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Measurement of Impact of Selected Industrial Engineering Practices on Companies' Economic Performance

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Industrial engineering (IE) represents a significant tool how to eliminate waste in both manufacturing and other areas of the enterprise. This helps reduce costs, increase production effectiveness and other characteristics, which can lead to better competitiveness and performance. Finding IE methods that have significant impact on overall business performance is the main purpose of this paper. Another objective was to determine whether the impact of industrial engineering methods applies to all industries in the Czech Republic or whether it applies only to selected industries. The data was obtained through an online questionnaire survey, the survey focused on a wide range of manufacturing companies (N=235) from different industries, different sizes and ages. For comparing the overall business performance among individual respondents, a ROE 1 (Return on Equity) indicator was selected. To measure this indicator from the impact of the tax, investment and credit policy, a modified ROE indicator (ROE 2 calculated first with EBITDA - Earnings before Interest, Taxes, Depreciation and Amortization and then ROE 3 calculated with EBIT - Earnings before Interest and Taxes) was used. The results show that the use of IE methods in manufacturing plants is limited to a few selected methods. Similarly, only a few industrial engineering methods are typically used in high performance firms and can therefore be said to be involved in increasing performance. The statistically significant relationship between specific IE method and the higher performance measured by ROE 1 or ROE 2 was observed only for standardization, 5S, JIT, APS and six sigma. Presented research also shows that this influence of methods does not apply to individual IE methods globally in all the sectors studied, but only in some of them.

Keywords: *Industrial Engineering; Economic Performance; Lean Production; Lean Six Sigma; Standardization, 5S, JIT.*

Introduction

Industrial engineering (IE) and the related concept of lean is a tool that has spread during years almost all over the world, both in manufacturing companies and in service companies or healthcare sector (Radnor *et al.*, 2012; Rajnoha & Chromjakova, 2009; Piercy & Rich, 2009; Suarez-Barraza *et al.*, 2012; Stefko *et al.*, 2016). For our research and for the needs of literary research, we focused on the lean concept, lean six sigma. These two concepts then cover all the specific IE tools that were part of our research.

A relatively large number of case studies deal with the contribution of the individual lean methods, especially in reducing production and related costs and improvements in shop floors (Sjoberg *et al.*, 2012; Jaca *et al.*, 2014; Ablanedo-Rosas *et al.*, 2010; Singh *et al.*, 2013; Tucek *et al.*, 2013). Further studies address the implementation of the lean as a concept and include both the external environment (supply chains, strategic partnerships with suppliers and customer interaction) and the internal environment (processes, technology, quality, innovations, organizational aspects, social factors, sustainability etc.) (Tizroo *et al.*, 2017; Sharma *et al.*, 2015; Muhammad *et al.*, 2017; Yoo & Seo, 2017; Rajnoha & Lesnikova, 2016; Monni *et al.*, 2017; Krause, 2017; Kocmanova *et al.*, 2017; Koraus *et al.*, 2017; Afonina, 2015; Virglerova *et al.*, 2016; Urban & Joubert, 2017; Kozubikova *et al.*, 2015).

The investments in introducing lean return several times in the form of cost reductions, increased labor productivity, shorter delivery times or higher quality (Al Smadi, 2009; Ginevicius *et al.*, 2015). Although the relationship between lean production and the production performance of the company was studied (Cua *et al.*, 2001), and higher performance should lead to higher economic performance (the most commonly measured by financial indicators), this relationship was not sufficiently confirmed (Losonci & Demeter, 2013).

The empirical results of the relationship between overall business performance and IE methods, and hence lean, are very indefinite (Losonci & Demeter, 2013). It is

possible to search for studies that have confirmed this relationship (Fullerton & Wempe, 2009) but there are also studies that have not confirmed a statistically significant relationship (Ahmad *et al.*, 2004; Losonci & Demeter, 2013). These and also other studies operate with a lean concept and do not focus on the relationship between individual IE methods and economic performance (Tucek *et al.*, 2017).

Some studies focus only on some selected lean instruments. However, lean instruments are selected at random and in most cases different authors focus on the same methods, e.g. JIT (Just in Time), or Total Quality Management – TQM (Mackelprang & Nair, 2008; Brah & Chong, 2004). These studies are either focused on production performance or their conclusions are inconsistent.

The main purpose of this paper is to determine whether some of the IE methods affect overall business performance measured by the ROE (Return on Equity) indicator and quantify this impact. Our previous research has shown that IE methods are not implemented globally in all industries of the national economy without exception.

Our research provides a further insight into this issue. What methods of IE are the most common among Czech firms? Do some IE methods affect the ROE indicator? Which methods are applied by more efficient firms? Our research answers these basic questions in the following sections.

Literature Review

Business performance and market positioning are key concepts for today's businesses (Yoo & Seo, 2017). Any competitive advantage that firms can get is very valuable, and firms are looking for ways to reach them (Koraus *et al.*, 2015; Soltes & Gavurova, 2015; Virglerova *et al.*, 2017; Batchimeg, 2017; Belas *et al.*, 2017). One of the possible ways how to increase productivity, change a corporate culture or cleaning up shop floors, reduce cycle time and improve value for customers is lean or in the case of reducing waste and rework six sigma (Naslund, 2008).

Lean contains a set of tools to help firms identify the direction of improvement, so it is not tools that can be deployed at anytime, anywhere (Holweg, 2007). For the successful implementation of lean, each tool or method needs to be adapted to the specific business conditions (Furlan *et al.*, 2011). In the beginnings, the lean methods were primarily used in the shop floors and had an impact only on local performance without a clear impact on overall system performance (Holweg & Pil, 2001). However, lean and IE does not just mean focusing on improving the performance of the shop floor. The basic purpose of the lean should be seen in increasing value for the customer by improving the product or service and eliminating waste (Shah & Ward, 2007; Simpson & Power, 2005).

The main purpose of lean is to eliminate waste at every level and maximize the value for customer (Bhim *et al.*, 2010). To maximize the advantage of lean implementing, it is necessary to focus not only on its internal implementation but also on the implementation throughout the entire value chain (Bhasin, 2012). According to Lewis (2000), a critical issue seems to be the inability to appropriate the added value achieved through the implementation of IE methods and savings brings by their usage.

Application of lean is not a one-time project; it is a long-term effort to change the organization. There are four basic phases of lean implementation, which firms pass through: cells and assembly lines, shop-floor, value stream and value systems (Hines *et al.*, 2004).

The extent of use of IE methods and tools has already been the subject of earlier research. For example, in his research, Bhasin (2012) also identified the most used IE methods in a given sample of respondents - it was TPM (Total Productive Maintenance), attacking value and seven wastes, process mapping, 5S and visual management, kaizen and continuous improvement. Similar research is presented by Glass *et al.* (2016). This research was held in Germany, Switzerland and Austria and the main emphasis was the identification of differences in the implementation of individual IE methods among the industry. The 2011 study (Eswaramoorthi *et al.*, 2011) identified the status of lean methods in the Indian machine tool industry – most common methods in this case were e.g. cross-functional teams, work standardization, 5S, Poka yoke or cell layout. Another study was conducted between US and UK businesses, highlighting the need for a thorough analysis of the current value streams in firms and a detailed preparation of the future shape of these value flows.

IE methods can be implementing unsystematically in random order, and their selection is often random in enterprises. However, their systematic deployment can bring much better results - it is often useful to implement them together. Typical example of this are TQM (Total quality management), TPM and JIT (Just-in-Time). These methods together form a comprehensive and consistent set of production methods aimed at improved performance. TPM has a positive and significant direct relationship to performance as well as an indirect relationship through the JIT method with low cost, high level of quality and compliance with delivery times. In practice, it is very common that these three methods are implemented at the same time. Cua *et al.* (2001) define two sets of activities related to the implementation and use of these three methods - the first group is common to all three methods (vision, strategic planning, interdisciplinary training and employee involvement). These activities provide support mechanisms for implementing discussed EI methods. Unlike these common activities, each method is characterized by unique practices that are more technically or process-oriented. These specific practices represent the basic techniques of each method. (Cua *et al.*, 2001) The simultaneous implementation of JIT, TPM and TQM could lead to better business performance. The simultaneous implementation of these methods is also profitable in view of the same supportive activities that are needed for successful implementation, such as 5S, Kaizen, visualization.

Andersson *et al.* (2006) defined the basic differences and similarities between TQM, lean (and the six sigma methodology). E.g. while lean and six sigma are primarily aimed at improving through projects, TQM highlights the commitment and engagement of all employees. All three approaches are focused on processes (Andersson *et al.*, 2006). The relationship of lean – six sigma – TQM has been the subject of further research (Dahlgaard-Park & Dahlgaar, 2006).

Similar findings are reported by other study (Naslund, 2008) in which the relationship between TQM, JIT and lean was discussed. According to this study, lean and six sigma basically share the same fundamental approach to change and improvement as JIT and TQM and the main ideas of JIT and lean do not differ from the main ideas of TQM.

The impact of IE and lean on company performance (measured most often by financial indicators) has also been the subject of recent research. However, the results of these studies are inconsistent. For example, Fullerton & Wempe (2009) found the positive and direct effect of lean on financial performance measured primarily by ROS (return on sales) indicator. Similar results were also presented in the 2011 study – lean demonstrates positive impact on financial performance measured by the ROS and ROA (return on assets) indicators (Yang, *et al.,* 2011). On the other hand, Jayaram *et al.* (2008) concluded that lean does not affect financial performance measured by ROA indicator.

We present a summary table (Table 1), which summarizes the knowledge in the field of IE method research and company performance measured by different performance indicators. For comparison, we chose the most commonly used IE methods - the lean concept (the degree of implementation of which is most often described by the self-assessment by the firm), JIT, TOC (Theory of constraints) and TQM. We have not selected country studies or a specific focus. Presented studies are sorted by year of publication and a brief description of the main findings is given.

Based on the objective of this article and based on the study of the available professional resources, we selected 25 IE methods in our research and we focused on finding and describing their impact on the overall performance of enterprises represented by the ROE (return on equity) indicator.

Table 1

Overview of Relationship between IE Methods and Business Performance

Authors	IE method	Link to performance indicator	Country	Research conclusions
Cua, McKone, Schroeder (2001)	TQM, JIT, TPM	Manufacturing performance, unit cost of manufacturing	Cross-country sample	Higher level of manufacturing performance can be achieved by simultaneous implementing of TQM, JIT and TPM.
Huarng, Chen (2002)	TQM	Several indicators for cost reduction and business performance	Taiwan	TQM positively influence business performance.
Sale, Inman (2003)	TOC, JIT	Sales level, market share, operating profits, ROI …	US	Firms using TOC can achieve significantly higher performance than firms using only JIT or traditional manufacturing.
Jayaram, Vickery, Droge (2008)	LEAN	ROI, ROS, ROA	North America	There was no positive or negative relationship between LEAN and the firm's financial performance.
Fullerton, Wempe (2009)	LEAN	ROS	US	Positive affect of LEAN on financial performance.
Yang, Hong, Modi (2011)	LEAN	ROA, ROS	Cross-country sample	LEAN improves productivity and reduces the asset base which causes improvement of financial performance.
Nawanir, Teong, Ohman (2012)	LEAN	Profitability, Sales	Indonesia	LEAN positively associate with business performance.
Danese, Romano, Bortolotti (2012)	JIT	Unit cost of manufacturing, inventory turnover, cycle time	Cross-country sample	JIT positively affect efficiency.
Losonci, Demeter (2013)	LEAN	Sales, market ratio ROS, ROI	Cross-country sample	There are no obvious financial benefits in the group of LEAN producers.
Chavez, Yu, Jacobs, Fynes, Wiengarten, Lecuna (2014)	Internal LEAN practices	Market share, ROI, growth of market share, growth of ROI	Republic of Ireland	Effect of LEAN on organizational performance was inconclusive. LEAN practices enable improvement in performance only in case of low levels of technological turbulence environments.
Khanchanapong, Prajogo, Sohal, Cooper, Yeung, Cheng (2014)	LEAN	Manufacturing cost	Thailand	Cost performance is positively affected by LEAN.

Objectives, Data and Methodology

The main purpose of our study is to examine the extent to which firms use individual IE methods and to find out if some of the methods affect the economic performance measured by the ROE indicator.

The impact of lean concept on performance has been the subject of several studies. However, individual studies are inconsistent in claiming that the lean concept has positive impact on the overall efficiency of the firm. Furthermore, there is no study of how the individual IE methods and, therefore, the lean concept affects the economic performance of the firm measured by ROE. To achieve the research objectives the following research hypothesis were defined:

H1: We assume that firms implementing specific IE methods achieve significantly higher overall performance measured by the ROE indicator.

H2: We assume that the hypothesis H1 apply in all industries. We claim that the positive impact of specific IE methods on performance applies in all industries.

Data about the primary database of random selected enterprises from different industries we obtain by extensive online survey. We searched for firms on online publicly available databases and on corporate websites if they were available to them. The questionnaire was distributed in two

rounds and we obtained data (correctly filled out questionnaires) from a total of 235 firms. We consider the size of the research sample as being sufficiently representative.

A part of the questionnaire was a list of twenty-five methods and tools of IE. The most common names of the IE methods were used in the list of methods offered (some of which we assumed to be less well known or which are often part of corporate expertise under a different name were briefly explained). In the list of offered IE methods, both groups of the methods have been applied – local methods (e.g. visualization, 5S, etc.), as well as the methods that affect firms as a whole – global methods (e.g. TQM concepts or JIT philosophy).

For the statistical evaluation of the relationship between the selected variables was used Pearson's Chi-square Independence Test. This test is used to find out how likely it is that the observed frequencies distribution is due to chance. This test compares the consistency of observed distribution of data with expected distribution data in the case of independent variable categories. Pearson's Chi-square test defines two basic hypothesis which are being tested during the analysis. Hypothesis H_0 assumes that the relative distribution of first variable are independent of the second variable. For our purposes, zero and alternative statistical analysis are defined as follows:

H_0: There is no statistical significant correlation between tested IE methods and the ROE indicator.

H_1: There is statistical significant correlation between tested IE methods and the ROE indicator.

The p-value is used to accept or reject the zero hypothesis. The level of significance, which is necessary for comparison with the p-value, was set as $\alpha = 0{,}05$.

We are aware that ROE is not the most appropriate indicator. More appropriate indicator would be the EVA (economic value added) indicator (which we consider to be unrealistic for the survey). For this reason, we have decided to use another two indicators - modified ROE, that were calculated not with EAT (earning after taxes), but with EBITDA – earnings before interest, taxes, depreciation and amortization (ROE 2), and EBIT – earnings before interest and taxes (ROE 3). The impact of investment policy, tax policy was eliminated for ROE 3 and even the impact of depreciation and amortization were eliminated for the ROE 2 indicator. Respondents could choose from a six-degree scale for all three indicators. These six categories were merged into only three groups - inefficient firms, firms with average performance, high-performance firms. Modification of ROE categories from six to three categories is shown in the Table 2.

Table 2

The ROE Indicator

ROE value	Selected group
ROE 1	
< 0%, 0 – 2%	Inefficient firms
2 – 4%, 4 – 6%, 6 – 8%	Firms with average performance
8 – 10%, > 10%	High-performance firms
ROE 2	
< 0%, 0 – 10%	Inefficient firms
10 – 20%, 20 – 30%, 30 – 40%	Firms with average performance
40 – 50%, > 50%	High-performance firms
ROE 3	
< 0%, 0 – 4%	Inefficient firms
4 – 8%, 8 – 12%, 12 – 16%	Firms with average performance
16 – 20%, > 20%	High-performance firms

Although the detailed distribution of respondents according to the ROE indicators on the six-degree scale would allowed us for more detailed statistical analyzes, we narrowed down the number of categories for all ROE indicators. The main reason for the reduction of categories was the low numbers in the individual pivot tables for the performed statistical tests and failure to meet the minimum values for all Pivot Tables cells.

Research Results

The total number of respondents who participated in our research was 235. This sample included firms from the whole regions of the Czech Republic, from different sectors of the national economy, different ages, different forms of business, capital structure and size (in the terms of numbers of employees). From the perspective of the industries was in the sample most frequently represented mechanical engineering (51 firms – 21,70 %), construction (37 firms – 15,74 %), electrotechnical (27 – 11,49 %), wood processing industry (20 firms – 8,51 %) and automotive industry (20 firms – 8,51 %).

The Extent of Use IE Methods in Czech Republic

The extent of use of the various methods of IE is given in the Table 3. This analysis was performed for all respondents who participated in our research.

Table 3

Frequency of Use of IE Methods – All Industries

	Is used	Is used - percentage	Is not used	Is not used - percentage
Standardization	104	44.26%	131	55.74%
Kaizen	78	33.19%	157	66.81%
MRP I	76	32.34%	159	67.66%
5S	75	31.91%	160	68.09%
Visualization	72	30.64%	163	69.36%
MRP II	71	30.21%	164	69.79%
TQM	56	23.83%	179	76.17%
Poka-yoke	53	22.55%	182	77.45%
JIT	52	22.13%	183	77.87%
Kanban	52	22.13%	183	77.87%
TPM	49	20.85%	186	79.15%
6 sigma	48	20.43%	187	79.57%
QFD	46	19.57%	189	80.43%
SMED	38	16.17%	197	83.83%
APS	30	12.77%	205	87.23%
TOC	29	12.34%	206	87.66%
MOST	28	11.91%	207	88.09%
OPF	22	9.36%	213	90.64%
DMAIC	22	9.36%	213	90.64%
VSM	20	8.51%	215	91.49%
Andon	17	7.23%	218	92.77%
Jidoka	17	7.23%	218	92.77%
Heijunka	16	6.81%	219	93.19%
Hoshin kanri	15	6.38%	220	93.62%
DBR	14	5.96%	221	94.04%
BPR	0	0.00%	235	100.00%

The most commonly used IE method is standardization (is used by 40 % of all respondents). The high frequency of use of this tool is mainly related to the universality of its use. Firms use standards in almost every of their activities. Frequency of use of the other most common IE methods differs substantially from the standardization frequency.

As we can see in the Table 3, the second to sixth most frequently used methods are very similar and differ only slightly. A relatively large jump between the sixth and seventh method is again followed by very small differences. This can be explained by the similarity of individual methods. The first group of methods (primarily visualization, 5S and kaizen) are methods that are rather local and relatively simple to implement. The frequency of implementation of the MRP I and MRP II methods can then be explained by the relatively long time that this method is used in the conditions of the Czech Republic (hence had enough time to expand in the firms).

In contrast, the second set of methods (JIT, kanban, TQM) are methods much more challenging to implement. Also, their impact is not local but rather global in the enterprise. Primarily, JIT and TQM are mostly philosophies, where corporate culture is also important, and it is necessary that all the employees follow these concepts.

IE Methods and Business Performance

For all surveyed IE methods, we analyzed their impact on the ROE 1, ROE 2 and ROE 3 indicator by Pearson's Chi-square test. The basic results of this test for the ROE 1 and IE methods are listed in the following table (Table 4).

Table 4

IE Methods x ROE 1 – Statistics (All Industries)

IE method	Value	Asymptotic Significance	Research results (H_0 is confirmed/rejected)
Standardization	6.988	.030	Rejected
5S	7.237	.027	Rejected
JIT	13.891	.001	Rejected
APS	7.085	.029	Rejected

Due to the low frequencies, one of the basic conditions of the Chi-square test (maximum of 20 % of theoretical frequencies may be less than 5) was not met for last three methods from Table 3 (Hoshin kanri, DBR and BPR). Therefore, these methods were not part of further analysis.

According to Table 4, at the level of significance $\alpha = 0.05$, the zero hypotheses of independence H_0 for standardization, 5S, JIT and APS were rejected. The relationship between these methods and the size of ROE 1 indicator is strong statistically significant. For all other methods, the p-value is greater than the level of significance and the zero hypothesis of independence was accepted. Consequently, it can be stated that there is no statistically significant relationship between these methods and the size of the ROE 1 indicator.

For the first group of IE methods (with significant statistically influence on the size of ROE 1 indicator – standardization, 5S, JIT and APS) more detailed statistical analysis was carried out. The observed and expected values were compared, and the individual residues calculated (Table 5).

Table 5

EI Methods x ROE 1 – Residues (All Industries)

	Low performance <0% - 2 %	Average performance 2–8 %	High performance Over 8 %
STANDARDIZATION			
is used	-5.1	-4.2	9.3
is not used	5.1	4.2	-9.3
5S			
is used	-8.7	5.3	3.4
is not used	8.7	-5.3	-3.4
JIT			
is used	-7.0	-3.6	10.6
is not used	7.0	3.6	-10.6
APS			
is used	0.3	-5.9	5.6
is not used	-0.3	5.9	-5.6

Standardization has a significant effect on the value of the ROE 1 indicator (Table 4). As can be seen in Table 5 the residue levels indicate, that standardization is typically used in the firms with higher level of ROE 1 indicator. The results suggest that the implementation of standardization has a positive impact on business performance measured by the ROE 1. The residue levels show that the firms that do not use standardization reach lower ROE 1 values - these are inefficient firms (negative ROE 1 to 2 %) or medium-performance firms (ROE 1 2–8 %). The use of standardization is typical for high performance firms (ROE 1 over 8 %).

Clear impact on the size of ROE 1 can be also seen in the case of 5S method (Table 4). At the level of significance $\alpha = 0.05$, considering the residual values (Table 5), can be stated that 5S is used in more efficient firms. Firms using this method achieve average (2–8 %) or high (over 8 %) ROE 1 ratios. By contrast, negative residual values at lower ROE 1 indicate that the use of this method is not typical for inefficient firms with negative or very low values of ROE 1.

The impact on economic performance measured by the ROE 1 indicator is also statistically significant for the JIT method. Even with this method, it can be stated that its implementation has a positive effect on the size of the ROE indicator. Firms using this method achieve higher efficiencies - they achieve higher ROE values (typically over 8 %). On the other hand, firms that do not use this method are less efficient and achieve lower ROE values (less than 8 % or even negative).

According to Table 4 we can conclude that also the APS affects overall business performance. According the residues is evident that firms using this method achieve a better performance measured by the ROE 1 indicator. For the firms using APS are typical values higher than 8 %. It can be stated that this method is typically used by high-performance firms that achieve ROE 1 values 8 % or higher.

As can be seen from the previous text, IE methods that have a statistically significant effect on ROE 1 (standardization, 5S, JIT and APS) are typically used in more efficient firms. On the other hand, the use of these methods in inefficient firms is not typical.

An identical statistical evaluation of dependence was also made with the modified ROE 2 indicator (calculated

with EBITDA) and ROE 3 (calculated with EBIT). The test results are listed in the following tables.

The second indicator – modified ROE indicator (ROE 2 counted with EBITDA) showed similar results as the statistical tests for ROE 1 indicator. According to Table 6, at the level of significance $\alpha = 0.05$, the zero hypotheses of independence H_0 for standardization, 5S, JIT and six sigma were rejected. The relationship between these methods and the size of ROE 2 indicator is strong statistically significant.

For all other EI methods, the p-value is greater than the level of significance and the zero hypothesis of independence was accepted. The relationship between these methods and business performance was confirmed in the both cases (ROE 1 and ROE 2) for three equal methods – standardization, 5S and JIT. The fourth method varies for each section – for ROE 1 it is the APS method, for ROE 2 it is six sigma.

For the first group of IE methods (with significant statistically influence on the size of ROE 2 indicator – standardization, 5S, JIT and 6 sigma) more detailed statistical analysis was carried out. The observed and expected values were compared, and the individual residues calculated (Table 7).

Table 6

IE Methods x ROE 2 – Statistics (All Industries)

IE method	Value	Asymptotic Significance	Research results (H_0 is confirmed/rejected)
Standardization	6.079	.048	Rejected
5S	13.108	.001	Rejected
JIT	6.846	.033	Rejected
6 sigma	10.676	.005	Rejected

The analysis results for the standardization (Table 6) revealed strong statistically significant dependence of this method and overall business performance measured by the modified ROE 2 indicator. As in the previous case of ROE 1 (Table 5) is the use of this method typical especially for high performance firms with ROE 2 over 40 % (Table 7).

A very strong relationship was also demonstrated between 5S and ROE 2 (Table 6). According to the residual levels can be concluded that the use of 5S is also typical for high performance firms (ROE 2 over 40 %). Conversely, for low performance or inefficient firms (ROE 2 less than 10 %), is the use of this method not typical (Table 7).

Very similar results as in the case of ROE 1 also apply to the JIT method in case of ROE 2. JIT has a demonstrable impact on the overall business performance measured by ROE 2. The residue levels (Table 7) shows that by using this method firms achieve above average levels of ROE 2 over 40 % - the use of JIT is typical for high-performance firms. For low performance or inefficient firms is not the use of JIT typical.

The relationship between six sigma and business performance measured by the modified ROE 2 is also statistically significant (Table 6). Based on the residue levels (Table 7) can be stated that the use of this methods is typical for high performance firms, reaching the ROE 2 values over 40 %. In contrast, the use of six sigma is not typical in low-performing firms and medium-performing firms (ROE 2 10–40%).

The statistical analysis of the influence of selected IE methods and two levels of ROE (ROE 1 calculated with EAT, ROE 2 calculated from EBITDA) was described in the previous text. The results showed that for these two indicators are the minimum differences between the methods that have a statistical effect on the performance of the firm. For both ROE indicators, dependency for four methods has been detected. Three of these are identical for both indicators (standardization, 5S, JIT). Modified ROE 2 and ROE 3 indicators were used primarily to eliminate the impact of tax, credit and investment policies on overall business performance measured by ROE. Given that the impact of the three methods mentioned above has been confirmed in both cases, we consider these results to be relevant.

Table 7

EI Methods x ROE 2 – Residues (All Industries)

	Low performance <0% - 10 %	Average performance 10 – 40 %	High performance Over 40 %
STANDARDIZATION			
is used	-5.7	0.3	5.4
is not used	5.7	-0.3	-5.4
5S			
is used	-8.1	0.8	7.3
is not used	8.1	-0.8	-7.3
JIT			
is used	-5.3	0.7	4.7
is not used	5.3	-0.7	-4.7
SIX SIGMA			
is used	-2.5	-3.6	6.1
is not used	2.5	3.6	-6.1

The same analysis was processed for the last indicator ROE 3 (calculated with EBIT). The following tables again show results of the Pearson chi-square test of independence for all surveyed IE methods (Table 8) and the observed frequencies, calculated expected frequencies and residues levels for selected EI methods (Table 9).

Table 8

IE Methods x ROE 3 – Statistics (All Industries)

IE method	Value	Asymptotic Significance	Research results (H_0 is confirmed/rejected)
Standardization	14.864	.001	Rejected
MRP I	6.430	.040	Rejected
5S	6.095	.048	Rejected
MRP II	7.107	.029	Rejected
TQM	15.193	.001	Rejected
JIT	18.369	.000	Rejected
QFD	6.684	.035	Rejected
SMED	6.258	.044	Rejected
APS	9.271	.010	Rejected
MOST	6.154	.046	Rejected
DMAIC	7.024	.030	Rejected

According to Table 8, at the level of significance $\alpha = 0.05$, the zero hypotheses of independence H_0 for standardization, MRP I, 5S, MRP II, TQM, JIT, QFD, SMED, APS, MOST and DMAIC were rejected. The relationship between these methods and the business performance measured by the ROE 3 indicator is strong statistically significant. Of these eleven methods, three are the same as for ROE 1 and ROE 2 (standardization, 5S and JIT). Also, the fourth methods for previous ROE indicators

(APS for ROE 1 and six sigma for ROE 2) are identical also for ROE 3.

For all remaining EI methods can be stated that there is no statistically significant relationship between these methods and overall business performance measured by the size of the ROE 3 indicator.

The impact of standardization on business performance measured by ROE 3 is statistically significant. The use of this method is based on the residual value (Table 9) typical for high performance firms (with ROE 3 over 16 %).

The use of the 5S method is, based on the residual value (Table 9), typical for high performance firms (ROE 3 over 16 %) and for the firms with an average performance level (ROE 3 4-16 %).

According to residues levels (Table 9) for six sigma and APS method can be concluded, that the use of both methods is typical for high performance firms. On the other hand, according to the residue levels (Table 9) firms with very low performance (ROE 3 less than 4 %) or inefficient firms (ROE 3 less than 0 %) and firms with average performance (ROE 3 4–16 %) do not typically use these methods – six sigma and APS.

Table 9

EI Methods x ROE 3 – Residues (All Industries)

	Low performance <0% - 4 %	Average performance 4 – 16 %	High performance Over 16 %
STANDARDIZATION			
is used	-5.6	-6.0	11.6
is not used	5.6	6.0	-11.6
5S			
is used	-8.1	3.8	4.3
is not used	-8.1	-3.8	-4.3
JIT			
is used	-4.8	-6.0	10.8
is not used	4.8	6.0	-10.8
APS			
is used	-1.9	-4.3	6.1
is not used	1.9	4.3	-6.1
SIX SIGMA			
is used	-2.5	-3.6	6.1
is not used	2.5	3.6	-6.1

As can be deduced from the previous results, the range of methods affecting ROE 1 and ROE 2 performance are similar, but for ROE 3 shows significant differences. Possible explanation for this situation is given in the Discussion.

Sectoral Benchmarking

The presented results induce the question whether the above applies globally in all industries in Czech Republic. That is why we have decided to proceed sectoral benchmarking. Even for this analysis was used the Pearson's Chi-square test of independence. For the purposes of this test, the following hypotheses have been defined:

H_0: There is no statistical significant correlation between using selected IE methods and industries.

H_1: There is statistical significant correlation between using selected IE methods and industries.

For this comparison, only the sectors whose number in our original sample (235 companies) was greater than 10 were selected (N = 191). These are the following:

- Mechanical engineering: 51 firms
- Construction: 37 firms
- Electrotechnical: 27 firms
- Automotive: 20 firms
- Wood processing: 20 firms
- Food industry: 15 firms
- Plastic industry: 11 firms
- Transport and logistics: 10 firms

According to Table 11 can be stated that the use of both methods (standardization and 5S) is typical in mechanical engineering, electrotechnical industry, automotive and plastics industry. Differences in the use of these methods between different industries have been demonstrated and the research hypothesis H2 was rejected. Firms implementing specific IE method can achieve significantly higher performance, but this do not apply commonly in all industries.

Sectoral benchmarking was performed for methods with expected suitable frequencies for Pearson's chi-square test. We did not operate with the rest of the surveyed methods due to non-compliance with the basic conditions of this test (more than 20 % of the expected frequencies were less than 5 and some expected frequencies were less than 2). The result of test is shown in Table 10.

Table 10

IE Methods x ROE 3 – Statistics (All Industries)

IE method	Value	Asymptotic Significance	Research results (H_0 is confirmed/rejected)
Standardization	26.769	.000	Rejected
Kaizen	19.308	.006	Rejected
MRP I	26.034	.000	Rejected
5S	27.297	.000	Rejected
Visualization	26.322	.000	Rejected
MRP II	21.749	.003	Rejected
Poka-yoke	36.359	.000	Rejected
JIT	10.385	.168	Confirmed

At the level of significance $\alpha = 0.05$, the zero hypothesis of independence H_0 for standardization, Kaizen, MRP I, 5S, visualization, MRP II and Poka-yoke were rejected. The relationship between these methods and the type of industry in which the firm operates is statistically significant. Methods are dependent on the industry in which the company operates – these methods are typical in some of the industries.

The zero hypothesis of independence H_0 for JIT was confirmed. The use of JIT is typical in all industries. Since only standardization and 5S represent the methods that demonstrated the relationship to business performance in the previous analyzes and at the same time has been proven the relationship with industry, only these two methods were selected for further detailed analysis. Residuals are shown in Table 11.

Table 11

EI Methods x Industries – Residues

	Mechanical engineering	Construction	Electrotechnical industry	Automotive	Wood processing	Food industry	Plastics industry	Transport and logistics
STANDARDIZATION								
is used	2.0	-7.4	3.3	7.6	-0.4	-5.1	0.8	-0.7
is not used	-2.0	7.4	-3.3	-7.6	0.4	5.1	-0.8	0.7
5S								
is used	7.4	-6.0	1.2	5.5	-4.5	-3.9	1.4	-1.2
is not used	-7.4	6.0	-1.2	-5.5	4.5	3.9	-1.4	1.2

Discussion

The previous text also commented similarity between results for the ROE 1 and ROE 2, and the relatively large difference between these two ROEs and ROE 3. We believe that the main reason for this difference can be an enhanced financial effect implicitly incorporated into the ROE 3 calculation construct itself. The tax effect can be excluded because the sample under examination was homogeneous and it includes only companies operating in the Czech Republic with the same tax rate (income tax rate).

The following decomposition of the EVA indicator (source: Rajnoha, R., 2017, own research not published yet) shows gradual adjustments and first and second dividing by to the equity, where:

C … capital
D … debt
E…. equity
rd … cost of debt
re … cost of equity
WACC…. weight average cost of capital

$$EVA = EBIT - interest$$

$$EVA = EBIT - (C \times WACC)$$

$$EVA = EBIT - \left[C \times \left(rd \times \frac{D}{C} + re \times \frac{E}{C}\right)\right]$$

$$EVA = EBIT - \left[C \times \frac{1}{C}(rd \times D + re \times E)\right]$$

$$EVA + (rd \times D + re \times E) = EBIT$$

Whole equation can be divided fraction 1 / E. After that we get:

$$\frac{EVA}{equity} + \frac{rd \times D + re \times E}{equity} = \frac{EBIT}{equity}$$

The relationship between EVA and E represents the operational profitability of own capital (Equity) calculated from the EVA. The second fraction in previous equation represents the financial leverage effect. And on the right side of equation we get our ROE 3 indicator measured with EBIT.

$$\frac{EVA}{equity} = \frac{EBIT}{equity} - \frac{interest}{equity}$$

The second dividing whole equation will bring the following adjustment:

$$EVA = EBIT - interest$$

This decomposition shows that besides the derivation of interest by equity is also EVA indicator derived by equity. So small change of the ratio of debt and equity (or the difference in ratio of the merged firms) will result in a higher difference in their overall performance measured by ROE 3 (EBIT / E). Firms with only a small share of debt (D) seem to be more efficient than with the traditional ROE (EAT / E). In this way the higher ROE 3 performance is influenced by the second order partial derivative of equity. Up to second order partial derivative by equity show ROE 3 relatively more performed than ROE 1.

The ROE 3 indicator artificially multiplies the financial leverage effect and consequently more IE methods appear to be better for higher performance businesses. Since this indicator (EBIT / E) is used in the world, for example in the US, we used this indicator additionally as the third to complement our research. Even though they are different from the other two ROEs, precisely because of the above decomposition and its impact on ROE. In addition, we also suppose that under the conditions of the Czech Republic or the Slovak Republic, it is quite typical to finance companies in the form of loans from their owners.

Conclusions

In this study, we set up to investigate the impact using the specific IE methods on overall business performance.

The first step was to determine the extent of use of individual IE methods in the Czech Republic. The most commonly used IE methods in the world include e.g. 5S, visualization, standardization, JIT or Poka Yoke (Bhasin, 2012; Glass *et al.*, 2016; Eswaramoorthi *et al.*, 2011). In our research, we achieved practically the same results, as all the above-mentioned methods were among the ten most frequently used methods.

Based on the results presented in the previous text, the following conclusions were formulated:

H1: To confirm or reject this research hypothesis, it was necessary to examine the verity of this statement for each surveyed method. Based on previously described results, we can say that our assumption that the use of specific IE method causes significantly higher overall business performance do not apply generally for all IE methods. The statistically significant relationship between specific IE method and the higher performance measured

by ROE 1 or ROE 2 was observed only for standardization, 5S, JIT, APS and six sigma. The research essentially confirmed the prevailing view that the selected IE methods positively affect business performance and competitiveness (Huarng, 2002; Fullerton & Wempe, 2009; Yang *et al.*, 2011; Nawanir *et al.*, 2012; Danese *et al.*, 2012; Todorovic & Cupic, 2017). Although the studies mentioned above (including ours) focus on the overall performance only with different indicators, none of the above used the ROE indicator.

This finding leads to the question of its general validity in all industries in the Czech Republic:

H2: Due to low frequencies for some industries, we choose for sectoral benchmarking only following industries: Mechanical engineering, Construction, Electrotechnical, Automotive, Wood processing, Food industry, Plastic industry and Transport and logistics. Based on the analyzes we can state that the impact of standardization and the 5S method on the performance of the company (i.e. firms using these methods achieve higher performance) applies only in mechanical engineering, electrotechnical, automotive and plastics industry where the use of these methods is typical.

We also realize, of course, that other indicators for measuring total corporate performance, such as ROA (Return on Assets) or ROS (Return on Sales), could be used in our research. However, we think that ROA is rather an imaginary indicator, from which it is hardly possible to infer without detailed knowledge of the company and the way of its financing (especially in the Czech Republic, it is often the financing of the company in the form of a loan from its owners). On the other side ROE indicator can be used for performance benchmarking (i.e. comparison with competitors in the same industry) without any problems.

For the future, however, we are planning to expand our research of IE methods by other alternative indicators as well as other V4 countries such as Slovak Republic or Poland.

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