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Overall Equipment Effectiveness within Counterfactual Impact Evaluation Concept

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Abstract

Counterfactual impact evaluation (CIE) is a scientific quantitative approach mainly based on experiments and quasi experiments. CIE is trying to prove a causal relationship between outputs and outcomes. CIE does not take into account coherence of external incentives of companies with internal incentives that have or may have an impact on the behaviour of enterprises. The paper sets up internal evaluation indicators for businesses, counterfactuals useful for creating a more complex metrics evaluating businesses in the area of performance. The aim of the paper is to present model situation using the elementary principle of counterfactual impact evaluation based on "the Overall Equipment Effectiveness (OEE)".

Keywords: CIE; OEE; production process; business evaluation.

JEL classification: M11; M21; M29.

1. INTRODUCTION

Counterfactual impact evaluation (CIE) is a systematic and an empirical study of the effects which is attributed to intervention – to certain change, help or support. The CIE analysis is currently being used as an assessment tool for the impact of support from the European Funds in the 2014-2020 programming period. In this area of evaluation, there is no interconnection between external incentives influencing the behavior of enterprises and internal incentives which have or may have an impact on business behavior. The current state of scientific counterfactual impact evaluation understanding brings innovation potential, particularly in the use of CIE for assessing the impact of internal incentives affecting business performance. Internal business processes are thought as those incentives taking place in the internal environment. The result of the counterfactual impact evaluation

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application should lead to the creation of not only quantitative evaluations but also qualitative oriented case studies that would help to demonstrate how to integrate the CIE into an enterprise's internal evaluation system, how to link the results of internal evaluation with the results of external evaluation. External evaluation linked to internal evaluation brings analogy to the interconnection of the SWOT analysis philosophy, which basically combines internal and external business incentives. However the evaluation lacks a more sophisticated evaluation tool to measure the impact of the company's activities.

Management of business entities especially from area of manufacturing enterprises (such as industrial, agricultural, construction enterprises) is significantly affected by the effect of production processes on individual machines or production lines. It can be assumed that the seed of the economic result is influenced at the production stage in terms of costs. Future products with their technical parameters and quality can influence the revenues of economic activity. One of the elements, which can be seen as an indicator of production factors consumption, is the fulfillment of the consumption standard of the relevant material inputs, referred to the THN (the Technical Economic Consumption Standard). The contribution of the paper can be seen in the suggestion of a production process metric proposal applicable to the internal environment assessment of the manufacturing companies for the purposes of counterfactual impact evaluation and the suggestion of support for such as business entities.

2. THEORETICAL BACKGROUND

Authors such as Imbens and Wooldridge (2009), Wooldridge (2010), Gertler *et al.* (2011), Khandker *et al.* (2010), Angrist and Krueger (2001), Angrist and Pischke (2009), Duflo *et al.* (2007), Morgan and Winship (2010), Mouque (2012), Potluka (2014), Potluka and Špacek (2013), Potluka *et al.* (2013), Hora *et al.* (2015), Zavřel (2015) focus only on assessing the impact of external incentives on business behavior in the case of the counterfactual impact evaluation. There is not experience with the implementation of the impact of internal incentives on business behavior in the case of the counterfactual impact evaluation. The whole process of the counterfactual impact evaluation involves qualitative studies with accurate process mapping, setting qualitative evaluation criteria, followed by quantitative evaluation and counterfactual calculation, and then finding out whether without the provided support the process would work better and if better results without support are achieved (Morgan and Winship, 2010). The process of counterfactual evaluation is related to the identification of areas included in the counterfactual impact evaluation, to the identification of indicators, data collection, gross impact calculation, estimation of counterfactual situation and determination of net impact. Measurement of impact within the concept of this paper can be understood as the difference between the situation of a group of companies measuring and evaluating the production process and the situation that would occur if the production process is not measured and evaluated within the internal environment of business.

T. Borovska *et al.* (2017) discuss the task of optimizing manufacturing systems, waste recycling, based on the methodology of optimal aggregation. They discuss mathematical model of structure with positive feedback and resource programmatically implemented as parameterized function user and problem of optimal multi-circuit production system aggregation. They analyze optimizing system with multiple types of wastes and by-products. Waste equipment has become a key application area for extended producer responsibility based on their research. Formulation and solution of the problem of optimal aggregation of elements of the production system “innovations, development, production” by equivalent optimal element are presented by T. M. Borovska *et al.* (2014) and T. N. Borovska *et al.* (2014). Production system and its elements are considered as technological resource converters. An optimal aggregation methodology, which integrates the equivalent transformations of structures of production systems and sub-optimization of subsystems are used within their research. Generalized models of production functions - parameterized and stochastic were developed and studied. Stochastic models of parametric relations among the elements "innovations", "development", "production" are developed and studied there. Optimal aggregation of typical structures of production systems with parametric connections: "production – development", "production – warehouse", "production with recycling" that satisfy the set requirements are analyzed by T. Borovska (2015), T. N. Borovska (2014b, 2014a). The properties of this class of models for production systems are insufficiently investigated. Concrete partial results of modeling for these tasks are presented in the paper T. Borovska (2015), T. N. Borovska (2014b, 2014a). Extended producer responsibility (EPR) is according to Gu *et al.* (2017) important to achieve a sustainable economy system because EPR can guarantee that these companies implementing EPR can obtain average profit margins. According to Gu *et al.* (2017) the time sequence and a gradually increasing productive time fund, which is easy for producer to adopt, are determined to achieve a sustainable time fund system. Wang *et al.* (2017) systematically analyzes the physical and financial operating mechanisms of the production systems in Japan, Germany, Switzerland, and China, in addition to the responsibilities borne by the various stakeholders in the life cycle production chain. The research of Wang *et al.* (2017) analyze the production operating mechanisms of the above four countries in the terms of the time fund, the object of time fund, and the time fund operation. The result shows that although the operation mechanism of production systems varies greatly in different countries, there are some similar problems in evaluating the production process and in production information value utilization.

The value of information on production process should be exploited to build up a new evaluation model for production process evaluation that closely corresponds to a reverse production chain for recovery and utilization to making the product manufacturing much efficient and the overall efficiency of business entities. The objective measure of manufacturing enterprises is the overall equipment effectiveness (OEE) indicator of production facility within the production process, which is created for the analysis and evaluation of the production processes of the manufacturing enterprises. Gehlof (2016) and Synek (2011) express the OEE as the ratio of the time during which the production facility is able to produce a good product per full performance with acceptable quality to the real time during which production actually take place. The ideal result for OEE is 100%.

3. METHODOLOGY

This part of the paper introduces the proposed methodology which the authors would like to apply within the manufacturing enterprises in the area of production process analysis. The production process itself based on the authors is reflected in the economy of production in a way that can be identified in the elementary form as:

$$OEE = \frac{Q_{REAL\ QUAL}}{Q_{PLAN\ QUAL}} \tag{1}$$

where: OEE: Overall Equipment Effectiveness;

$Q_{REAL\ QUAL}$: Real number of produced quality products [natural units];

$Q_{PLAN\ QUAL}$: Planed number of produced quality products [natural units].

The overall equipment effectiveness indicator of production facility measures the relation between the real production of identical products ($Q_{REAL\ QUAL}$) and the planned production volume (identical products), ($Q_{PLAN\ QUAL}$). It is assumed for the planned production values that the manufacturing process is set up so that only products of a design which meets their qualitative requirements (identical products) are produced.

The volume of production is influenced by the time fund for which the production facility is in active mode when the products are really produced *(T_P)* and the output of the production facility *(V)*. Decomposition of the production volume *(Q)* into the elementary factors – the productive time fund *(T_P)* and the output of the production facility *(V)* are determined by:

$$Q_{REAL} = T_{P\ REAL} \times V_{REAL} \tag{2}$$

$$Q_{PLAN\ QUAL} = T_{P\ PLAN} \times V_{PLAN} \tag{3}$$

where:

Q_{REAL}: Real production including nonidentical products [natural units];
$T_{P\ REAL}$: Real productive time fund [hour];
V_{REAL}: Real output of the production facilities [pc/h];
T_{PLAN}: Planed productive time fund [hour];
V_{PLAN}: Planed output of the production facility [pc/h].

The pyramidal decomposition of the OEE indicator according to the expression (1) can be expressed as:

$$OEE = \frac{Q_{REAL\ QUAL}}{Q_{PLAN\ QUAL}} = \frac{Q_{REAL\ QUAL}}{Q_{REAL}} \times \frac{Q_{REAL}}{Q_{PLAN\ QUAL}} \tag{4}$$

Using the relationships (2) and (3), than equation (4) can be adapted into the following form:

$$OEE = \frac{Q_{REAL\ QUAL}}{Q_{PLAN\ QUAL}} = \frac{Q_{REAL\ QUAL}}{Q_{REAL}} \times \frac{Q_{REAL}}{Q_{PLAN\ QUAL}} = \frac{Q_{REAL\ QUAL}}{Q_{REAL}} \times \frac{T_{P\ REAL}}{T_{P\ PLAN}} \times \frac{V_{REAL}}{V_{PLAN}}$$

$$OEE = \underbrace{\frac{Q_{REAL\ QUAL}}{Q_{REAL}}}_{\substack{\textit{Quality}\\ \textit{indicator}\\ C_{QUAL}}} \times \underbrace{\frac{T_{P\ REAL}}{T_{P\ PLAN}}}_{\substack{\textit{Time utilization}\\ \textit{indicator}\\ C_{EXT}}} \times \underbrace{\frac{V_{REAL}}{V_{PLAN}}}_{\substack{\textit{Output utilization}\\ \textit{indicator}\\ C_{INT}}} \tag{5}$$

or in form:

$$OEE = \frac{Q_{REAL\ QUAL}}{Q_{REAL}} \cdot \frac{T_{P\ REAL}}{T_{P\ PLAN}} \cdot \frac{t_{K\ PLAN}}{t_{K\ REAL}} \tag{6}$$

where:

$t_{K\ PLAN}$: planned value of the labour-intensity standard [h/pc];
$t_{K\ REAL}$: real value of the labour-intensity standard [h/pc].

Whereas the real value of the labour-intensity standard *($t_{K\ REAL}$)* is determined on the basis of the real production *(Q_{REAL})* and the real productive time fund *($T_{P\ REAL}$)*, it possible to use the relation for calculating the real value of the labour-intensity standard *($t_{K\ REAL}$)* – to modify the resulting expression for the "Overall Equipment Efficiency (OEE)" indicator calculation – to the following form:

$$t_{K\ REAL} = \frac{T_{P\ REAL}}{Q_{REAL}} \tag{7}$$

Fitting the expression (7) into the formula (6):

$$OEE = \frac{Q_{REAL\ QUAL}}{Q_{REAL}} \cdot \frac{T_{P\ REAL}}{T_{P\ PLAN}} \cdot \frac{t_{K\ PLAN} \cdot Q_{REAL}}{T_{P\ REAL}}$$

$$OEE = \underbrace{\frac{Q_{REAL\ QUAL}}{Q_{REAL}}}_{\substack{\textit{Quality}\\ \textit{indicator}}} \times \underbrace{\frac{T_{P\ REAL}}{T_{P\ PLAN}}}_{\substack{\textit{Time utilization}\\ \textit{indicator}}} \times \underbrace{\frac{t_{K\ PLAN} \cdot Q_{REAL}}{T_{P\ REAL}}}_{\substack{\textit{Output utilization}\\ \textit{indicator}}} \tag{8}$$

The quality indicator evaluates the proportion of real produced identical products to the planned quantity. As part of the planning mechanism, it is assumed, that only identical (quality) products are produced during the production process at time known as the productive time fund ($T_{P\ PLAN}$).

For many production processes, there is necessary in connection with the quality evaluation to regard the fact, if the identical product has undergone the manufacturing process for the first time without forced repairs (some manufacturing operations have to be repeated). In this case, it seems to be appropriate to add the percentage of success of the products that have passed the production process at the first pass.

Share of the products with first pass:

$$\text{Qual 1} = \frac{Q_{REAL\ QUAL\ "1"}}{Q_{REAL\ QUAL}} \cdot 100 \qquad [\%] \tag{9}$$

A significant loss of "identical products" is the waste in many cases which beyond the framework standards THN when a new campaign within the production program is starting. It is up to the management of the appropriate business unit to be able to suggest steps to prevent (limit) losses in the production process.

The time utilization indicator of production capacity assesses the relation between the real productive time fund *($T_{P\ REAL}$)* and the planned productive time fund *($T_{P\ PLAN}$)*. Both the real productive time fund and its planed value are derived from the nominal time fund *(T_N)*, which represents the time of operation of the production facility. The nominal time fund is related to the work on shifts in which the production facility is in operation. Generally, the nominal time fund is determined as:

$$T_N = T_{CAL} - T_{NOTWORK} \tag{10}$$

where:

T_{CAL}: calendar time fund [days, hour];

$T_{NOTWORK}$: time fund during which the production facility is not in operation [Saturdays, Sundays, holidays, plant shutdown].

The following relation is used to determine the productive time fund $T_{P\ PLAN}$ respectively $T_{P\ REAL}$:

$$T_{P\ PLAN} = T_N - T_{DOWNTIME\ PLAN}$$

$$T_{P\ REAL} = T_N - T_{DOWNTIME\ REAL}$$

where:

$T_{DOWNTIME\ PLAN}$: planed time within the nominal time fund, for which the facilities do not produce (malfunction, rebuilding to other assortment, adjusting the machine, lack of material, etc.);

$T_{DOWNTIME\ REAL}$: Real time within the nominal time fund, for which the facilities do not produce (malfunction, rebuilding to other assortment adjusting the machine, lack of material, etc.).

In order to increase the value of the productive time fund $T_{P\ REAL}$, it is necessary to reduce the time spent on downtime $T_{DOWNTIME\ REAL}$. The requested effect can be achieved by improving the organization of work, for example in the following items: coordinated supply of material, optimal level of production, reducing the proportion of failures (mechanical, electrical, technological) by prevention in the field of maintenance of the production facilities, etc.

The output utilization indicator of production capacity evaluates the ratio between the real reported output of the assessed production facility *(V_{REAL})* and its projected (planned) value *(V_{PLAN})*. The relation can also be transformed into the mathematical expression in the form of:

$$\frac{V_{REAL}}{V_{PLAN}} = \frac{t_{K\ PLAN} \cdot Q_{REAL}}{T_{P\ REAL}} \tag{11}$$

The quantification of the output utilization of the production capacity with the application of the expression on the right side of the equation (11) is subject to options of using more accessible collected data.

Influencing the output utilization indicator of the production capacity is closely related to the utilization of the technical parameters of the relevant production facility. In a simple way, the problem can be formulated as follows: to reduce the labour-intensity of the relevant manufactured product. The qualification potential of the operating staff has the important role here, the staff decides about the possibilities to transform the technical parameters of the facility into the maximizing the output.

4. THE EXAMPLES OF THE APPLICATION OF THE PRINCIPLES OF COUNTERFACTUAL IMPACT EVALUATION USING OEE

Applying the principles of counterfactual impact evaluation for assessing the quality indicator within "Overall Equipment Efficiency" (OEE) measurement is associated with evaluating the impact of measures to increase the proportion of identical products that have passed the production process at the first pass to the OEE value. Other indicators contributing to OEE indicator can be worsened (the time utilization indicator, the output utilization indicator). Furthermore, it is important to evaluate the impact of the measures to reduce the loss as a result of exceeding the THN standard to the OEE indicator when launching a new product campaign.

Applying the principles of counterfactual impact evaluation for assessing the use of the time fund in the measurement of "Overall Equipment Effectiveness" (OEE) should assess the impact of the activities taken in the area of maintenance prevention of the production facility. Scheduled repairs should reduce the failure of the production facility and thereby increase the value of OEE through increasing the productive time fund ($T_{P\ REAL}$). Other indicators contributing to OEE indicator can be worsened (the quality indicator, the output utilization indicator of production capacity). It is important to objectify the value of the $T_{P\ PLAN}$ in order to improve the time utilization of the production aggregate. Manufacturing businesses should reduce the downtime due to faults of the production facility through organizing the preparation of maintenance staff for troubleshooting in the production process.

Applying the counterfactual impact evaluation principles for assessing the use of performance parameters of the production facility in the measurement of "Overall Equipment Effectiveness" (OEE) should assess and evaluate the impact of the qualification growth of the operating staff to the achieved output of the production equipment. Measures should be taken in order to increase equipment performance by using technical tools. It is important to objectify the value of planned output *(V_{PLAN})* in order to improve the performance assessment of the production unit.

5. CALCULATION AND EVALUATION OF OEE INDICATOR IN MODEL SITUATION

The "Profil" company operates the "Largo" line for the production of thin-walled welded profiles. The line works in three-shift operation and its basic technical and economic parameters are listed in the following Table no. 1.

Table no. 1 – Technical and economic parameters of the "Largo" production line in 2012 and 2013

		Units	**Planned result**	**Real result (month in 2012)**	**Real result (month in 2013)**
(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*
Nominal time	T_N	*[day]*	21	21	21
Nominal time	T_N	*[hour]*	504	504	504
Downtime	$T_{DOWNTIME}$	*[hour]*	84	92	90
Productive time fund	T_P	*[hour]*	420	412	414
Value of the labour	t_K	*[hour/t]*	0.125	0.128	0.127
Production volume	Q	*[t]*	3,360	3,218.75	3,259.8425
Of which non-identical production.	*Q*	*[t]*	*0*	*296*	*251*
THN total		*[kg/t]*	1,120.00054	1,125.00106	1,124.000951
THN fixed		*[t]*	1.8	3.4	3.1
THN variable		*[kg/t]*	1,120	1,125	1,124

Source: own processing

In order to reduce the proportion of non-identical production, "Profil" management has introduced measures of a technical character to reduce non-identical production, which in turn reduces the value of "The Quality Indicator" in the comprehensive assessment of "Overall Equipment Efficiency (OEE)". It also expects a reduction in the number of non-identical products when adjusting the production line to the desired assortment item or its size. However, the proposed measure entails the risk of its negative impact on other indicators ("The time utilization indicator" and "The output utilization indicator"), which form a complex within the OEE.

The columns (e) and (f) of the table provide data on the assessment of the situation prior to the introduction of a technical measure to reduce non-identical production.

- Nominal time: The time fund available after deduction of non-working days (Sundays, free Saturdays, holidays, part of the fund may also be a plant shutdown). The conversion of the nominal time fund in days is transformed into the number of hours depending on the work on shifts. In the case of three-shift operation, the following applies: TN [hour] = TN [day] 24

- Downtime: It is a time fund within the nominal time fund. For its duration the production line does not produce. These include, in particular, mechanical disturbances and faults on the electrical equipment of the production line, the conversion of the production line to another size of the product or a completely new assortment, etc.; including time to produce unavoidable defective production ("non-identical products")

- Productive time fund: Is the time when the production equipment actually produces the required assortment (both identical and non-identical). The amount of the productive time fund is determined by the difference between the nominal time fund and the downtime.

- Value of the labor: Represents the time required to produce 1 t of closed profiles on the welding line.

- Production volume: Is the amount of production realized on the subject production line over the monitored period (month). In the reported production level, "non-identical production" (296 tons in column "e" and 251 tons in column "f") is also included as shown in Table no. 1. It is a production that has the specifications that not meet to the requirements of the standards, but that is selling at a lower price than meets the standards or possible to repair the product by repeating the operation where the error occurred (for example: by extra equalizing the non-conforming profiles in terms of straightness, cutting the profile to the desired length, etc.).

Table no. 2 – Technical and economic parameters of the "Largo" production line in 2014 and 2015 (after the implementation of a "technical measure")

		Units	**Planned result**	**Real result (month in 2014)**	**Real result (month in 2015)**
(a)	***(b)***	***(c)***	***(d)***	***(e)***	***(f)***
Nominal time	T_N	*[day]*	21	21	21
Nominal time	T_N	*[hour]*	504	504	504
Downtime	T_{PROST}	*[hour]*	84	98	94
Productive time fund	T_P	*[hour]*	420	406	410
Value of the labour	t_K	*[hour/t]*	0.125	0.1266	0.126
Production volume	Q	*[t]*	3,360	3,206.951	3,253.9683
Of which non-identical production.	*Q*	*[t]*	*0*	*98*	*64*
THN total		*[kg/t]*	1,120.00054	1,123.00081	1,123.000645
THN fixed		*[t]*	1.8	2.6	2.1
THN variable		*[kg/t]*	1,120	1,123	1,122

Source: own processing

Table no. 2 presents the technical-economic parameters of production after the implementation of a "technical measure" to reduce non-identical production. From the point of view of the nominal time fund, these are comparable periods as in Table no. 1.

- THN total: is the summarization of THN fixed and THN variable items. It is a standard that determines consumption of the input material (strip steel) in the production of welded profiles.

- THN fixed: there is included the consumption of strip steel when adjusting the production line to the desired size and shape of the future profile. The consumption of strip steel for production line adjustment is not affected by the volume of profile production in the given campaign.

- THN variable: consumption of strip steel for the reported production (planned, real).

For the purposes of assessing the anticipated impacts of the adopted technical measure the "Overall Equipment Efficiency (OEE)" was calculated, both without the effect of the technical measure ($OEE_{WITHOUT}$) in the years 2012 and 2013, and following the implementation of the above-mentioned technical measure (OEE_{TECH}) in 2014 and 2015:

$$OEE_{WITHOUT2012} = \frac{Q_{REALQUAL}}{Q_{REAL}} \cdot \frac{T_{P\ REAL}}{T_{P\ PLAN}} \cdot \frac{t_{K\ PLAN} \cdot Q_{REAL}}{T_{P\ REAL}}$$

$$OEE_{WITHOUT2012} = \frac{3\,218.75 - 296}{3218.75} \cdot \frac{412}{420} \cdot \frac{0.125 \cdot 3218.75}{412}$$

$$\boldsymbol{OEE_{WITHOUT2012} = 0.8699 \equiv 86.99\ \%}$$

$$OEE_{WITHOUT2013} = \frac{3259.8425 - 251}{3259.8425} \cdot \frac{414}{420} \cdot \frac{0.125 \cdot 3259.8425}{414}$$

$$\boldsymbol{OEE_{WITHOUT2013} = 89.55\ \%}$$

For the purposes of the OEE_{TECH} calculation the items related to the reality, used results in columns (e) and (f) "Real result" are used, see Table no. 2.

$$OEE_{TECH2014} = \frac{Q_{REALQUAL}}{Q_{REAL}} \cdot \frac{T_{P\ REAL}}{T_{P\ PLAN}} \cdot \frac{t_{K\ PLAN} \cdot Q_{REAL}}{T_{P\ REAL}}$$

$$OEE_{TECH2014} = \frac{3\,206.951 - 98}{3218.75} \cdot \frac{406}{420} \cdot \frac{0.125 \cdot 3206.951}{406}$$

$$\boldsymbol{OEE_{TECH2014} = 0.9219 \equiv 92.19\ \%}$$

$$OEE_{TECH2015} = \frac{3\,253.9683 - 64}{3\,253.9683} \cdot \frac{410}{420} \cdot \frac{0.125 \cdot 3\,253.9683}{410}$$

$$\boldsymbol{OEE_{TECH2015} = 0.9494 \equiv 94.94\ \%}$$

Summary of the impact of the adopted technical measure on the OEE indicator:

There was a positive trend in the development of the OEE indicator (Table no. 3), which is not characterized by a step change in development between 2013 and 2014, when a "technical measure" has been implemented to reduce the incidence of non-identical production. However, the non-identical production itself shows a significant step change between years 2013 and 2014 (see Table no. 3).

Table no. 3 – Development of the OEE indicator, including the linear development trend

Indicator		Year 2012	Year 2013	Year 2014	Year 2015
OEE	%	86.99	89.55	92.19	94.94
OEE (trend)	%	86.94	89.59	92.24	94.89
Non-identical production	t	296	251	98	64

Source: own processing

Table no. 1 and Table no. 2 also show the impact of the adopted technical measure on the THN indicator of strip steel consumption. Obviously, the measure positively affected the process of adjusting the newly introduced profile, with the use of much less hoops for "forced non-identical products".

6. DISCUSSION

Overall Equipment Effectiveness (OEE) measures how close you are to perfect production and that is why this method is useful for all manufacturers. The key to applying to any industry is a clear definition of time utilization, quality and output utilization. The results of the time utilization, quality and output utilization are useful for production planning but if they are not clear defined and are used in the OEE calculation they can hide the true capacity of the production process. This can artificially raise OEE score while this can hide loss and can slow improvement.

In assessing the impact of the measures taken on their expected effect in the form of a reduction in "volume of non-identical production", it is also possible to use the elementary principles laid down by the counterfactual impact evaluation. Counterfactual indicates a hypothetical situation that will occur if certain change, activity is not realized. In the presented model situation, it is possible to quantify the value of the "adjusted increase (decrease) of the monitored indicator". The indicator in this case is the amount of "non-identical production" that does not show the required parameters resulting from the contractual relationship with the customer.

Calculation of the adjusted loss of "non-identical production" (NP) attributable to the implemented "technical measure" to reduce non-identical production in absolute value (i.e. in natural units [t]):

$$\text{"}adjusted\ decrease\ NP\text{"} = NP_{1.year\ TO} \cdot \left(\frac{NP_{2.year\ TO}}{NP_{1.year\ TO}} - \frac{NP_{2.year}}{NP_{1.year}}\right)$$

$$\text{"}adjusted\ decrease\ NP\text{"} = 98 \cdot \left(\frac{64}{98} - \frac{251}{296}\right) = -19\ t$$

$$\text{"}adjusted\ decrease\ NP\text{"} = -19\ t$$

In conclusion to the quantified decline in "non-identical production", it can be noted that the "technical measure" itself can be attributed to the loss of non-conforming production -19 tons between the years 2014 and 2015. If we simply compare the absolute values, the loss of non-identical production is -34 tons.

7. CONCLUSIONS

The overall equipment effectiveness (OEE) indicator is considered to be an objective indicator of manufacturing enterprises within the internal business environment according to Gehlof (2016) and Synek (2011). The paper presents the elementary form of the production process through the OEE indicator and characterizes the pyramidal decomposition of the OEE indicator. The paper presents examples of the application of the counterfactual impact evaluation principles with using the OEE indicator in order to evaluate the production quality, to evaluate the use of the time fund and to evaluate the use of the performance parameters of the production equipment within the overall efficiency measurement of the production process. The OEE indicator can help businesses to concentrate on losing their potentials in the mentioned areas. Manufacturing enterprises should use the OEE indicator for management and measurement of business performance.

Based on the analysis of the data development of individual indicators influencing the overall efficiency value of the production equipment it can be stated that the achieved effect of the adopted technical measure to reduce non-identical production was not fully reflected in the OEE. The “technical measure” has also been reflected in other factors that affect OEE (increase in downtime). Elementary principle of OEE indicator used in counterfactual impact evaluation can help companies measure their efficiency of production process as an internal incentive influencing business development.

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