

## **Cost Efficiency Indicators of Lean Production Instruments**

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**Abstract.** Currently lean production techniques and tools penetrate into the industrial enterprises: System 5S, Continuous Flow, Gemba ("the actual place"), Kanban ("Pulling System), KPI, Key indicators, etc. The article is aimed to analyse the experience of implementing lean production instruments on the example of large industrial enterprises. The main goal of lean production is reduction of wastes which do not add value to the product. Implementation of the lean production technologies has costs of introduction that means need of assessment of cost efficiency of projects on implementation of lean production technologies. At the same time, it is important to develop instruments for making decision on expediency of introduction of lean production tools at preliminary stages. Two main tools are offered in this article. The first is an indicator of cost efficiency of introduction of lean production instruments. This indicator shows that the project will be effective if gain of the outputs exceeds the costs of introduction. The second one is a method of calculation of the maximum costs of introduction of lean production tools when the project is effective. The developed instruments were approved on the example of introduction of lean production instruments in Kalashnikov Concern and JSC Elecond which are two large scaled machine-building enterprises. The results of approbation demonstrate the practical importance of the carried-out research.

### **1. The relevance of the topic**

Currently lean production techniques and instruments penetrate into the industrial enterprises of Russia. Lean production or Lean-technologies is the business management philosophy which is based on the ongoing effort to eliminate all wastes which are known as "muda", namely the loss of overproduction; "waiting/lost time"; losses during unnecessary transport; losses resulting from extra unnecessary stages of processing; losses of oversupplies; losses due to unnecessary motions; losses because of defects, etc. [1-9]. The ultimate goal of lean production is to reduce all activities which do not add any extra value of the product life-cycle and to decrease performance through losses cut off. In general, lean production tools are focused firstly on improving the performance and reduction in time required to any process [10-11], but the adaptation of the lean production technologies has costs, which implies the economic efficiency of the lean production technologies implementation to be assessed.

Lean production is, first of all, a philosophy that consists in value stream for the consumer, flexibility, identification and reduction of losses or muda, continuous improvement of all activities at all levels of the organization or kaizen, involvement and development of personnel in order to meet more effective the customers' demands as well as other stakeholders' [12, p. 43]. Not "who will not keep a penny shall never have many" but special way of thinking and new mind gain success. The

term "lean" has several meanings including “skinny”, “thin” or “thrifty”. But “thrifty” does not mean “greedy”. The main essence of “lean production” principle is that the production process is constantly being improved, reducing various types of “muda” including all types of actions that do not bring value to the consumer [13]. Taiichi Ohno (the founder of the Toyota production system) notes that in the most streamlined process, losses are more than 80%, and the value created in the process is less than 20%. So, maybe it is impossible to design any process with no losses? To answer this question, let us consider the main types of losses or muda [14]:

1. Transportation what means that the transportation of finished products and work in progress must be optimized and reduced in terms of time and distance;
2. Inventory what means the more goods or items on stock, the more «frozen» cash;
3. Motion as muda includes all type of operators and equipment which increase time expenditure;
4. Waiting is a term for products in work in progress;
5. Overproduction as the type of loss is the most significant of all;
6. Technology often disables tailoring good to meet all requirements of the final consumer;
7. Defects add time loses and waste funding.

Most of the working time is muda, and only 1/8 of manufacturing process aim to value creation, and therefore, to make a profit. It is impossible to get rid of these losses completely, because they are inherent part of any production process. But it is quite possible to lose the main “share” [15]. The main issue for organization which is implementing a lean production system is to reduce non-value-added actions. This will significantly reduce the production cycle and reduce the final cost of production. This is what the principles of lean manufacturing are aimed at (table 1).

**Table 1.** Lean manufacturing principles [16, p. 75].

Principles	Brief description
Strategic focus	The organization is based on the strategic objectives of the management system and production system.
Design and implementation of the value stream	All processes and operations are stuck into a continuous value stream.
Continuous improvement	Purpose: improving customer value, improving value stream, reduction of muda, engaging in staff development.
Pull	The supplier produces exactly as much as the consumer requires and only when required.
Visualization and transparency	All participants in the process see the value stream and have the relevant information about it.
Built-in quality	The required level of product quality is ensured at all stages of the life cycle.
Fact-based decision-making	Registration of all events, their further processing and analysis at the place of origin.
Standards compliance	Strict compliance with standards, regulations and instructions of the enterprise.

General lean manufacturing approaches are closely tied to the approaches of the quality management system (QMS). Deming’s principles, Juran’s quality improvement, Ishikawa’s diagram – these tools are applicable to lean manufacturing. But is the lean manufacturing system itself up to Russian realities? Who has the most significant impact on the success of the lean production implementation? The staff, of course. The human factor is in the first place in any production system.

It is equal for both top management and regular worker. All the goals of top management and actions of employees should be coordinated and focused on the common goals.

It is extremely difficult to achieve full coherence of the production system of the enterprise in the Russian practice. Most often, everyone works for his personal goal, not for the common one. The philosophy of lean production involves mixing of personal goals with the corporate goals. Often, managers, adopting lean production, forget that the Japanese system is focused primarily on the Japanese mentality, where everyone knows his place in the overall production chain. In Russia, individualism is stronger than in Japan. Therefore, individual principles and approaches to working can cause widespread opposition. The whole system should be changed and only then lean production will work «as it should».

Although enterprises try to make business processes more transparent by using corporate information systems, most of the information, in the interests of managers, remains covered. And these ones are also elements of the Russian practice. If in Japan an employee, coming to the company, penetrated with its philosophy from top to toe, in Russian enterprises, if you ask the employees what is the mission and purpose of the enterprise in which they work, it is very rare to get the correct in terms of lean production answer. And this is the main problem. It is impossible to be completely devoted to work, to try to improve it and to reduce unproductive expenses if ones do not know for what and for the sake of what they work, what value it bears first of all for the organization. Therefore, such a position should be achieved when the personal goals of the employee will coincide with the goals of the enterprise.

This can be achieved through more transparent business processes, visual information, staff training and coaching. Having realized why they follow the path of Japanese practice and, with the support of an active part of employees who understand and are ready to adopt a new way of production, they can move forward, to introduce lean production tools into practice. Whether it is job facilities system, so called 5S? or value stream mapping, there is no difference [17]. The main point is work with the staff, which depends on whether the system will take root and whether it will work as it should.

The paper analyzes the experience of implementing lean production tools at two large engineering enterprises of the Udmurt Republic, which showed that the introduction of lean production tools demands certain investment costs. Therefore, there is a need to assess the costs of implementation of lean production tools in the practice of industrial enterprises. The introduction of lean production tools is mainly a low-cost measure, but, nevertheless, it requires costs, which automatically implies the need to assess the economic efficiency of projects for their implementation.

## **2. Problem statement**

To date, methods for assessing of the economic viability of any project generally developed and well-known. They are relative methods based on the calculation and comparing of the given costs, simple methods that do not take into account the time factor, complex methods based on cash flow discounting [18-20]. However, these methods require a preliminary examination of work processes in the organization, the development of a technical project, and this has costs which are still remain uncertain whether they are going to pay off or not. And only after the development of the project, it is possible to estimate the costs of implementation and indicators of economic efficiency. Therefore, at the preliminary stage of decision making on the need for lean production project to be implemented, the greatest costs which company can take on should be estimated. Thus, this study focuses on the developments of the decision-making tools which enable to evaluate the feasibility of the lean production tools implementation in the preliminary stages.

## **3. Theoretical part**

At the preliminary stages of decision-making, the researcher does not have an accurate forecast of future project revenue streams, but one has some fair information about the current costs of production and sales of products. All costs can be considered as variable costs and fixed costs. And also available

information about the production volumes and, possibly, the failure of the production plan. In the broadest possible terms, the total costs ( $TC$ ) can be expressed:

$$TC = VC + FC = UPC \times Output + FC_{UC \times} \quad (1)$$

here  $VC$  is variable costs per unit time,  $FC$  – fixed costs,  $UPC$  – unit production costs.

Consequently, the total unit production cost is:

$$TUPC = \frac{FC}{Output} + UPC \quad (2)$$

In economic terms the lean production tools implementation is expensive but and should cut costs. However, cost reduction is possible if there is either a saving in current costs or an output growth. In the first case, the project is effective if savings on operating costs are greater than implementation costs-to-be:

$$SOC \geq IC. \quad (3)$$

However, savings are calculated over a period (usually a year) and investments are non-recurrent, so the two cannot be compared directly. In this case, by analogy with the indicator present values of costs and present values of benefits, the investment may not be added up to a comparable form through the normative rate of return ( $RPN$ ), which expresses the duration investment payback period:

$$SOC \geq RPN * IC, \quad (4)$$

$$RPN = \frac{1}{PP}, \quad (5)$$

where  $PP$  is a payback period (normative or desirable for the investor) and it is measured in years.

In the second case, if the production and sales are growing and the potential outcome expanding should be taken into account and production costs with implementation costs should be less than production costs before implementation. For comparability of calculations, the unit cost indicator (unit cost) can be used to get an inequality, where the left side is the cost before implementation, the right side is after implementation:

$$\frac{FC}{Output} + UPC \geq \frac{FC + IC}{Output \cdot (1 + GRO)} + UPC, \quad (6)$$

Here  $GRO$  is the growth rate of output,  $IP$  is implementation costs.

The formula can be transformed by cancelling out the variable costs, and the remaining terms are reduced to a common denominator.

$$\frac{FC}{Output} - \frac{FC}{Output \cdot (1 + GRO)} \geq \frac{IC}{Output \cdot (1 + GRO)}.$$

Next, the right part of the inequality can be moved to the left and reduced to a common denominator:

$$\frac{FC \times GRO - IC}{Output \cdot (1 + GRO)} \geq 0 \quad (7)$$

The essential point of the indicator is the increase in the costs of the lean production tools implementation should be covered by output and sales growth. If there is no increase in output and sales, then the inequality is false and consequently the project is not economically effective. This means that the numerator of the ratio must be greater than zero:

$$FC \times GRO - IC \geq 0,$$

and this inequality enable to figure out the maximum value of implementation costs where the project will be still effective:

$$IC = FC \times GPO \tag{8}$$

Thus, assuming that the changes in production and sales are being planned, the following indicators obtained:

- criterion of economic efficiency of lean production tools implementation, which can be used for decision-making to be carried out before the project starts up (formula 7);
- the maximum value of the implementation cost when the project is still effective (formula 8).

**4. Analysis of the experience of industrial enterprises in the implementation of lean production tools and testing the results of the study**

The results of this research were tested while the lean production tools were implemented in JSC Concern Kalashnikov [20-21], which is one of the largest arms manufacturers in Russia. In 2015, the company launched a large-scale program for the development of the production system to increase labor productivity several times over the current levels till 2020, to reduce production costs and working capital as well as significantly reduce time expenditure for comprehensive research, development and promotion programs for new products. Several pilot workshops were selected for lean production tools to be implemented. The table shows the tools that have been successfully implemented to date.

**Table 2.** Lean production tools introduced at JSC Concern Kalashnikov.

The lean production basic tools	Introduced at the enterprise
<b>The workplace organization method (5S):</b>	
1S: "Sort" (sorting through all items in a location and removing all unnecessary items from the location);	+
2S "Set In order" (Putting all necessary items in the optimal place for fulfilling their function in the workplace);	+
3S "Shine" (Sweeping or cleaning and inspecting the workplace, tools and machinery on a regular basis);	-
4S "Standardize" (Standardizing the processes used to sort, order and clean the workplace);	-
5S "Sustain" (The developed processes by self-discipline of the workers)	
Continuous Flow	+
Gemba ("The actual place")	+
Hoshin Kanri ("Policy management")	+
Kanban ("Pulling system")	+
Key Performance Indicators (KPI)	+
Muda (Waste)	+
Overall Equipment Effectiveness (OEE)	+
Single Minute Exchange of Die (SMED)	+
Standardized Work	+
Total Productive Maintenance (TPM)	+
Value Stream Mapping (VSM)	+
Visual Factory	+
Changes for Better (Kaizen)	+, -

To reach level 2S Set in Order (Seiton): all objects in the workplace were placed rationally, the location of the equipment and storage of tools, equipment (temporary storage of components is allowed – with the condition of designation) was defined. These spots are visualized and correspond to the layout which is located on the area. The actual location corresponds meets the layout.

Next, the degree of necessity of things were determined (see table. 3).

**Table 3.** Determination of necessity of things.

Rank	Necessity (frequency of use)	Storage solution (distribution)
LOW	Items had not been used in the last year	Remove them
	Items had been used once in the last 6-12 months	Store them at a known distance (separate warehouse in the production area)
MIDDLE	Items which had been used once in the last 2-6 months	Store them at a known distance (separate warehouse in the production area)
	Items which are used more than once a month	Keep them in the middle distance, not far from the workplace (a warehouse on the area/in department)
HIGH	Items used one time per week	Store near the workplace
	Items used daily.	Store in the workplace or carry with you
	Items used hourly	

Conventionally, the frequency of use of things is ranked into three degrees:

- low - items not used in the last year or used once in the last 6 – 12 months;
- middle - items that have been used more than once a month or once in the last 2 to 6 months;
- high - these are items that are used daily, at least once a week. Depending on the frequency of use, storage areas are classified.

The next step is 3S: Shine (Seiso) All employees of departments and divisions were involved in the process of cleaning. The floor covering and marking are clean (there are no longtime pollution). The equipment is clean, without no longtime stains. Working areas, industrial furniture, equipment, packaging, locations of objects, including hard-to-reach, are clean. Control and measuring devices are functioning properly. Objects for regular cleaning are defined. The frequency of cleaning is set. Ones who in charge of cleaning are defined, cleaning areas are distributed. The schedule of cleaning and control of workplaces is made and carried out (daily, weekly and monthly types of works are defined). On the sites posted and performed schedules of removal of household and industrial waste.

The next step is to gain the level 4S: Standardize (Seiketsu). To do this, developed workplace standards and placed in the workplace.

The last stage will be the achievement of level 5S: Sustain/Self-discipline (Shitsuke) The obtained results are secured by audit. Audit is not only a way for assessing the performance of implementation of the 5S system by management, but also a tool for self-monitoring and self-analysis of working groups and their leaders. The Concern has developed forms of self-audits on the 5S system. Self-audits of 5S are carried out every week, the results are posted on the sites.

Also, the implementation of the system of organization of workplaces 5S in JSC Elecond was analyzed [23]. In general, it can be noted that the use of similar procedures in both enterprises differ slightly in the form of visualization. But it should be noted that the period of implementation of the project at the level of a particular workshop takes 6 months, starting from the 0 stage - preparatory, and from the sixth to the ninth months there is a reinforcement the results of the achieved results through standardization and reinforcement of usual skills. Despite the duration of the implementation

phase of the implementation procedures there is an increase in current costs, the main costs are composed of:

- 1) the amount of additional remuneration of working groups in the areas where the system is implemented,
- 2) costs of employee training,
- 3) additional material costs (which are very small, in the form of costs for stationery and paint for marking zones).

In Table 4 the structure of implementation costs by stages and by type of costs is shown.

**Table 4.** The structure of implementation costs by stages and by type of costs.

The phases of 5S implementation	Cost structure by stages	Types of costs for the implementation of 5S	Cost structure by cost type
1-Removing unwanted items	0.11	Salary	0.61
2-Set in Order (Seiton), rational placement of objects	0.18	Contributions to extra-budgetary funds	0.18
3-Cleaning, inspection, troubleshooting	0.09		
4-Standardization of regulations	0.38	The cost of training	0.20
5-Compliance and improvement	0.17	-	-

In the structure of costs, the largest share falls on the 4th stage of standardization of rules, and the main costs are associated with the cost of labor. In relation to the workshop cost, the share of implementation costs does not exceed 0.5%, but in general, the design of the workplace does not require investment costs and, ultimately, should drive to a reduction in current costs. According to the experience of JSC Elecond reduction of current costs was about 5% of the workshop cost, the value is not great, but the ratio of implementation costs and current cost savings amounted one to ten. For each ruble of the costs of implementation received a reduction in the workshop cost by 10 rubles, which indicates the effectiveness of projects in the implementation of the 5S provision of workplaces.

Next, we consider the lean production tool, which required investment costs from organizations which is named Kaizen-proposals [24-26]. Kaizen is a Japanese philosophy or practice that is fixed on continuous improvement of production processes, development, supporting business processes and management; it is «continuous improvement», it is continuous improvement, starting with production and ending with senior management, from the top-management to the ordinary worker. The main component of Kaizen is a system of proposals aimed at improving its own work, saving raw materials, energy and other resources, improving working conditions, improving equipment, processes, tools and devices, etc. A distinctive feature of Kaizen in Japan is not economic efficiency, but positive changes in the attitude to work, to the growth of interest in achieving the overall goals of the company. Kaizen mostly performs the functions of staff motivation. In Russian practice, «commercial purposes» still prevail.

Concern Kalashnikov has implemented Kaizen proposals since 2015. For the 2015-2016 period 901 proposals were submitted, of which 280 are implemented, it enabled to obtain an annual economic

effect of 10.4 million roubles. In addition to the economic effect, there was a decrease in defects, in some industries the decline was 70%. In 2017, the following data were obtained (table 5).

**Table 5.** Effect of the Kaizen proposals in 2017.

Production	Filed	Realized	Economic effect for 2017, RUB.
1. Weapons production division	808	364	9009140
2. Department of tools production	299	113	84244
3. Department of production of special equipment	353	138	4942125
4. Design and technology center	375	175	2012308
<b>TOTAL:</b>	<b>1835</b>	<b>790</b>	<b>16047818</b>

In 2017, out of 1835 Kaizen proposals submitted by the Concern, 790 proposals were implemented and put into practice. The overall economic effect amounted to more than 16 million rubles. The initiators of the proposals accepted for implementation can get a one-time payment of 200 rubles and a bonus at the end of the year in the amount of 1-7% of the achieved economic effect, i.e. the employee's interest is visible.

But in some structural units the desired results are not obtained. So, in the workshop Department of Machine Tools and Equipment Overhaul the project for the submission and implementation of Kaizen proposals began to be implemented in 2017, and during this period 23 Kaizen proposals were submitted, and only 2 were implemented, which resulted in an annual savings of 35 thousand rubles. There is neither the desired increase in the number of submitted proposals, nor a significant economic effect. One of the reasons for such low efficiency was technical issues which are: employees do not fully understand how to submit Kaizen proposals in paper form; how to estimate current and investment costs for Kaizen proposal; lack of feedback when assessing Kaizen proposals by the expert group, etc. Therefore, by analogy with other structural units, it is proposed to automate the process of Kaizen proposals submission through the information stand-kiosk. It allows one to apply for the implementation of the Kaizen proposal in real time, track its processing, acceptance or rejection, find out at what stage of implementation the adopted project is and the timing of payment of remuneration. The cost of one kiosk with the cost of delivery, installation and necessary software is about 110 thousand rubles, because the costs are generally not significant, it is planned to recoup them for the year. In 2017, the company has already spent more than 1 mln roubles on the installation of interactive kiosks. To assess the effect, use the formulas (3) and (4). If we assume that the situation with the number of submitted and accepted Kaizen proposals in the «Department of machine tools and capital repairs of equipment» will not change, then this event will not be effective, the annual savings of 35 thousand rubles will be below the cost of implementation. Even if we assume that the Concern plans to recoup investment costs for 2-3 years, the project will also not be effective. Therefore, to make a decision, it is necessary to clearly understand whether the implementation of the project will lead to a corresponding increase in the number of submitted and accepted Kaizen proposals.

## 5. Conclusions

The carried-out research enables to develop and test the decision-making tools regarding the necessity the lean production which work on the preliminary stage. However, the proposed tools are based on the assessment of the economic efficiency of projects, which is not the essential goal of lean



production. Therefore, the proposed tools should be updated and improved by some quality parameters which indicate purposes of applying of specific lean production tools.

## 6. Acknowledgments

This work is supported by the Kalashnikov Izhevsk State Technical University (Izhevsk, Russia) under grant 38.04.04/18SNG.

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