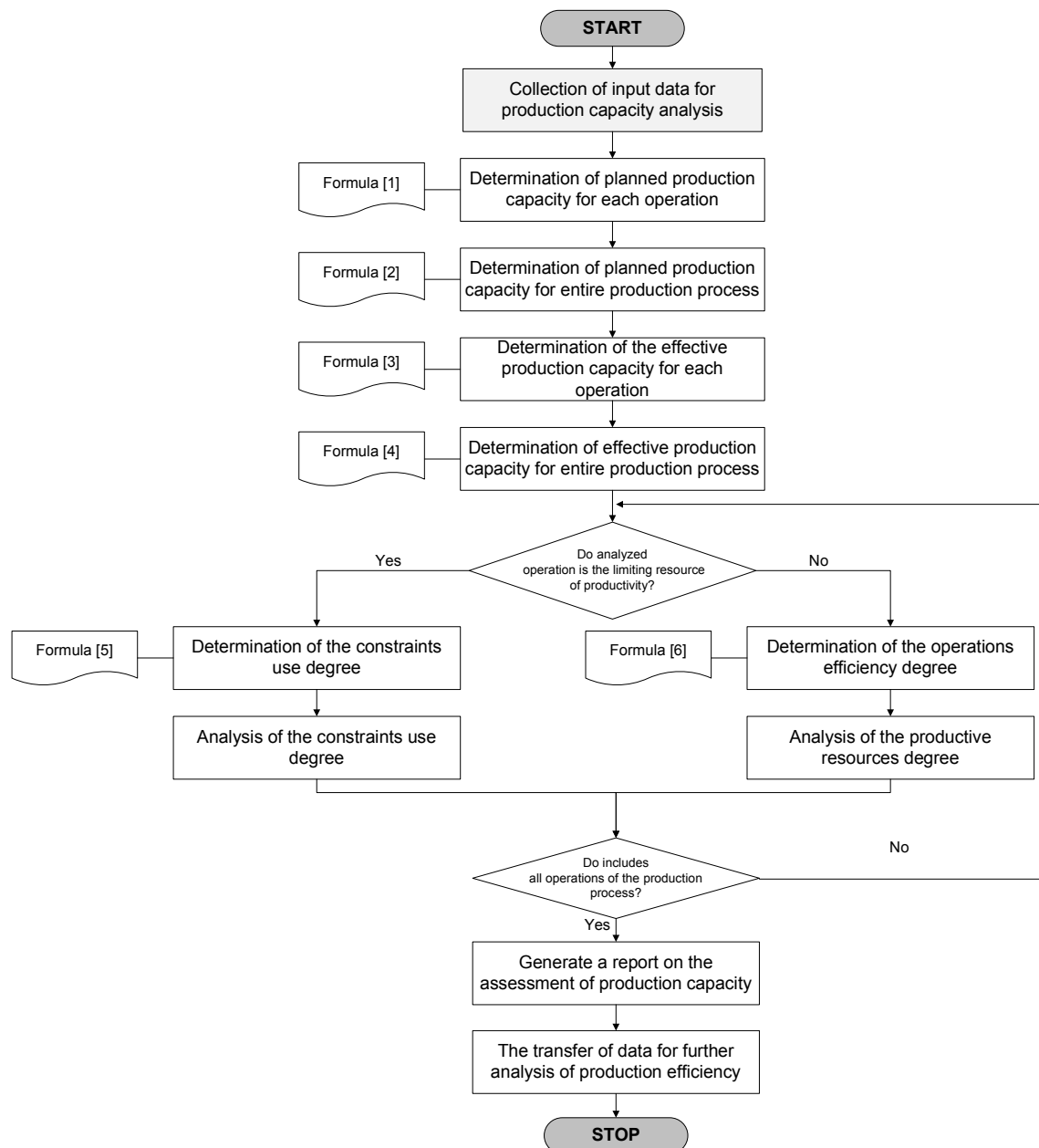
Making the detailed analysis of purposes of balancing of resources and the most often used methods to eliminate problems associated with this issue, it can be concluded that, the presented problems of an effective balancing of production resources are determined by factors, which influence both on the organisation of the production process as well as the efficiency of cause-effect relationships throughout the whole supply chain. The key factor of balancing is to determine the requirements for individual resources in the same measures or units. However, the selection of a right measure in case of very developed process structures is a very difficult task. The analysis and the evaluation of an efficiency of the conducted production process should be the subsequent stage after successful balancing of resources.

THE ANALYSIS OF PRODUCTION CAPACITY

The determination of the capacity is one of the most important factors, which influence the efficiency of the evaluation of the production efficiency at the operation level. The method of determining the capacity depends on the assumed level of accuracy of conducted analysis of resources in terms of efficiency. The capacity is a very significant problem in terms of production efficiency, because it is based on the process of matching the available capacity of all available resources to planned demand, which absorbs the analyzed production resources.

It should be desired during the analysis of the efficiency of the production process to increase of the productivity through the maximum utilization of available tools in a given time (e.g. depending on the number of planned changes in production). However it should be remembered that, the increase of production capabilities could be only reached, when the additional workstations involved, are fully utilized. This situation entails a lower level of investment as well as a high indicator of resources utilization, but at the same time it also reduces the volumes of production [Waters 2002]. According to the Author, the reliable and unambiguous assessment of productivity is difficult due to the lack of comprehensive indicators, which enable to determine it. The productivity is analyzed not only at the level of a workstation, but also of a particular operation, as well as for the entire production process. It should be noted that the efficiency of production resources is defined as the maximum quantity of products, which can be produced in a specified period of time.

The presented scientific deliberations related to the maintenance of excessive unused production capacities, confirm only the ambiguity and the complexity of the issue of the production efficiency. The algorithm of an effective analysis and the evaluation of the efficiency of production process has been developed. It is presented in the Figure 7. A detailed description of the stages of the analysis of production efficiency is presented later in this article, based on a practical example of the use of the analysis of the production efficiency, published by the Author in [Koliński, Golińska 2011b].



Source: own work

Fig. 7. The general schema of the analysis of production capacity
 Rys. 7. Ogólny schemat analizy wydajności produkcji

The planned production capacity refers usually to ideal conditions, ignoring any breakdowns or disruptions in the production process [Waters 2002]. The planned production capacity does not include the unproductive time, associated with the deliberately planned breaks. In order to calculate the planned production capacity of the entire production process, it is necessary first to determine the capacities of individual operations. In case of the production operation, which is performed on several workstations, its production capacity is calculated as a sum of the capacities of individual separated workstations. The following formula presents above-mentioned assumptions and dependencies:

$$W_{PO} = \sum_{i=1}^n \frac{t_{d_i}}{t_{j_i}} \quad [1]$$

where:

W_{PO} – the planned production capacity of the operation,

t_{d_i} – available production time for the workstation j ,

t_{j_i} – unit execution time for the operation performed on the workstation j ,

n – quantity of workstations.

Based on the presented dependencies, the production capacity of individual operations should be determined. And the determination of the production capacity of the entire production process should be the subsequent step of the analysis. The production capacity of the entire process is determined by the productivity of the operation, which is the smallest one. The discussed relationship can be presented by the following function:

$$f(W_{PP}) = \min(W_{PO1}, W_{PO2}, \dots, W_{PO_n}) \quad [2]$$

where:

W_{PP} – the planned production capacity of the production process,

W_{PO1} – the planned production capacity of the first operation,

W_{PO_n} – the planned production capacity of the n operation.

The effective production capacity is a more realistic indicator, which determines the production expectations in normal conditions [Waters 2000]. The determination of the indicator of the effective production capacity is based on the similar ideology, which was presented in case of the analysis of the planned production capacity. The effective production capacity of the operation is the sum of productivities of all workstations, where it is performed. The following formula presents above-mentioned assumptions and dependencies:

$$W_{EO} = \sum_{i=1}^n \frac{t_{d_i} - t_{b_i}}{t_{j_i}} \quad [3]$$

where:

W_{EO} – the effective production capacity of the operation,

t_{d_i} – available production time for the workstation j ,

t_{b_i} – unproductive time for the workstation j (breaks, maintenance, etc),

t_{j_i} – unit execution time for the operation performed on the workstation j ,

n – quantity of workstations.

It should be noted, that the operation of the lowest production capacity, limits the efficiency of the entire production process. Therefore the effective efficiency of the entire production process can be presented by the following formula:

$$f(W_{EP}) = \min(W_{EO1}, W_{EO2}, \dots, W_{EO_n}) \quad [4]$$

where:

W_{EP} – the effective production capacity of the production process,

W_{EO1} – the effective production capacity of the first operation,

W_{EO_n} – the effective production capacity of the n operation.

The determination of the effective level of the utilization of individual operations of the production process concerns the ratio between the real production efficiency and the effective production capacity of the operation. The determination of the utilization rate of the operation is useless in case of operations, limiting the production process, because it is almost 100%. In case of other operations, the determination of the level of the effective utilization of the operation enables the further analysis of the utilization of individual workstations. According to the Author, two measures should be distinguished depending on the impact of a given operation on the efficiency of the entire production process:

- The degree of the effective utilization of the operation/workstation,
- The degree of the utilization of the limiting factor.

The analysis of the degree of the effective utilization of the operation, which is the limitation of the production process, is pointless due to the fact, that this degree is equal or almost equal to 100% according to the concept of bottlenecks in the production process. The utilization ratio of the limitation can be interpreted as follows:

$$\text{utilization ratio of the limitation} = \frac{\text{effective efficiency of production process}}{\text{planned efficiency of the operation}} \quad [5]$$

The very important part of the analysis of the production efficiency and the estimation of bottleneck's efficiency is the analysis of the possibility of reducing the unproductive time (e.g. by reducing the number of changeovers or by the increase of production batch volumes) and its impact on the production efficiency. It should be mentioned, that each optimization of the limitation has a positive effect on the production efficiency, because it increases the effective efficiency of the entire production process. Due to that, the particular focus should be placed on optimization activities related to bottlenecks' performance and loads. Therefore it is worth to be aimed, that the detailed production planning, oriented on bottlenecks, should be the basis for the estimation of the efficiency of the limitation [Domański, Hadaś 2010]. According to the scientific literature, the theory of constraints both in the area of production planning and management [Goldratt, Cox 2004] as well as in economic aspects [Corbett 1998] is widely proposed to be used. According to the Author, the implementation of basic tools of the theory of constraints could be effectively used to build a comprehensive model for the estimation of the efficiency of the production process.

The utilization ratio of limitation can be interpreted as follows:

$$\text{effective utilization ratio of the operation} = \frac{\text{effective efficiency of production process}}{\text{planned efficiency of the operation}} \quad [6]$$

Similarly, the analysis of the utilization ratio for the individual workstations can be conducted. However in this case, the uniform utilization of all workstations should be secured. It should be also noted, that the smaller the value of the level of the utilization of a particular workstation, the greater probability of the necessity of the diversification of tasks or works at this workstation. Therefore analyzing the production efficiency it should be concluded that, too big diversity of operations performed at one workstation has a negative impact on its efficiency ratio. This is due to the increase of changeover times (unproductive time), which consequently decreases the effective production efficiency.

SUMMARY

The issues presented in this paper, cover the research results obtained by the Author, both on the ground of the business practice and the literature review. The theoretical deliberations, detailed described in this paper, were presented in the form of an algorithm and correlated with various decision-making levels of the company, in accordance with the main aim of this paper. The presented solution should be treated as a proposal how to obtain the reliable input data, indispensable for the further comprehensive analysis and the estimation of the efficiency of the production process. The issues of the efficiency are widely discussed in the scientific literature, but there is still lack of a comprehensive method, which enables the multivariate analysis and the estimation of the production process. When building a model for the evaluation of the efficiency, the correlation of all levels of business management should be taken into consideration. The ecological aspect of the production, gaining lately the special attention, should be also considered. The implementation of IT systems, supporting the management process, is a practical problem related to the process of building the production efficiency model. The functionalities of such supporting systems enable to obtain and analyze all aspects necessary to fulfil a comprehensive analysis. Therefore, it seems to be reasonable, to prepare a separate IT tool, which will focus on a comprehensive analysis of the production process efficiency and which should be considered as the future direction of researches in this area.

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OCENA EFEKTYWNOŚCI PRODUKCJI - ANALIZA PROBLEMU W ŚWIETLE LITERATURY

STRESZCZENIE. Wstęp: Efektywność produkcji jest jednym z najważniejszych problemów współczesnej logistyki, zarówno na poziomie operacyjnym, jak i strategicznym. Podniesienie poziomu efektywności procesu produkcyjnego można osiągnąć na wiele sposobów.

Wybór problematyki efektywności produkcji jest spowodowany brakiem opracowanego kompleksowego modelu służącego do analizy efektywności procesu produkcyjnego, zarówno w literaturze przedmiotu, jak również w praktyce przedsiębiorstw.

Metody: Głównym celem artykułu jest usystematyzowanie procesów uzyskania danych wejściowych do modelu oceny efektywności produkcji. W artykule przedstawiono metodologię budowy modelu oceny efektywności produkcji na wstępnym etapie analizy.

Wyniki i wnioski: Podstawowym założeniem wstępnej analizy modelu jest skoordynowanie celów decyzyjnych na wszystkich poziomach zarządzania. Przedstawione założenia należy traktować jako wstępną analizę niezbędną do wielowariantowej oceny efektywności procesu produkcyjnego, skoncentrowaną na poziomie operacyjnym.

Słowa kluczowe: efektywność produkcji, controlling produkcji, bilansowanie zasobów, wydajność produkcji.

BEWERTUNG DER PRODUKTIONSEFFIZIENZ - ANALYSE DES PROBLEMS IM LICHT DER GEGENSTANDSLITERATUR

ZUSAMMENFASSUNG. Einleitung: Die Produktionseffizienz stellt eines der wichtigsten Probleme der gegenwärtigen Logistik, sowohl auf dem operativen, als auch auf dem strategischen Niveau, dar. Die Erhöhung der Effizienz eines Produktionsprozesses kann unterschiedlich erreicht werden.

Die betreffende Auswahl der Problematik der Produktionseffizienz ist auf den sowohl in der Gegenstandsliteratur, als auch in der Unternehmenspraxis bestehenden Mangel eines komplexen, der Analyse der Effizienz des Produktionsprozesses dienenden Modells zurückzuführen.

Methoden: Das Ziel des vorliegenden Artikels ist es, die für die Gewinnung von Input-Daten für das Modell zur Bewertung der Produktionseffizienz dienenden Prozesse zu systematisieren. Im Text des Artikels wurde die Methodologie für den

Aufbau eines für die Bewertung der Produktionseffizienz brauchbaren Modells in der einleitenden Etappe der Analyse dargestellt.

Ergebnisse und Fazit: Eine grundlegende Zielsetzung der einleitenden Analyse des Modells ist es, die Entscheidungsziele auf allen Managements-Ebenen weitgehend zu koordinieren. Die dargestellten Annahmen sind als eine einleitende, für die Mehrvarianten-Bewertung der Effizienz eines Produktionsprozesses unentbehrliche und auf das operative Niveau konzentrierte Analyse aufzufassen.

Codewörter: Produktionseffizienz, Produktionscontrolling, Bilanzierung von Beständen, Produktionsleistung

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