

# Research on the impact of human capital on the lean production implementation

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## ABSTRACT

The study is devoted to the actual problem of using new resources for human capital growth, particularly the implementation of Lean. The study aims to identify the dependence of the implementation results at Russian enterprises on the level of human capital development and other factors. The subject of the study is the dependence of the results of Lean implementation on the main groups of aggregated indicators characterising the production system. The primary research methods used written surveys of experts and regression analysis of survey results. The dependence of the results of the implementation of lean production (R) on the aggregated indicators of human capital (H), corporate culture (C) and the Lean implementation process (P) is investigated. The dependences of the results of lean production on the corresponding optimal predictors have relatively high coefficients of determination:  $R^2(H) = 0.69$ ;  $R^2(C) = 0.78$  and  $R^2(P) = 0.80$  for regression models in the form of 4th-degree polynomials. The indicators that have the most significant impact on the results of Lean implementation have been identified. For the predictor of human capital, this is staff educational level (weight – 0.29), staff willingness to study (0.25), the satisfaction of age characteristics (0.24) and discipline (0.22); for the predictor of corporate culture - the culture of cooperation (0.35), the culture of appearance (0.24), work according to the rules (0.24); for the Lean implementation process - consolidation of the changes made (0.83). For the generalised optimal predictor, the dominant factors are the consolidation of the changes made (0.79), the speed of changes implementation (0.11) and the willingness of staff to learn (0.10). All surveyed organisations are divided into three clusters according to the dependence of Lean implementation results on the generalised aggregated predictor. The share of companies that have most successfully implemented Lean is 26%, the average rating of their success on a five-point scale is 3.8. The study results can be used in developing lean production implementation programs at enterprises and in strategic planning to increase the efficiency of human capital.

**Keywords:** *Human capital, Lean production, Corporate culture, Culture of cooperation, Change, Educational level, Regression analysis.*

## 1. INTRODUCTION

By the end of the 20th century, human capital became the dominant global value [1, 2], comprising up to 80% of the world's wealth. At the same time, its growth was mainly based on an increase in the proportion of the population with a tertiary education [3]. However, to date, in developed countries, up to 50% of the population has a tertiary education, and further

growth is difficult [4]. The growth of the working-age population is also slowing down.

This has led to the extreme urgency of using new human capital growth resources, including implementing "lean production" - Lean [5]. Despite the proven economic efficiency of Lean, attempts at its widespread implementation often fail, although positive dynamics are present [6, 7].

In Russia, Lean was first implemented in 2001 at the Ford automobile factory in Vsevolozhsk, Leningrad region. Today, this model has found applications in many sectors of the Russian economy. The authors of [8] indicate that the main problem in the Lean implementation is the "human factor".

A detailed study of Lean implementation in Russia is conducted by Kaizen Institute Russia [9]. The latest research of this organisation aimed to understand why 95% of Lean implementation programs are unsuccessful. At the same time, as criteria for success, it was assumed that the growth of marginality indicators should be more than 10% annually; a reduction in the volume of defects by 2 times a year; an increase in labour productivity by 20% annually. A pessimistic view of the results of Lean implementation may be associated with a very high bar of "success".

This study aims to identify the dependence of the results of Lean implementation at Russian enterprises on the level of human capital development and other factors.

The paper uses softer Lean implementation indicators compared to [9], which allowed us to quantify the results obtained.

## **2. PUBLICATIONS REVIEW IN THE FIELD OF RESEARCH**

An analysis of publications on the impact of human capital on the nature of Lean implementation shows a close relationship between these factors. For example, in [10], R. Cornelissen showed that the most significant challenges companies face when implementing Lean are related to people management issues. Difficulties in changing the culture cause these challenges, and that people have their understanding of issues and personal experiences.

R. Bocquet et al. [11] studied the relationship between Lean and human resource management and concluded that this relationship is different at different stages of Lean implementation. At the discussion stage, Lean was perceived as a tool system for solving production difficulties and financial problems. This has led companies to simplistic expectations about Lean. At the initial implementation stage, emphasis was placed on Lean tools, and people were not paid attention. This negatively affected the well-being of employees and managers who did not understand what they needed to do in the new conditions of lean production.

In [12], attempts were made to understand how the motivation factor can influence the improvement of operational activities after implementing Lean programs. The results prove the hypothesis that the motivation of teams of workers in the Lean

implementation process significantly affects the degree of success of the process.

The role of culture in Lean is analysed in [13]. As studies have shown, it's vital the organisation's culture, national culture, and work culture must correspond to Lean production. First of all, you need to understand the culture of Toyota and the Lean culture, since using only tools and techniques is not enough.

Lean has also become widespread in Sweden. This experience is analysed in [14]. The factors were divided into groups: "People, culture, organisation" and "Physical, technical and business factors". The results showed that the Lean implementation often requires more effort and time than initially planned. It is shown that it is crucial to teach "lean" thinking." Comparing Toyota's lean production and Swedish companies reveals that most of their differences are related to people. Roadmaps for achieving goals may differ in different cultures with a shared vision and goals.

## **3. RESEARCH METHODOLOGY**

The main research methods used in the study were: a systematic approach, the formation of the characteristics of the questionnaire based on the analysis of the works of previous authors, a written survey of experts using the questionnaire and regression analysis of the survey results.

The questionnaire was formed based on the input-output scheme of the lean production implementation process. The input parameters' measurement of the process is carried out using questions (indicators) that characterise human capital – H, and corporate culture - C. At the same time, it was believed that other differences in the external conditions of the functioning of organisations were insignificant. The characteristics of the processes taking place in the company during the lean production implementation, which are indicated by the symbol – P, are measured mainly using indicators of organisational change. At the exit from the system, the implementation results of lean production – R are measured using indicators that characterise the success of implementing improvements in the organisation's activities and the realisation of the advantages of lean production.

Each indicator block contains 7-8 questions. Respondents were asked to estimate their value on a 5-point scale (2 to 5). Then the average estimates for each block were determined (sometimes with weight), and regression analysis of the interdependence of groups of indicators was carried out. The respondents were experts in lean production from 19 organisations who either led the Lean implementation themselves or advised these organisations on Lean issues.

**Table 1.** Indicators of lean production implementation results

No.	Indicator
R <sub>1</sub>	To what extent, in your opinion, is it possible to implement Lean in the organisation?
R <sub>2</sub>	How does the organisation's management assess the current implementation results?
R <sub>3</sub>	To what extent is it possible to implement the Lean implementation program on schedule?
R <sub>4</sub>	To what extent has the corporate culture changed due to Lean implementation?
R <sub>5</sub>	How much has the organisation's market position changed due to the Lean implementation?
R <sub>6</sub>	How does the Lean implementation affect the timing of the production of products?
R <sub>7</sub>	How does the Lean implementation affect the production cost?
R <sub>8</sub>	How does the Lean implementation affect the production quality?

## 4. STUDY RESULTS

### 4.1. Questionnaire development

The questionnaire, which was offered to respondents, consists of four blocks: "Characteristics of human capital at the beginning of Lean implementation", "Characteristics of the corporate culture at the start of the Lean implementation project", "Lean implementation and related changes", "Lean implementation results". Similar groups were successfully used in work [5]. The "Lean Implementation Results" block is key in the study. It includes eight indicators (R<sub>1</sub> – R<sub>8</sub>) of results (Table 1).

The block "Characteristics of human capital..." includes eight indicators (H<sub>1</sub> – H<sub>8</sub>) characterising the level of education and professional qualifications of personnel, health status, as well as the ability to work in a disciplined and regular manner (Table 2).

The E. Schein model [15] was used as the main one to form a block of corporate culture indicators. Due to

the specifics of the written questionnaire, the number of indicators was limited. At the same time, those most relevant aspects for lean production were selected from the E. Schein model. In particular, two indicators were selected from the sections "The study of artefacts", "The study of proclaimed values", and "The study of basic concepts".

One of the significant differences between the Japanese and American lean production models is the difference in the decision-making approach: individual or collective. Therefore, an indicator from the W. Ouchi model [16] on group decision-making and group responsibility was additionally used to identify proximity to one of these two cultures. In the block reflecting the Lean implementation process, indicators of the general characteristics of the changes were used [17].

### 4.2. Analysis of the survey results

Table 3 summarises the 5-point estimates of respondents to the questions of the block "Results of the

**Table 2.** Indicators of human capital

No.	Indicator
H <sub>1</sub>	Staff educational level
H <sub>2</sub>	Staff readiness to work with existing equipment and corporate culture
H <sub>3</sub>	Staff willingness to improve their skills, to study
H <sub>4</sub>	Staff creative characteristics
H <sub>5</sub>	Staff satisfaction of the age characteristics
H <sub>6</sub>	Staff turnover
H <sub>7</sub>	Staff discipline, including technological
H <sub>8</sub>	Staff health

**Table 3.** Survey data on the results of lean production implementation

Indicator number	Respondent's number																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
R <sub>1</sub>	5	5	4		5	5	3	3	2	2	2	3	3	3	3	2	2	2	2
R <sub>2</sub>	4	4	4	4	4	4	4	4	3	3		4	4	4	3	3	3	3	2
R <sub>3</sub>	5	2	4	3	2	2	3	3	3	3	3	3	3	3	3	3	2	2	2
R <sub>4</sub>	4	5	3	4	5	5	4	3	3	3	3	3	3	3	3	4	3	2	2
R <sub>5</sub>	4			4		3	3	3	3	3		3	3	3	3	3		2	2
R <sub>6</sub>	4	5	4	4	4	4	4	4	5	4	4		3	3	3	3	3	2	2
R <sub>7</sub>		4		3	3	3	4	4	4	4	4	3	3	3	3	3		2	2
R <sub>8</sub>	4	3	4	4	3	3	4	4	4	4	3	3	3	3	3	2		2	2
Average	4.3	4.0	3.8	3.7	3.7	3.6	3.6	3.5	3.4	3.3	3.2	3.1	3.1	3.1	3.0	2.9	2.6	2.4	2.0

lean production implementation..." The top row of the table shows the numbers of respondents from 19 organisations; the columns show the numerical values of their answers to questions R<sub>1</sub> - R<sub>8</sub>. The last line shows the arithmetic mean of the respondents in the block. Answers to questions H<sub>1</sub> - H<sub>8</sub> of the block "Characteristics of human capital at the beginning of LEAN implementation" are given in Table 4, which is formed similarly to Table 3.

The regression dependence R<sub>k</sub>(H<sub>k</sub>) of the results of Lean implementation on the characteristics of human capital (HC) when approximated by a polynomial of the 4th degree has a somewhat monotonous graph and the coefficient of determination R<sup>2</sup> = 0.52. When approximated by a polynomial of the 6th degree, R<sup>2</sup> = 0.71, the dependence graph fluctuates unnaturally strongly.

Therefore, we will use trends in the form of polynomials of the 4th degree, which we will denote by the symbol Pn4. Using Table 4 data, we can form a predictor of human capital (HC), which will provide a more satisfactory regression relationship with a high coefficient of determination. To determine the values of the optimal predictor, we sum up the values of H<sub>k</sub> for each respondent with weighting coefficients K<sub>k</sub> according to the formula (1), where Σ K<sub>k</sub> = 1:

$$H_{\Sigma} = \Sigma H_k K_k. \tag{1}$$

Next, we optimise the values of K<sub>k</sub> in such a way that the coefficient of determination of the regression dependence is maximal. The optimisation was carried out by the coordinate descent method with a cyclic change of K<sub>k</sub>.

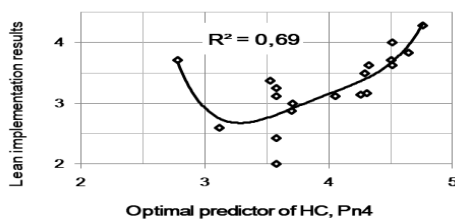
The most significant contribution to the HC

**Table 4.** Survey data on the human capital indicators block

Indicator number	Respondent's number																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
H <sub>1</sub>	5	5		3	5	5	5	5	4	5	5	5	5	5	3	3	5	5	5
H <sub>2</sub>	4	4	5	2	4	4	5	4	4	4	4	5	3	3	4	5	3	4	4
H <sub>3</sub>	5	4	5	3	3	4	5	4	3	3	4	3	4	3	4	3	3	3	3
H <sub>4</sub>	5	4	4	3	4	4	3	3	3	2	4	4	4	3	4	3	4	3	3
H <sub>5</sub>	4	4		3	5	4	4	4	4	3	5	4	3	3	4	5	2	3	3
H <sub>6</sub>	5	4	5	2	5	5	3	5	2	3	4	5	4	4	4	4	3	3	2
H <sub>7</sub>	5	5	5	2	5	5	3	4	3	3	3	5	4	3	4	4	2	3	3
H <sub>8</sub>	5	5	5	4	5	5	4	3	4	3	3	5	5	4	4	4		5	3
Average	4.8	4.4	4.8	2.8	4.5	4.5	4.0	4.0	3.4	3.3	4.0	4.5	4.0	3.5	3.9	3.9	3.1	3.6	3.3

predictor is made by the indicator "staff educational level" ( $K_1 = 0.29$ ). The indicator "staff readiness to learn" ( $K_3 = 0.25$ ) is the second place. Next – "staff satisfaction of the age characteristics" ( $K_5 = 0.24$ ) and "staff discipline" ( $K_7 = 0.22$ ). The leading role of such indicators is quite logical since lean production largely depends on the desire to explore a new area of operational activity and requires strict adherence to lean production principles.

The regression dependence of the results of Lean implementation on the predictor of human capital optimised for the 4th-degree polynomial is shown in Figure 1. Due to the optimisation of the HC predictor, the determination coefficient increased to the value  $R^2 = 0.69$ .

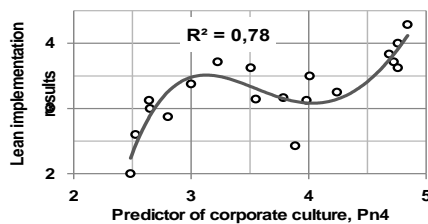


**Figure 1** Dependence of lean production implementation results on HC predictor.

The point with the lowest value of the HC predictor corresponds to sufficiently large values of the results, which leads to the non-monotonic behaviour of the regression dependence. Most likely, this effect is a manifestation of the Dunning–Kruger model [18]. According to this model, specialists with very low qualifications significantly overestimate their self-esteem.

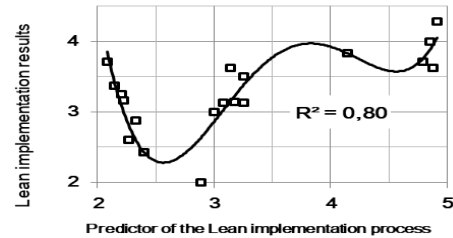
Similarly, the regression dependence of Lean implementation results on the characteristics of the corporate culture optimised for Pn4 (Figure 2) was analysed. It can be seen that the coefficient of determination  $R^2 = 0.78$ , and this is more than for the predictor of human capital.

Among the optimal coefficients  $K_k$  for the predictor of corporate culture, the culture of cooperation has the greatest weight ( $K_6=0.35$ ). Next in importance are the culture of order ( $K_7 = 0.24$ ) and "working by the rules" ( $K_1=0.24$ ). It is also essential to use personnel promotion to reward employees ( $K_5=0.16$ ).



**Figure 2** Dependence of Lean implementation results on the predictor of the corporate culture.

The regression dependence of Lean implementation results on the block of indicators of the implementation process and related changes is presented in Figure 3. The coefficient of determination, in this case, is more significant than for the two groups of indicators discussed above and is for Pn4 -  $R^2 = 0.80$ .



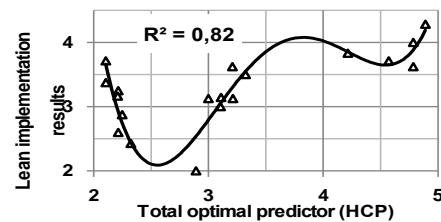
**Figure 3** Dependence of the results on the predictor of the implementation process.

Among the optimal  $K_k$  coefficients for the Lean implementation process, the consolidation of the changes is of dominant importance ( $P_7 \approx 0.83$ ). In second place is the speed of Lean implementation ( $P_3 \approx 0.06$ ).

To assess the total impact of all the characteristics of the three blocks (HCP) on the results of Lean implementation, we will select the three most significant attributes from each block and form an optimal predictor from them. The regression dependence of Lean implementation results on the optimal predictor R (HCP) is shown in Figure 4. For Pn4, the coefficient of determination  $R^2 = 0.82$  is more significant than the dependencies of the implementation results on individual groups of indicators discussed above.

A block of implementation indicators dominates the total predictor of HCP, and it is crucial to consolidate changes ( $K_k = 0.79$ ). This is followed by the speed of Lean implementation (0.11) and staff willingness to learn (0.10).

Figure 4 shows that the experimental points are grouped into three clusters. For the five points with the highest Lean implementation results ( $R = 3.6 - 4.3$ ), the optimal predictor of HCP is greater than 4.2. Six points with average R values in the range 3.0 - 3.7 have a predictor of HCP in the range 3.0 - 3.4. The values of the HCP predictor for the third cluster are less than 2.4.



**Figure 4** Dependence of Lean implementation results on total optimal predictor (HCP).

Let's consider separately the organisations included in the cluster with the highest results, represented by respondents with numbers 1-3, 5 and 6. Table 5 shows the average values of indicators for these respondents. It can be seen that the evaluation of the results of Lean implementation, on average for the cluster, is relatively large and amounts to 3.8. Implementing programs within the planned deadlines (3.0) and the impact of Lean implementation on the cost of producing products (3.3) received a low rating.

The average estimates of indicators for the block of indicators of human capital and corporate culture are high; they are 4.6 and 4.7, respectively. The lowest rating (4.2) among the indicators that make an essential contribution to the HC predictor is the indicator of the readiness of personnel to improve their skills to study. In the corporate culture block, the lowest ratings have indicators of the use of personnel promotion to reward employees who have achieved success in work (4.4) and an understanding of what it means to "do right" (4.4).

The average value of the estimates for the implementation process block was only 4.4, although this block occupies a vital position in the Lean implementation. The lowest score in this block (3.6) is for the indicator P<sub>1</sub>, which characterises the conditionality of the lean production implementation for external reasons.

In our opinion, it is also important to pay attention to the fact that according to the analysis, the number of successful organisations in terms of Lean implementation is 26% of the total number of respondents, which is significantly more than when determining success by the Kaizen Institute Russia method (5%) [9].

**5. RESULTS DISCUSSION**

The works [5], [19] consider the factors influencing the increase in human capital effectiveness through the implementation of strategic management in corporations and the activation of R&D teams. It draws attention to the fact that the indicators reflecting the performance and human capital characteristics in these works and this study are quite different. It is advisable to compare the systemic differences in these three types of activities, which are the same among the strongly influencing indicators.

Of course, it is possible to find additional factors that can significantly affect the performance of activities. However, the limited number of respondents is the fundamental difficulty in identifying them as part of many indicators. And in the future, this should be given key attention.

**6. CONCLUSIONS**

Based on the survey data of specialists of enterprises leading the Lean implementation process, studies were conducted on the dependence of Lean implementation results on aggregated indicators of human capital (H), corporate culture (C) and the lean implementation process (P).

It is shown that the regression dependence of Lean implementation results on the optimal predictor of human capital has a relatively high coefficient of determination  $R^2 = 0.69$  for a trend in the form of a polynomial of the 4th degree (Pn4).

The following indicators make the most significant contribution to the predictor of human capital: staff educational level (0.29), staff readiness to study (0.25), staff satisfaction of the age characteristics (0.24) and

**Table 5.** Characteristics of Lean implementation by successful companies

Average values of indicators for respondents 1–3, 5, 6							
Results		HC		Culture		Process	
R <sub>1</sub>	4.8	H <sub>1</sub>	5.0	C <sub>1</sub>	5.0	P <sub>1</sub>	3.6
R <sub>2</sub>	4.0	H <sub>2</sub>	4.2	C <sub>2</sub>	4.6	P <sub>2</sub>	5.0
R <sub>3</sub>	3.0	H <sub>3</sub>	4.2	C <sub>3</sub>	4.8	P <sub>3</sub>	4.4
R <sub>4</sub>	4.4	H <sub>4</sub>	4.2	C <sub>4</sub>	4.5	P <sub>4</sub>	4.4
R <sub>5</sub>	3.5	H <sub>5</sub>	4.3	C <sub>5</sub>	4.4	P <sub>5</sub>	4.4
R <sub>6</sub>	4.2	H <sub>6</sub>	4.8	C <sub>6</sub>	5.0	P <sub>6</sub>	4.3
R <sub>7</sub>	3.3	H <sub>7</sub>	5.0	C <sub>7</sub>	4.4	P <sub>7</sub>	4.8
R <sub>8</sub>	3.4	H <sub>8</sub>	5.0	–	–	–	–
	3.8		4.6		4.7		4.4
Average values for indicator blocks							

discipline (0.22).

The dependence of Lean implementation results (Pn4 trend) on the optimal predictor of corporate culture reaches a determination coefficient  $R^2 = 0.78$ . The culture makes the most significant contribution to the predictor of the corporate culture of cooperation (0.35), the culture of appearance (0.24) and the culture of working according to the rules (0.24).

The dependence of Lean implementation results on the optimal predictor of the implementation process (trend Pn4) has a coefficient of determination  $R^2 = 0.80$ . The dominant contribution to the optimal predictor is made by the indicator "consolidation of the changes made" (0.83).

The dependence of the Lean implementation results on the generalised optimal predictor, which includes the main indicators of the three blocks (HCP), reaches a determination coefficient of  $R^2 = 0.82$ . The most significant contribution to the optimal predictor is made by: the consolidation of the changes made (0.79), staff willingness to learn (0.10) and the speed of changes implementation (0.11).

All organisations surveyed in the study are divided into three clusters according to the dependence of the results of Lean implementation on the generalised optimal predictor (HCP). 26% of organisations implemented lean production most successfully, and the average assessment of their Lean implementation results on a five-point scale was 3.8.

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