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Evaluation of Batch Production Processes Based on Seven Criterions

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Abstract

To answer growing demand on products adapted to clients' individual needs, it is required to develop new ways of measurement and rating for batch production processes. The researchers developed method which allows synthetic and complex evaluation, as well as improvement of these processes. Case study with participating observation, non-participating observation, interviews, and the analysis of historical data was conducted in order to analyse a production company. Researchers developed concept of a multi-criteria evaluation method, with rating based on the following criterions: market, economical, ecological, social, technological, planning and general development – each including individual indicators.

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Keywords: multi-criteria rating; batch process; production measurement; technological rating; process evaluation

1. Introduction

The measurement of production processes has evolved along with expansion and development of these processes and entire production systems. Over time simple measurement methods that evaluate each aspect related to realization of production process became insufficient. Creation of new, more complex measurement methods have been undertaken, which were combined into multi-criterion rating later on. It allowed to measure processes under specific aspects, and results of these more complex measurements proved useful in elaboration of improvement plans. Additionally, difference in characteristics of basic production types, which are batch, line, and stationary production [1, 5] require individual approach. Some measurement methods, which are perfectly fit for line production, provide

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unreliable results in case of being used for another type of production. In view of this dilemma, the researchers decided to develop multi-criterion measurement method adapted strictly to batch production. The concept of seven-criterion rating method includes: technological, economical, ecological, social, market, planning and general development criterions. Each criterion has individual partial measurement factors assigned to it, which allows complex rating of each aspect.

2. Designation of multi-criterion process rating measurement

Rating of production process can be performed using various available measurers, as well as multi-criterion measure, if such has been developed. If there is lack of specific measurement method for the type of process performed in company, it must be developed individually. While developing multi-criterion measurement three stages of procedure should be followed [4, 9, 12], as in scheme presented in the Fig. 1.

The first stage is associated with choice of proper measurers. Proper measurer is defined as one that allows complex evaluation of process, which means it allows the evaluation of the process in many aspects, which are corresponding with companies' main resources. For example measurement combined with machine work, personnel work and customers' rating or financial expenses. Choice of measurers must be decided by manager, with support of most experienced workers.

The second stage is associated with determination of normalization function for all measurers. Since it is possible to acquire data distinguished by variety of units and scales, it is necessary to unify collected data to dimensionless unified scale, in order to compare specific processes. The normalization function allows the transformation of the measurement value presented in its unit into normalized state corresponding to established range of values (usually values ranges from 0 to 10). Applied to all measurement, it brings all values to a common denominator. This way many incomparable otherwise measurements can be formed into multi-criterion rating measure. It is crucial to develop exactly one function for each measure in such way, that the normalized result would represent state of process corresponding to this measurement. Value of 0 is assumed to correspond with inacceptable state, while the value of 10 corresponds with perfect state and 5 corresponds with the average state. It is also possible to adopt different mathematical functions in order to normalize the results. Normalization function can be designed based on historical data regarding specific measurer from companies which share common field (comparison method) or based on experts' opinion. Both methods can be adapted simultaneously as well.

The last, third stage is assigning weights to each measurer. Correct weight assignment relies on assigning higher values to key aspects of process rating. It is assumed that sum of all weights should be equal to 1 (which corresponds to 100%). This value is not necessary, but it simplifies the calculation of synthetic measurer value. Just as in case of measurer selection or function creation, it is recommended to entrust this task to experts, in order to increase reliability of the results based on appointed weights.

Fig. 1 presents procedure of multi-criterion production process rating measurer application, along with questions used in developing measurer. The presented stages allow to personally developing measurement that would allow for complex production process rating.

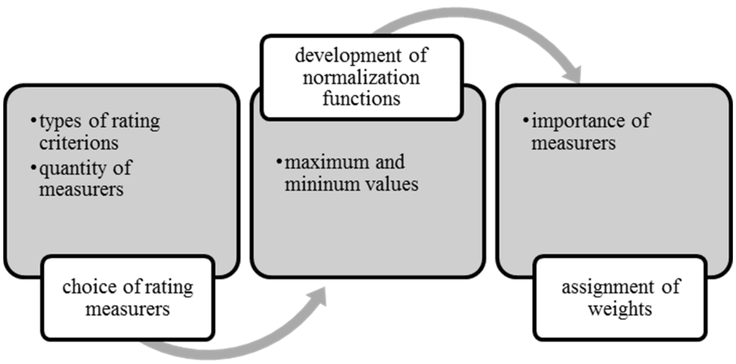

Fig. 1. Multi-criterion measurement rating development steps.

3. Concept of seven-criterion batch production process course rating measure

Concept of seven-criterion batch production process course rating measurer includes following criterions [7, 12]:

- Economical criterion applies to evaluation of the productions' cost levels connected with the process subjected to analysis and necessary investment funds
- Ecological criterion is about means of natural environment protection, utilization and segregation of wastes and usage of various media. This criterion is about social responsibility of companies
- Social criterion concerns working conditions (ergonomics on work centers), requirements on personnel qualifications and satisfaction from work – rated for example by measuring absence at work or with survey
- The market criterion is about evaluation if the product or additional services meet clients' individual needs and if the prices and time between the product being ordered and delivered to the client are elastic. It is about evaluation of product based on clients' point of view
- Technological criterion, which concerns implementation of production process course, is based on machines' work and production workers' work evaluation
- General development criterion allows the evaluation of a companies' state not only by measuring fulfilled production processes, but by its general condition as well
- Planning criterion is related to fulfilling general production schedules, which is one of the main targets of production control.

Fig. 2 presents the structure of multi-criterion process rating measure, showing main evaluation criterions for which more specific measures were selected.

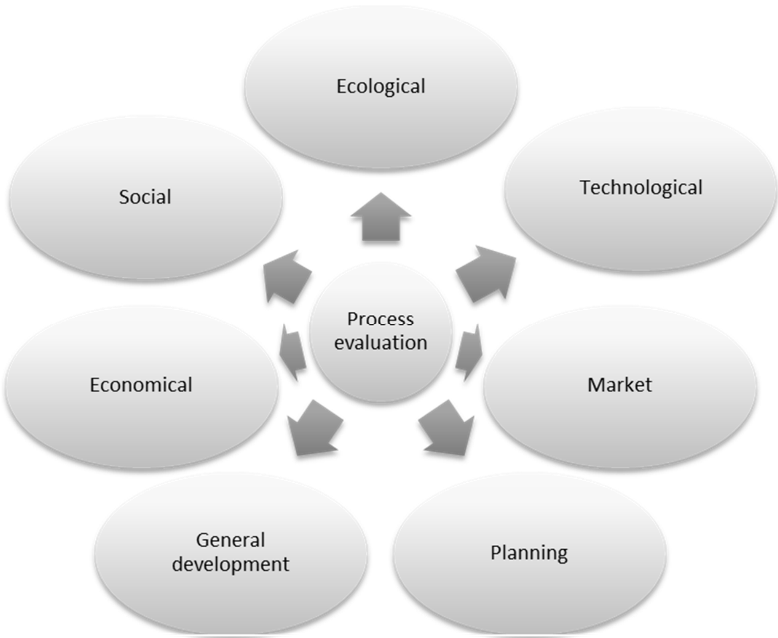

Fig. 2. Multi-criterion batch production process rating measurer.

3.1. Technological Criterion

During selection of measures suitable for technological criterion, the main attention was focused on evaluation of utilization of each work center associated with production process, such as machines or production employees. Following measures were planned to be used at first:

- OEE – Overall Equipment effectiveness, consisting [3, 10, 11, 14]:
  - Availability
  - Efficiency
  - Quality
- Employees' time usage – calculated as ratio of time during which worker performed actions directly linked with production to duration of work shift
- MTTR – mean time to repair [8]
- MTBF – mean time before failure [8].

The measures listed above would verify time spent by machines and employees spent on production actions, quality of crafted products, duration of repairs and reliability.

After initial research in a production company [6, 13] researchers decided that utilizing OEE factor for work centers in batch production process leads to false results, especially in case of efficiency. The calculation of efficiency measurement in the company implied calculating target production with assumption of the milling machines' efficiency derived directly from manufacturers' catalogue parameters. In case of small-lot production, in which duration of each technological operation are very varied (for example during research they varied from 3 to 50 minutes), designation of maximum production proved impossible. This was the reason why time of the milling machines' work was compared to time of production assuming its maximal working parameters. Value of resulting efficiency measurer was 0.66. The result was influenced by the fact that employee reduced cutting speed in order to preserve durability of drill and to reduce vibrations of the machine, which could lead to defects.

In addition, the measurement of quality measurer must have been considered. In theory this measurer should be calculated as the ratio of proper production, products meeting quality requirements, to actual production. In case of producing many different products on single station, it is necessary to define what "the actual production" means. While the research in company X was conducted 11 different types of elements were crafted, from 1 to 14 units of each element, which globally added up to 45 pieces. Production of these elements required 99 technological operations, from 2 to 40 minutes of duration each. 92 operations were made in correct way. Each type of element was characterized by different complexity of operations required on each work center. Some of them were ready for assembly after treatment on one work center, while other required treatment on many work centers, sometimes more than one treatment on a single station, before they could be assembled.

The term "to perform technological operation" means performing action over one element, which begins with the element being placed in the machine and with the machines' activation, and ends when the element leaves the machine. The term "many technological operations" applies to crafting elements that require more than one technological operation on single work center performed in a sequence [13].

During measurement 40 elements were qualified as production (value F) meeting quality requirements, whole production was equal 45 (value E), therefore quality component value would be calculated as:

$$Quality = \frac{F}{E} = \frac{40}{45} = 0{,}8888 \quad (1)$$

The authors suggested alternative approach, in order to take into account variable amount of technological operations performed on each product. The component value would be calculated as:

$$Quality = \frac{G}{H} = \frac{92}{99} = 0{,}9293 \quad (2)$$

where:

G – number of correctly performer operations

H – number of technological operations.

It was assumed that technological rating would concern every work center individually.

Additionally it would require constant data gathering via computer software. Interpretation of the output would be performed by designating unacceptable values and performing correcting actions on work centers that do not meet the requirements.

3.2. Ecological Criterion

Along with development of social responsibility of business and increase of concern about environment protection, rating of processes with ecological criterion was introduced. Researchers proposed evaluation of two aspects. First aspect concerns waste administration, including amount of waste and means of its utilization. Second aspect concerns usage of media, such as water and energy. Chosen measurers represent both aspects.

The first measure is based on the amount of waste produced. However, if the rating would take into consideration the mass of the waste, it would not be possible to designate normalization functions, since various batch processes in the company would generate different values of wastes' mass. Therefore it is necessary to elaborate measures as ratio of waste mass to quantity of produced products over time. It means that the measurement would require constant data gathering and periodical measurers' value calculation.

The second measurement concerns waste utilization. This measurement is calculated in form of periodical audit, which would answer the questions:

- How the waste is stored?
- How is it transported?
- How is it utilized?
- Is it possible to use waste in further production process?

The measure of media usage would require constant measurement. In this case, as in case of amount of waste measurer, it is necessary to compare received value in order to contrast the different processes. Therefore these measures would be quotient of value of used media and size of production. Two approaches are considered. The first approach would require estimation of used media for specific type of products, second – global media usage for entire production. The first approach takes into account specifics of batch production, where every two products can be very different from each other and require completely different time of production and media usage, but this type of calculation yields much more complexity and more difficult calculation. The second approach is easier to use, however unless products produced in the company possess high level of resemblance, the results might carry errors.

3.3. Social Criterion

The social criterion is about evaluation of processes from its related personal point of view. This criterion also should be considered in two aspects. The first aspect concerns evaluation of work centers in the light of current norms and regulations, while the second aspect would represent workers' point of view.

Evaluation of work centers requires periodical audit, including questions according to individual norms and concerning distance between machines, protection equipment etc. After finishing the evaluation, depending on calculated result corrective actions should be undertaken.

The second aspect would require carrying out survey amongst personnel. They would evaluate work stations and work conditions. Additionally, in order to avoid unreliable results, since data derived from surveys is subjective, measurers related to absence and workers' rotation would be introduced.

3.4. Market Criterion

According to definition “production process is orderly series of actions, resulting in customer (user) receiving products (or services)” [2], therefore it is necessary to include criterion based on clients’ opinion about production processes. Introducing surveys filled by customers was the first idea; however, it would carry many difficulties concerning reliability of surveys, percentage of their completion and means of distributing these surveys to clients. This is why other measurements were suggested.

The first measurement is the ratio of complaints’ quantity to quantity of sold products. Calculation of the measure as a quotient instead of number of complaints allows comparing different processes over different durations of time.

The second measurement concerns mean time of consideration of a complaint. In case of positively considered complaints, time of repair, return of product or money would be taken into account as well.

The third measurement involves the possibility to modify offered products, the time between placing individual order and receiving product.

3.5. Planning Criterion

Batch processes are characterized by variable realization course, high variety and variability, therefore their proper planning is crucial. On account of that the researchers decided to include planning criterion. It would concern punctuality in realization of specific actions.

The first measurement concerns punctuality of delivery of final product to the client. The second measurer concerns punctuality of individual production processes. Both are calculated by evaluating ratio of orders delivered punctually to general production. The third measurement concerns punctuality of individual suppliers’ delivery.

3.6. Economical Criterion

Economical rating represents degree of production processes’ financial expenses. Two aspects should be considered.

The first aspect concerns expenses over one piece of product, including cost of components used for product assembly, cost of its storage, and cost of media usage. Additionally payback period should be considered. Depending on storage management method, it might be difficult to perform calculations of all costs with this method.

The second aspect is associated with need of obtaining new equipment such as measurement equipment or additional cutter or drill. Therefore second aspect would concern ratio of expenses on equipment to acquired income.

3.7. General Development Criterion

Six mentioned above criterions allow the evaluation of the course of batch production processes performed within production company. However the researchers decided to extend the multi-criterion rating by adding a criterion which would take consideration of companies’ general condition. Evaluation based on measurers would include general financial situation of company, its technological park and personnel.

4. Conclusion

The researchers developer concept of seven-criterion batch production process course rating measurer. This concept allows performing complex evaluation of process through many criterions. Evaluation was based on criterions: market, economical, ecological, social, technological, planning and general development. Additionally, several chosen measurers were modified, which allowed a comparison of their values with border values and other processes performed in company.

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References

[1] Brzeziński M. *Organizacja i sterowanie produkcją, Projektowanie systemów produkcyjnych i procesów sterowania produkcją* [Organization and production control design of production systems and production control processes]. Warszawa: Agencja Wydawnicza PLACET; 2002.
[2] Durlik I. *Inżynieria Zarządzania, Strategia i projektowanie systemów produkcyjnych* [Management engineering, strategy and design of production systems]. Warszawa: Agencja Wydawnicza PLACET; 2005.
[3] Hansen RC. *Overall Equipment Effectiveness: A Powerful Production Maintenance Tool for Increased Profits*. New York: Industrial Press Inc; 2001.
[4] Kosieradzka A. Metoda wielokryterialnej oceny produktywności [Multicriteria Productivity Measurement Method]. *Zarządzanie Przedsiębiorstwem* 2004;2:37–45.
[5] Kubiński W. *Inżynieria i technologie produkcji* [Engineering and technology of production]. Kraków: Uczelniane Wydawnictwa Naukowo-Dydaktyczne; 2008.
[6] Kukułka A, Barylski A. Metodyka badawcza z wykorzystaniem miernika całkowitej efektywności wyposażenia [Research methodology using overal equipement efficiency measurer]. In: Łopatowska J, Zieliński G, editors. *Zarządzanie operacyjne w teorii i praktyce* [Operational management in theory and practice], Gdańsk: Wydawnictwo Politechniki Gdańskiej; 2014, p.137–148.
[7] Kukułka A, Wirkus M. Zagadnienie opracowania i stosowania wielokryterialnego miernika oceny przebiegu procesu niepotokowego [Issue of multi-criterion measurer development and application in rating of batch production process course]. In: Knosala R, editor. *Innowacje w Zarządzaniu i Inżynierii Produkcji* [Innovations in Management and Production Engineering]. Opole: Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją; 2016, p. 621–631.
[8] Mączyński W. Miernik OEE, MTBF i MTTR – czy to coś więcej niż wartości bezwzględne? [OEE, MTBF and MTTR measurers – the absolute values, or something more?]. *Utrzymanie Ruchu* 2011;1:28–30.
[9] Pająk E. *Zarządzanie produkcją Produkt, technologia, organizacja* [Production management Product, technology, organisation]. Warszawa: Wydawnictwo Naukowe PWN; 2006.
[10] *The Productivity Press Development Team, OEE for Operators: Overall Equipment Effectiveness*. Portland Oregon: ProdPress.com; 1999.
[11] Williamson RM. *Using Overall Equipment Effectiveness: the Metric and the Measures*. Columbus: Strategic Work Systems, Inc; 2006.
[12] Wirkus M, Kukułka A. Ocena przebiegu procesów produkcyjnych [Rating of production processes course]. In: Knosala R, editor. *Innowacje w Zarządzaniu i Inżynierii Produkcji* [Innovations in Management and Production Engineering], Opole: Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją; 2015, p. 654–663.
[13] Wirkus M, Kukułka A. Obliczanie składowej jakości OEE przy wielu operacjach technologicznych [Calculation of quality component in OEE rate for multiple technical operations]. *Zarządzanie Przedsiębiorstwem* 2015;2:40–47.
[14] Iannone R, Nenni M. Managing OEE to Optimize Factory Performance. In: Schiraldi M, editor. *Operations Management*, Croatia: InTech; 2013, p. 31–51.