ASSESSING THE ECONOMIC EFFICIENCY OF LEAN TECHNOLOGIES IMPLEMENTATION IN AN INDUSTRIAL ENTERPRISE

Andrey Zaytsev, Peter the Great Saint-Petersburg Polytechnic University
Nikolay Dmitriev, Peter the Great Saint-Petersburg Polytechnic University
Bunkovsky Dmitry, East Siberian Institute of the Ministry of Internal Affairs of Russia

ABSTRACT

Management of any enterprise should be aimed at finding and implementing the most economically efficient projects to achieve strategic goals. Modern trends reinforce the importance of intensive means of achieving business efficiency that help to maximize performance and reduce costs with minimal capital investment. One such means is adoption of lean technologies. The advantages of lean manufacturing have been considered in detail by the economic community, but there are a number of challenges in the economic assessment of the results of investment projects associated with introduction and use of lean tools. In this study, the authors propose an original methodology for assessing the economic efficiency of investment projects involving implementation of lean production tools. To this end, it is necessary to analyze current research in this field, propose an instrumental approach to evaluating the economic efficiency of lean tools adoption, build an assessment algorithm, and test the method at an industrial enterprise. The study proposes to consider the quantitative and relative assessment of the economic efficiency of lean tools. Calculations are based on mathematical methods and achievements of investment analysis. The practical significance of this study consists in the development of the original methodology that makes it possible to assess the economic efficiency of using lean technologies to substantiate rationality of further development of an enterprise in this direction. Based on the developed methodology, it is possible to provide recommendations for optimizing business operations of an enterprise. To substantiate the feasibility of using the approach proposed by the authors, it was tested at an industrial enterprise operating in the North-West of the Russian Federation. It was established that the use of lean technologies in certain structural units of an enterprise increases economic efficiency, which makes it possible to substantiate the need for further implementation of these technologies in other units to strengthen strategic advantages.

Keywords: Strategic Development, Lean Technologies, Economic Efficiency, Lean Production, Efficient Production, Investment Activity, Strategic Advantages.

INTRODUCTION

A development strategy of any modern enterprise should consider the need to implement investment projects in order to maximize efficiency. In the context of transforming economic relations and the growing importance of intensive methods of production, managers are faced with the task of finding tools that could ensure sufficient performance at minimum cost (Asaturova & Khvatova, 2019; Asaturova, 2019). There are many economic practices for solving these tasks – including the use of lean technologies. Implementation of lean production tools can significantly improve management efficiency by rationalizing the use of resources within an enterprise (Balashova & Gromova, 2017a; Gobinath et al., 2015).

The positive effects of lean technologies can manifest themselves in material, technological, and temporal aspects. The material aspect includes a reduction of resource use through more efficient allocation. The technological aspect includes optimization of operations and faster use of production processes. The temporal aspect consists in reducing transaction costs, working hours of production workers and employees, and in using the remaining time with maximum productivity (Charron et al., 2014; Dmitriev et al., 2020b; Kruczek & Zebrucki, 2012). Despite many positive aspects for strategic development, there are also a number of problems in the assessment of potential economic benefits from implementation of lean production tools in the economic activities of a business entity. On the one hand, they facilitate more competent use of available material and human resources, on the other – excessive material savings and reduced work time can harm the enterprise, or the resulting positive effect will not cover the investment costs associated with project implementation (Thoumy et al., 2018; Wang et al., 2017).

Any investment is risky, and only viable and efficient projects should be accepted for implementation. One feature of lean technologies is that it is impossible to precisely determine benefits that the enterprise will gain from its adoption. Therefore, assessment can be performed after the first stages of project implementation. Industrial enterprises are divided into structural production units, which makes it possible to implement lean production tools in specific structural units first and then move on to the next ones (Kristjuhan, 2010; Nikolova et al., 2019; Rosin et al., 2020). Thus, there is a need to assess benefits of an investment project for implementation of lean production in specific structural units of an industrial enterprise, which substantiates the relevance of this study.

The study aims to develop an original approach to assessing the economic efficiency of lean technologies implementation in an industrial enterprise. Hence, the authors solve the following tasks: analyze theoretical and practical research on lean production; propose an original instrumental approach to assessment; develop an algorithm for step-by-step assessment; approbate the proposed method at an industrial enterprise.

The significance of this work consists in development of the original methodology that makes it possible to assess the economic efficiency of lean technologies implementation in specific structural units to substantiate rationality of the enterprise's further development in this direction. The authors introduce the concepts of "minimum (absolute) efficiency" and "maximum (basic) efficiency", which characterize the level of benefits for an enterprise. Approbation of the developed algorithm confirms the efficiency of the proposed approach and viability of further development of this problem.

LITERATURE REVIEW

In the course of the study, the authors reviewed works in the field of resource management, investment analysis, and economics of industrial enterprises. The reviewed studies allowed the authors to consider different views on assessment of the efficiency of lean technologies and their advantages compared to traditional business approaches.

Particularly interesting from the perspective of resource management are the works of Luyster & Tapping (2006); Hobbs (2007). These studies examine the main characteristics of resource-saving technologies and their role in improving the economic efficiency of an enterprise and rationalizing its strategic operations. It is noted that lean technologies contribute to optimization of available resources. This view is also supported in the articles by Butler et al. (2018); Kristjuhan (2010); Alves & Alves (2015); Kannimuthu et al. (2018); Kasemsap (2014). Research shows that the use of resource-saving technologies in economic activities makes it possible not only to improve efficiency, but also to increase capitalization of the enterprise. This fact also reinforces importance of developing the problem of lean technology use.

The work of Masaaki (1986) examines the role of resource technologies in the competitive success of Japanese companies (through their consideration during the formation of a corporate development strategy). Actual research into lean production began with Ohno's study (1988) of Toyota. He defined lean technologies as the main model of resource management. The concept of lean manufacturing was elaborated in the works of George (2003); Liker (2004); Rother (2009); Byrne & Womack (2013). These authors noted that by using lean technologies, it is possible to enhance strategic competitiveness of an enterprise due to the following aspects: continuous reduction of costs, improvement of product quality; optimization of technological processes; following the just-in-time logic to control the speed of material flow; increased efficiency of economic activities due to internal reserves and all available resources; constant improvement of production and management processes, etc.

Thus, lean technologies can be regarded as a set of measures aimed at optimizing the processes of creating value for the end user, building value chains, ensuring the continuity of material flows, *"pulling"* from the customer down the process line (Charron et al., 2014; Kannimuthu et al., 2018; Junior & Godinho, 2010). From a philosophical standpoint, lean technologies can be considered as a production practice where each individual element and subject of the corporate structure strives for continuous improvement (Modrak, 2014).

The theoretical aspects of the possibility of assessing economic efficiency of lean technologies implementation were discussed in detail in the paper by (Dmitriev et al., 2020a; Dmitriev, 2020). It can be concluded that to build a calculation model, it is necessary to calculate the impact of lean production on the organizational processes within the company, to analyze what stages of value addition the final products go through, and to calculate the reduced costs with allowance for the absence of losses. It is also necessary to note the high importance of lean technologies for the intellectual development of enterprises, since they not only facilitate innovative development, but also make it possible to form the qualitative characteristics of human capital and its motivational components (Frackleton et al., 2014; Ling & Yumashev, 2018; Zaytsev et al., 2020).

Within the framework of this study, the authors took interest in practical and empirical studies on assessment of lean technologies and their importance in the economic process. In particular, Liker (2004) examined the practical results of the introduction of Toyota's production system at various stages of the business activity. Analysis is also presented in the works of. Deshpande et al. (2012); Suetina et al. (2014); Balashova & Gromova (2017a & b); Wang et al. (2017); Gonzalez et al. (2019), and others. It can be concluded that lean production tools can be adopted in various structural units of an enterprise, which makes it possible to consider each unit independently.

The authors also analyzed studies on corporate investment policy to determine the correlation between investment analysis lean production assessment. In particular, the authors reviewed articles by Adamenko et al. (2017); Krasyuk et al. (2018); Avduevskaia et al. (2018); Nikolova et al. (2019); Degtereva et al. (2019); Demidenko & Dubolazova (2019); Bai et al. (2019). It is very difficult to calculate factors that affect profitability of an investment project involving implementation of lean production tools. Such factors can include either external macroeconomic causes such as economic crises, escalation of inflation, or currency fluctuations, or internal causes related to organizational problems. It is worth noting that when implementing lean technologies in one structural unit, it is necessary to funnel investments into related units where lean production will not be implemented – for the betterment of the interaction between units and corporate stability. However, the level of investment is minimal, since organizational measures are a significant element of the concept.

At an industrial enterprise, lean technologists facilitate development of a system for organizing and managing production operations aimed at developing relationships with suppliers and consumers, making it possible to set up production with allowance for customer needs and minimize production defects. This not only reduces production, technological, and time costs, but also paves the way for innovative development. The issues of innovative development are addressed in the works of Biazzo et al. (2016); Demidenko et al. (2018); Kiseleva et al. (2017); Nikolova et al. (2017). Innovative development makes it possible to maintain and increase production capacity with less space required. It is almost impossible to precisely estimate positive effects, but a number of researchers note that implementation of lean technologies can reduce labor costs by at least 30% and free up more than 20% of production space, with up to 80% less time required for the development of new products and innovative modernization (Deshpande et al., 2012; Modrak, 2014; Thoumy et al., 2018).

Despite a fairly detailed study of theoretical materials on lean technologies, there is an insufficient number of approaches to assessing the economic efficiency of their implementation in an industrial enterprise. Economic literature addresses the problem under consideration in a significantly limited manner and provides no specific approaches, since it is almost impossible to accurately calculate the financial benefits from projects involving the implementation lean production tools. This fact substantiates the relevance of elaborating on the topic and building an original calculation model.

METHODS

Lean technologies are implemented in different structural units, so the economic effect can be calculated for each of them separately. The investment in such projects is usually insignificant, but it is difficult to estimate ROI due to the following factors: insufficient implementation of lean technologies prevents sizeable growth; efficiency increases not by means of lean technologies; there is a negative effect on units devoid of lean production.

This study is based on the assumption that investment should pay off and produce profit in the strategic perspective. Thus, in order to conduct a qualitative assessment, it is necessary to achieve a certain level of lean technologies implementation, beyond which the company would receive a positive effect specifically from them. The authors propose to define this level as *"basic"*.

First, it is necessary to determine the average annual profit of all structural units of the enterprise for each period:

$$V = \sum_{i}^{N} Vi + \sum_{i}^{L} Vi \ , (1)$$

Where, *V* is the average annual profit from manufactured products (only from production units);

Vi is the average annual profit from products produced by a particular unit, where *i* is the number of the unit;

N is the number of units without lean technologies;
L is the number of units with lean technologies.

Next, it is necessary to calculate the level of lean technologies implementation (*Lm)*:

$$Lm = \frac{\sum_{i}^{N} Vi}{V}, (2)$$

The next step is to define the basic level of lean technologies implementation (Lm_{bas}). It can be calculated using both mathematical methods and expert assessments. Based on this indicator, it is possible to determine the period when profit growth will most likely depend on lean production. In other words, it should be possible to assess the absolute economic efficiency. A graphical representation is provided in Figure 1 (Y1-Yj is the time period).

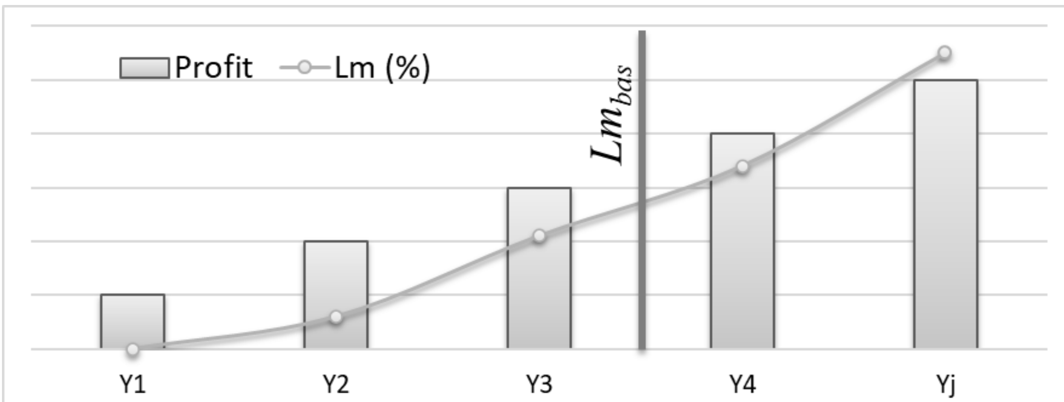


FIGURE 1
A GRAPHICAL REPRESENTATION OF THE BASIC LEVEL OF LEAN TECHNOLOGIES IMPLEMENTATION (Lm_{bas})

Absolute efficiency is achieved at $Lm_{bas} > Lm$, when the profit from the project is equal to the difference between the estimated profit (without lean technologies) and the actual profit. The absolute profit from the project includes only the difference gained over the time period above the basic level (in Figure 2, this applies to profit above Y4, since in the early periods profit cannot be attributed to lean production with 100% certainty). Thus, profit above the estimated level received over the years before the basic level of lean technologies implementation is considered a deviation and is not taken into account in the calculation of the absolute profit from the project.

Therefore, it is necessary to calculate two types of profit from the project: approximate and absolute. To calculate the approximate profit from the project, let us use formula 3, and formula 4 is used to calculate the absolute profit.

$$\Delta P = \sum(\mathrm{Y_j})\ (P_{(fact)} - P_{(plan)}), \quad (3)$$

$$\Delta P_{(abs)} = \sum(\mathrm{Y_j} \geq Lm_{bas})\ (P_{(fact)} - P_{(plan)}), \quad (4)$$

Where, ΔP is the approximate profit from the project;
$\Delta P_{(abs)}$ is the absolute profit from the project;

$P_{(plan)}$ is the profit of units without lean technologies implementation;
$P_{(fact)}$ – is the actual profit of units after lean technologies implementation;
Lm_{bas} is the basic level of lean technologies implementation;
Yj is the time period, where *j* is the number of the period;

Figures 2 and 3 shows the graphical representation of profit before and after lean technologies implementation and dynamics and accumulation of the absolute and approximate profit.

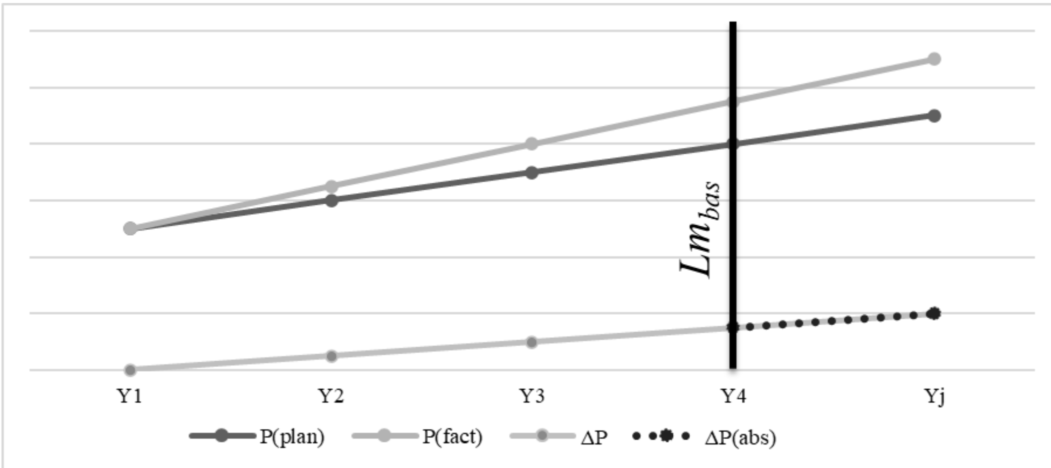


FIGURE 2
DYNAMICS OF RETURN INDICATORS

Based on Figure 3, it is possible to graphically determine the range of profit that the enterprise will receive from lean technologies implementation (*X*):

$$\Delta P \leq X \geq \Delta P_{(abs)}, \qquad (5)$$

At the next stage, the authors suggest considering assessment of the relative economic effect. This indicator reflects the qualitative effect of lean technologies. The relative economic effect of the project is calculated using formula 6, the absolute effect – using formula 7. Investment calculation is represented by formula 8.

$$E = \Delta P / I, \qquad (6)$$
$$E_{(abs)} = \Delta P_{(abs)} / I, \qquad (7)$$
$$I = \sum_t \left(\sum_i^N Ii + \sum_i^L Ii\right), (8)$$

E is the relative economic effect of the project;
$E_{(abs)}$ is the absolute economic effect of the project;
I is the amount of investment required for lean technologies implementation;
Ii is the amount of investment required for a specific business unit, where *i* is the number of the unit;
N is the number of units without lean technologies;

L is the number of units with lean technologies;
t is the time period.

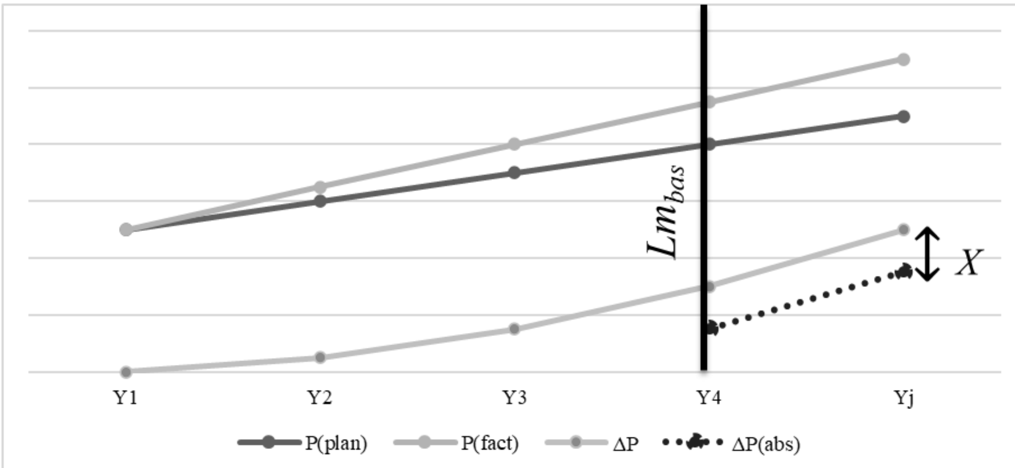


FIGURE 3
DYNAMICS OF PROFIT INDICATORS AND ITS ACCUMULATION

Thus, the relative efficiency of the investment project lies in the range between E and $E_{(abs)}$, which can be denoted by Y:

$$E \leq Y \geq E_{(abs)}, \quad (9)$$

Thus, the algorithm for assessing the economic efficiency of lean technologies implementation is as follows:

1. Calculating and substantiating investments for the project and assessing their viability;
2. Calculating the estimated average annual profit from products for each structural unit;
3. Calculating the actual average annual profit from products for each structural unit;
4. Determining the level of lean technologies implementation by year;
5. Determining the basic level of lean technologies implementation;
6. Calculating the approximate profit from lean technologies implementation;
7. Calculation the absolute profit from lean technologies implementation;
8. Determining the range of profit (X);
9. Calculating the relative economic effect of the approximate profit;
10. Calculating the relative economic effect of the absolute profit;
11. Determining the range of relative efficiency (Y) of lean technologies implementation;
12. Drawing final conclusions regarding efficiency of the investment project for implementation of lean technologies in structural units and deciding whether it should be extended to other units.

RESULTS

Let us consider the algorithm for assessing an investment project for adoption of lean production tools through the example of an industrial enterprise that implemented such a project in 2014-2018. This enterprise operates in the North-West of the Russian Federation. The company has six units, two of which have implemented lean production tools. The project duration was five years. It should be noted that for the project to function it was necessary to invest money in other structural units that did not use lean technologies. Table 1 shows the total amount of investment in the project. The total amount of investment at the examined enterprise over 5 years was 16.41 million monetary units. All figures are calculated without discounting.

Table 1
INVESTMENT IN PROJECT IMPLEMENTATION

Unit	Year					
	2014	2015	2016	2017	2018	Aggregate
1*	1.8	1.3	1.25	1.4	1.15	6.9
2*	1.3	1.19	1.15	0.99	0.87	5.5
3	0.26	0.18	0.17	0.19	0.15	0.95
4	0.18	0.26	0.19	0.17	0.16	0.96
5	0.25	0.25	0.24	0.21	0.24	1.19
6	0.17	0.16	0.17	0.19	0.22	0.91
Total	3.96	3.34	3.17	3.15	2.79	16.41

Note: Million monetary units

At this stage of the algorithm, the period can be defined not only in years, but also in quarters or months. It can be reduced or increased depending on the time required to implement the measures. The investment program is also calculated optionally and depends on many factors.

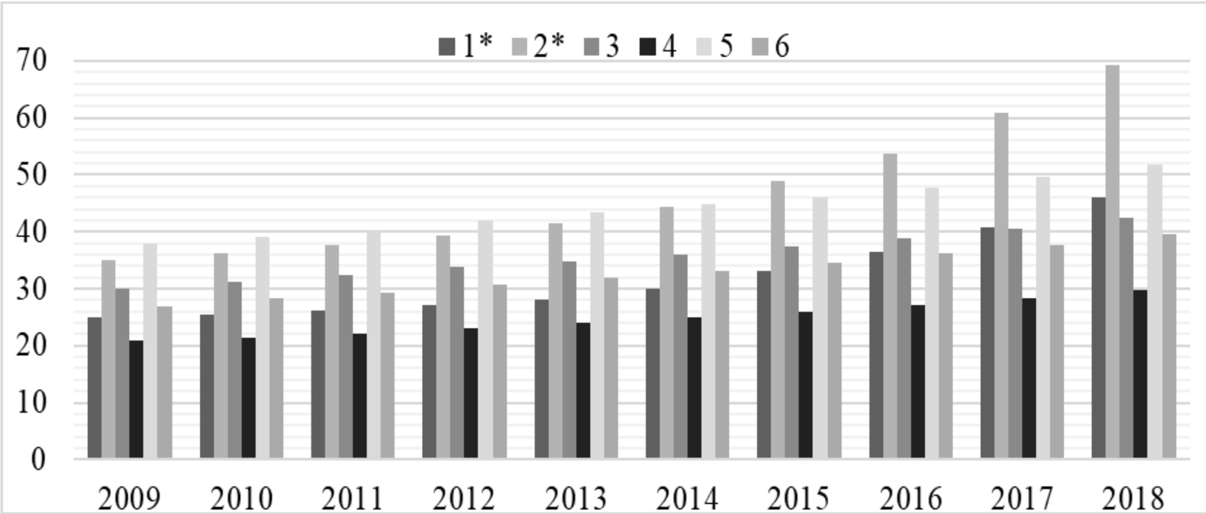
Table 2 shows the average annual profit from products manufactured by each structural unit over the five years before implementation of lean production and over the five years after.

Table 2
ACTUAL AVERAGE ANNUAL PROFIT FROM MANUFACTURED PRODUCTS

No.	Year									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1*	25.00	25.50	26.19	27.08	28.19	30.08	33.00	36.46	40.84	45.94
2*	35.00	36.23	37.71	39.29	41.38	44.36	48.84	53.77	60.81	69.14
3	30.00	31.26	32.48	33.81	34.86	36.04	37.41	38.87	40.62	42.45
4	21.00	21.44	22.21	23.17	24.09	24.96	25.96	27.10	28.38	29.77
5	38.00	39.10	40.35	41.89	43.35	44.74	46.04	47.74	49.60	51.69
6	27.00	28.22	29.37	30.63	31.92	33.23	34.63	36.15	37.70	39.48
∑	176.00	181.74	188.32	195.87	203.79	213.41	225.87	240.09	257.95	278.46

Note: Million monetary units

Figure 4 provides a graphical representation of changes in the average annual profit from production. An increase in production is visible across all structural units over the entire time period.



Note: Million monetary units

FIGURE 4
DYNAMICS OF THE AVERAGE ANNUAL PROFIT FROM PRODUCTION FOR EACH UNIT

To obtain more specific information, it is necessary to analyze the share of structural units 1 and 2. Table 3 shows the share of production of structural units 1 and 2 in the company's total production and the level of implementation of lean production since 2014. This information indicates a positive effect from the implementation of lean production.

Since 2014, there has been an increase in production at units with lean production, but there is a margin of error in the fact that the growth may not be related to the investment project, so it is advisable to calculate the basic value of the level of lean production implementation to obtain the absolute financial benefit. It is advisable to conduct this stage using the expert method with allowance for various factors. In this example, the authors use the arithmetic average of *Lm* for 2014-2018, which is 0.379.

Table 3
THE SHARE OF PROFIT FROM UNITS 1 AND 2 IN THE TOTAL PROFIT FROM PRODUCTION AND THE LEVEL OF LEAN TECHNOLOGIES IMPLEMENTATION

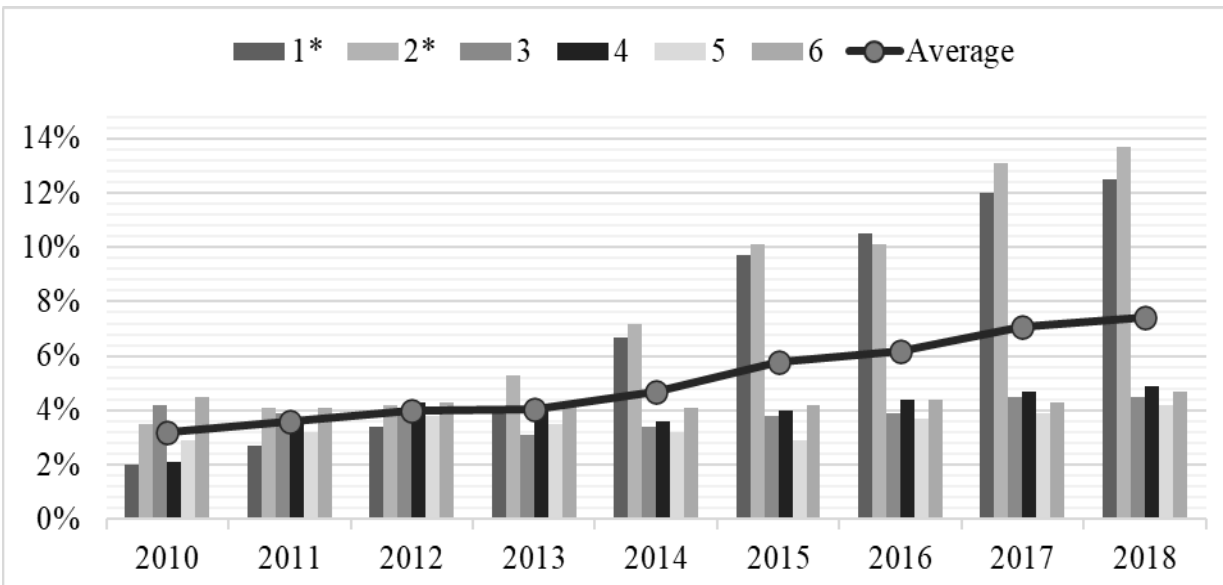
No.	Year									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
The share of 1* and 2* (%)	34.09	33.96	33.93	33.89	34.14	34.88	36.23	37.58	39.41	41.33
Lm						0.349	0.362	0.376	0.394	0.413

Table 4 shows the percentage change in the level of production compared with the previous year. During the period prior to implementation of lean production across all structural units, a fairly equal growth of production was observed. Since the implementation of the investment project, the overall performance of the enterprise has increased from 3.2% to 7.4% per year due to structural units 1 and 2.

The performance of the first structural unit has increased from 2% per year by 2010 to 12.5% per year by 2018, the second unit – from 3.5% per year by 2010 to 13.7% per year by 2018.

Table 4 **CHANGES IN THE LEVEL OF PRODUCTION (%)**										
No.	**Year**									
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
1*	-	2.0	2.7	3.4	4.1	6.7	9.7	10.5	12.0	12.5
2*	-	3.5	4.1	4.2	5.3	7.2	10.1	10.1	13.1	13.7
3	-	4.2	3.9	4.1	3.1	3.4	3.8	3.9	4.5	4.5
4	-	2.1	3.6	4.3	4.0	3.6	4.0	4.4	4.7	4.9
5	-	2.9	3.2	3.8	3.5	3.2	2.9	3.7	3.9	4.2
6	-	4.5	4.1	4.3	4.2	4.1	4.2	4.4	4.3	4.7
Average	-	3.2	3.6	4.0	4.0	4.7	5.8	6.2	7.1	7.4

Figure 5 provides a graphical representation of the percentage change in the production level of each unit.



Note: Million monetary units

FIGURE 5
DYNAMICS OF THE PRODUCTION LEVEL OF EACH UNIT

Based on Table 4, it is possible to calculate the average values for the total period before the implementation of lean production (2009-2013), after their implementation (2014-2018), as well as data for the entire period for all structural units (2009-2019) and for the units that did not undergo any changes (2009-2018*). This data is shown in Table 5. The obtained values make it possible to determine the potential growth of production in structural units 1 and 2 without lean technologies implementation.

Based on Table 5, it can be concluded that the implementation of lean production has affected the growth of profit from production. The average growth is not limited to lean units, which is indicative of the high efficiency of the investment project.

Table 5 PERCENTAGE CHANGES IN THE LEVELS OF PRODUCTION OVER TIME PERIODS				
Structural unit	**Period**			
	2009-2013	**2014-2018**	**2009-2018**	**2009-2018***
1*	3.1%	10.3%	7.1%	-
2*	4.3%	10.8%	7.9%	-
3	3.8%	4.0%	3.9%	3.9%
4	3.5%	4.3%	4.0%	4.0%
5	3.4%	3.6%	3.5%	3.5%
6	4.3%	4.3%	4.3%	4.3%
Average value	3.7%	6.2%	5.1%	5.1%

Table 6 shows the estimated profit of the enterprise without implementation of the investment project.

Table 6 POTENTIAL PROFIT OF THE ENTERPRISE BY UNIT WITHOUT THE IMPLEMENTATION OF LEAN PRODUCTION					
No.	**Year**				
	2014	**2015**	**2016**	**2017**	**2018**
1*	29.36	30.58	31.85	33.18	34.56
2*	43.10	44.89	46.76	48.70	50.72
3	36.04	37.41	38.87	40.62	42.45
4	24.96	25.96	27.10	28.38	29.77
5	44.74	46.04	47.74	49.60	51.69
6	33.23	34.63	36.15	37.70	39.48
∑	211.43	219.51	228.47	238.18	248.66

Note: Million monetary units

Once the expected profit without lean production has been obtained, it must be compared with the actual profit. The resulting difference will be the profit/loss from project implementation. Table 7 provides a detailed calculation.

Table 7 FINANCIAL BENEFITS FROM THE IMPLEMENTATION OF THE INVESTMENT PROJECT						
	2014	**2015**	**2016**	**2017**	**2018**	**Sum**
Fact	213.41	225.87	240.09	257.95	278.46	1215.78
Expectation	211.43	219.51	228.47	238.18	248.66	1146.25
Difference	1.98	6.36	11.62	19.77	29.8	69.53
Investment	3.96	3.34	3.17	3.15	2.79	16.41
Return	-1.98	3.02	8.45	16.62	27.01	53.12

Note: Million monetary units

Based on the obtained data, the approximate profit from lean production can be estimated at 53.12 million monetary units. That said, the absolute profit can be calculated by taking into account only the years where the level of adoption of lean production was above the basic level, i.e. where $Lm>0.379$. These years include only 2017 and 2018. This means that the absolute profit will be 16.62 + 27.01 = 43.63 (million monetary units). It can be concluded that the profit from implementation of lean production tools will be between 43.63 and 53.12 million monetary units.

The next step is to determine efficiency of the implemented investment project. To this end, let us use formulas 6 and 7: E = 53.12/16.41 = 3.24; E (abs) = 43.63/16.41 = 2.66. Thus, the approximate efficiency of lean technologies implementation is 3.24, and the absolute efficiency is 2.66. This means that there is a 1.6-2.2 return on every monetary unit invested.

CONCLUSIONS

The importance of addressing the issues of improving the efficiency of industrial enterprises is substantiated by their ability to reinforce the strategic competitiveness of the national economy. International experience shows that many industrial companies use lean production tools in their activities, which allows them to optimize production and obtain additional economic effects. Unfortunately, Russian enterprises hardly use lean technologies in their activities, which prevent them from achieving intensive development and boosting the overall performance of the national economy.

This is mainly due to the ambiguous position of lean production: many Russian enterprises do not have sufficient financial resources, and managers are not ready to take unnecessary risks. New methods of assessment would create new opportunities for the company's management in the development of lean technologies in corporate activities.

This study proposes an instrumental approach to calculating the economic efficiency of an investment project for implementation of lean production in specific structural units of an industrial enterprise. The novelty of the study consists in the possibility of quantitative and relative calculation of the minimum and maximum financial benefits gained by an enterprise from an investment project for the implementation of lean technologies.

The significance of this study lies in the development and testing of a methodology that makes it possible to assess the economic efficiency of using lean technologies to substantiate the rationality of the further development of an industrial enterprise in this direction. On the basis of the developed methodology, it is possible to form recommendations for optimizing the conduct of economic activities of industrial enterprises.

The developed algorithm makes it possible to determine the strategic prospects of the company's development with allowance for the need to optimize production. This may be in demand after adaptation for enterprises in other industries as well.

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