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APPLYING LEAN SIX SIGMA IN CONSTRUCTION. WORLD PRACTICE EXPERIENCE

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ABSTRACT:

Background: *persistent problems faced across the world by managing and construction companies (increasing construction costs, unsatisfactory level of construction materials quality, lack of coordination and consistency between process participants, decreased profitability of principal contractors, subcontractors and suppliers, failure to meet deadlines and budget deficit, inconsistency and fragmentation of processes) can be eliminated.*
Objective: *a centralized and integrated approach is needed to identify, prioritize, find and eliminate the origin of problems, help to develop effective solutions and manage consequent activities to get necessary results.*
Methods/approach: *foreign experience analysis has proved that both the required approach, the methodology and the problem-solving tools in the construction industry are available – this is the Lean Six Sigma management methodology, acknowledged as industry leading across the world. Without exaggeration, it seems possible to evaluate the results of Lean Six Sigma methodology practical application as outstanding since they stay ahead of the curve of industry average performance indicators in such developed economies as, for instance, the USA and Great Britain. The Lean Six Sigma methodology is focused on achieving world-class quality by eliminating all types of losses, costs, overhead expenditure and creating value for consumers.*
Results: *to achieve this goal, the Lean Six Sigma deployment affects all construction project participants involved and acting in the common interest - the customer, managing company, principal contractor, subcontractors, product suppliers, equipment suppliers, designers, surveyors.*
Conclusions: *the concept of "Six Sigma" allow in a fairly short time and with own resources to achieve production and services cost reduction, service delivery time reduction, increase in the volume of performed work, decrease of the design cost.*

Key words: Lean Six Sigma, construction, integrated supply chain, process cycle time, quality, waste, defects.

JEL classification: M110; O210; O31, O33

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INTRODUCTION

The development of the modern economic system of any hierarchical level is based on the constant pursuit of business entities to obtain competitive advantage for implementation of selected strategic objectives

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(Jarmusevica et al, 2019; Kurmanov & Petrova, 2019; Kurmanov et al, 2018; Uteubayev & Petrova, 2017; Yelubayeva et al, 2018).

A key feature of the Lean Six Sigma methodology application in the construction industry is the need to apply the methodology principles only in full and with all the parties engagement (contractors, suppliers, consumers) involved in the activity, while the main improvement efforts should be aimed at improving processes. A vital element of the Lean Six Sigma methodology in construction is the delivery of construction materials, products, equipment and JIT performance. To meet the just-in-time criterion, construction companies around the world are working to create their networks of suppliers and contractors, making significant efforts to adopt the same "Six Sigma" concept in order to overcome all sorts of difficulties and circumstances that cannot be foreseen within traditional contract.

The creation of integrated supply chains based on the Lean Six Sigma management methodology in several construction companies, ranging from the general contractor and to various suppliers, can provide not only a systematic solution to all the problems that any general contractor faces daily, but also bring the supplied construction products to the world-class quality level of 99.9%.

Lean Six Sigma methodology application in construction

Lean Six Sigma is an integrated concept of Lean Production and Six Sigma principles focused on eliminating losses and unproductive costs, reducing process variability and stabilizing product characteristic, including construction products.

In the first decade of XXI century active testing of tools and large-scale deployment of the Lean Six Sigma methodology in construction companies began through the application of its fundamental principles and tools in practice (Mikhalchenko V., et al., 2016).

Thus, the application of the concept of 3.4 defects per million possibilities (6 sigma level or quality at the level of 99.9%) as the main criterion for evaluating the interior decoration process in housing construction was first implemented in 2004 (Construction Task Force, 1998). The process indicators level was initially low, at 2 sigma level (more than 300 thousand defects per million possibilities or quality at the level of 69%), which served as a powerful incentive for close scrutiny of the performed work quality and compliance with quality standards by the contractor.

In 2006 (Fischer et al, 2014), the DMAIC project management cycle (ISO 13053-1:2011 Quantitative methods in process improvement - Six Sigma - Part 1: DMAIC methodology, Standard, 2011) was used as a model to improve interaction between project teams, reduce delays, add structure to the improvement strategy implementation and, ultimately, increase the construction processes efficiency (Oakland J.S., Marosszeky M., 2017).

Since 2009, the Lean Six Sigma methodology has been used as a strategy to increase efficiency and reduce costs in a government agency, the England Travel Agency. The Lean Six Sigma initiative, launched

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in the organization, is intended to be a response to a 20% reduction in government spending and help to more effectively spend budget allocated on road network management (the annual cost of maintaining 2,000 km of roads amounted to £2.5 billion before budget cuts). The cost of deploying and adjusting the Lean Six Sigma methodology to the organization amounted to £2 million, the amount of savings from implemented projects to improve the organization's performance is estimated at £43 million (Lange, 2016). Projects deploying the Lean Six Sigma methodology involve traditional infrastructure construction, road network expansion and asset management; moreover, the mandatory use of methodology tools is specified in contracts concluded with contractors. The management of motorways has also been completely changed: instead of expanding existing and building new roads, advanced technical means of collecting and processing information about traffic jams are used. In terms of building effective supply chains, the Lean Six Sigma methodology served as a base to develop a toolkit, helping to determine the progress level in deploying the Lean Six Sigma methodology by suppliers and contractors and to assess the penetration level of Lean Six Sigma into the organization's culture according to the criteria for adopting a methodology as a strategy, management leadership, value creation for the consumer, organizational culture transformation, process flows, process indicators monitoring, standard work performance, quality control, design and construction work performance, factory premises and production equipment maintenance, as well as related infrastructure (Ohno T., 1988).

Figure 1 shows the projection of the construction industry lag from the UK industry, in which the Lean Six Sigma methodology is widely used, as in most developed countries. Without the advanced management methodology application, construction costs tend to increase, so the timely application of such Lean Six Sigma methodology principles, as creating value for the customer, reducing costs and improving the value stream, plays a crucial role today.

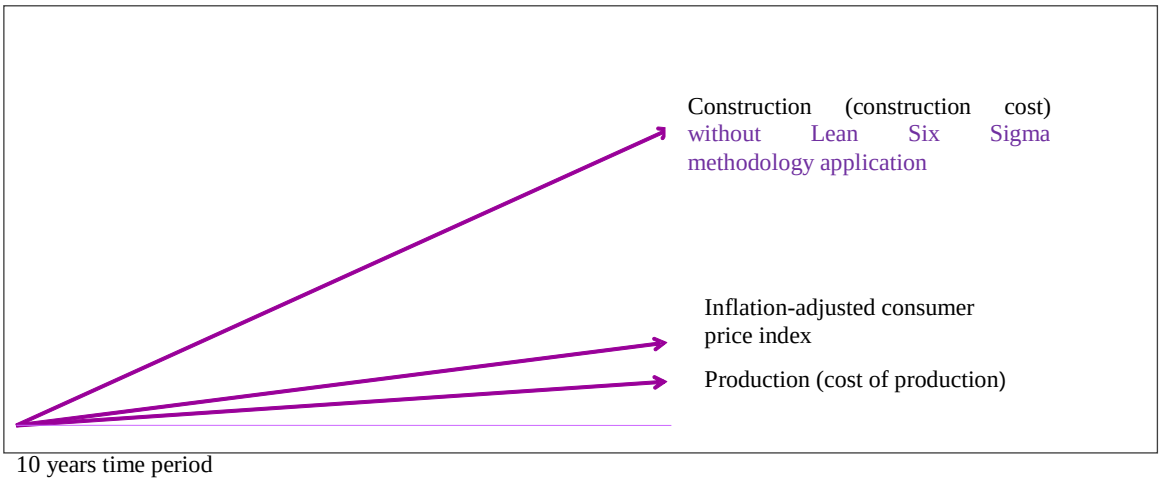

Figure 1. The construction industry lag from the industry, in which the Lean methodology is widely used

Source: developed by BAA (British Airports Authority), the former operator of several biggest British airports, currently the Heathrow Airport Holding

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By the value to the buyer the construction industry refers to important factors that significantly affect the decision to purchase. These, of course, include safety, meeting deadlines, limited access, maintenance, minimal remedial works, durability and quality, value for money.

The construction industry offers ample opportunities for making various measurements of performance indicators, but in terms of cost reduction, it would be practical to attribute a significant share of construction materials, transferred to the category of waste at the construction end, to the main losses. The key areas of loss accumulation, according to the Lean production concept, include unnecessary stocks, motion, conveyance, unproductive time and expectations, overproduction, unnecessary steps in processes, defects and throw-outs, as well as failure to use staff skills.

By creating a flow of value the movement of materials, information, equipment, people is meant, necessary to fulfill the consumer's order and at the same time bringing value (Linde et al., 2017). These include process mapping, the workspace organization according to 5S principle, integrated project teams, the just-in-time (JIT) concept, control cards and the systematic measurement of statistical indicators (the number of defective products, unresolved problems, unplanned downtime, compliance with the tact time, and operational efficiency) (Pheng & Hui, 2004).

Lean Six Sigma deployments in the organization

Deployment of the Lean Six Sigma methodology begins in the principal contractor's organization, and then cascades to other organizations in stages, depending on the criticality and importance degree of the delivered products/services for achieving the main goal.

The Lean Six Sigma methodology deployment is essentially a project, i.e. an activity that has a certain timeframe, requires certain resources and aimed at obtaining certain results. In addition to obtaining certain results (which may include, for example, improved processes, saved money, shortened deadlines, fulfillment of certain requirements, market share increase, etc.), the upper level organization goes through a transformation process that is deeper than tangible and visible project results, that is, a smooth transition from the current state of organizational culture to the world-class culture level. The transformation process, as well as the methodology deployment project itself, requires continuous and close attention of the management, but unlike the deployment project, the improvement projects implementation is executed on a systematic basis and by the trained personnel of the organization.

At the upper level, the Lean Six Sigma methodology deployment is carried out in several stages, which conceptually copy the DMAIC project implementation cycle according to the Lean Six Sigma methodology:

1) Conceptualization:

the conceptualization (definition) stage is the initial phase of the project, at which the resources for its implementation are determined, relationships are established between the project participants and

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stakeholders, a methodological procedure is executed to collect information about the organization's current state, allowing to understand the relationships in the organization and pre-determine the accumulation areas of loss, costs, defects and overhead costs, the main processes, needs and expectations of consumers, critical and important types of products, requirements imposed on suppliers;

2) Research:

the research (measurement and analysis) stage is an intermediate project stage, where the organization's state is audited in accordance with the score sheets for diagnostic audit and identification of organization's maturity level to deploy the Lean Six Sigma methodology, as well as an analysis of cause and effect relationships between accumulation areas of losses, costs, defects and overhead costs and the current state of the organization. The result of the research stage is an approved list of improvement projects (for example, the quality function deployment) to be implemented by project teams;

3) Implementation:

the implementation (improvement) stage is the main stage of the Lean Six Sigma methodology deployment, when improvement measures and projects are accomplished (for example, process improvement), necessary training materials are prepared, employees are trained, certified and engaged in projects , projects are guided by successfully certified employees and guided by external consultants.

4) Evaluation:

the evaluation (control) stage is the final stage before replication of the Lean Six Sigma methodology, where the improvement projects results and the organization's state from "as it was" to "how it became" are evaluated, a detailed plan for the Lean Six Sigma methodology development is prepared at upper-level organization, including the necessary work for continuous improvement;

5) Replication:

projects of transferring existing work methods according to the Lean Six Sigma methodology and communicating the principal contractor requirements for products/works/services to the suppliers of construction materials/products/works/services, which are, for example, part of the integrated supply chain.

Building the integrated supply chain based on Len Six Sigma methodology

For many years, such peculiarities of construction industry as inconsistent and fragmented processes and lack of coordination between suppliers and contractors, low quality construction products, have been ruthlessly criticized. According to experts in various countries, these problems are pervasive and entail serious consequences in the form of systematic failure to meet established deadlines, exceeding construction and subsequent operation costs, inefficient use of labor, waste of construction materials, and last, but not least, uncertain prospects for profit for participants involved in the construction.

One approach to solving these problems is building integrated supply chains based on the Lean Six Sigma methodology (Stewart & Spencer, 2006). The creation of integrated supply chains is the latest and

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revolutionary invention in the area of supply management and logistics (Womack & Jones, 2003). The main advantage of an integrated supply chain is the possibility of making profit for all participating parties - from the end customer to the supplier of construction materials. The essence of the integrated supply chain is in concentration of full responsibility at the top management level of the principal contractor, as well as close coordination and alignment in the supply chain (Mikhalchenko & Rubanik, 2019). As a rule, the central link in the organizational structure of an integrated supply chain is the principal's contractor's procurement department, which initiates the placement of all orders. Every step - from raw materials sources to final delivery to the customer - is considered part of the supply chain (Yelubayeva M. et al., 2018).

Creating an integrated supply chain is a significant opportunity to achieve the goal of creating value for the consumer at the lowest cost by expanding the scope of control and influence (Oakland J.S., 1995).

The basic principles of building the integrated supply chain are:

1. Competition through creating value for the consumer and ensuring the best value for money
2. Identification of value for the consumer
3. Establishing relationships with suppliers
4. Coordinated and aligned project activities
5. Cost management
6. Continuous improvement
7. Personnel development

The application of the seven principles of integrated supply chain creation requires a consistent and structured approach to the management of construction projects, which provides continuous support for of all supply chain participants integration by involving all interested parties in the process - from the supplier to the end user.

As a result of this approach, the consumer (customer) receives such benefits as saving, transparency of expenditure, improving the cash flow predictability both during the construction process and throughout the construction site life (Rumane A.R., 2019).

The practical application of this approach in foreign construction companies allowed obtaining the following results (Plenert G., Plenert J., 2018):

- Construction time reduction by 20%;
- Number of remedial activities in the project by 98%;
- The possibility of profit increase for contractors and suppliers by 8-14%.

CONCLUSIONS

Currently, an increasing number of organizations arrive at continuous improvement of processes vs. a one-time project for the processes reengineering. Improvement is necessary for any organization, because the level of most processes indicators tends to decrease over time, if not supported, and modern consumers are

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becoming more and more demanding and, frankly speaking, even spoiled with regard to quality. The rapid growth of consumer expectations, as a rule, motivates the organization to meet them. If this is not done, the loss of the client is guaranteed.

As practice shows, the concept of "Six Sigma" at foreign enterprises allow in a fairly short time (about a year) and with own resources to achieve the following results:

- Production and services cost reduction by 30-60%
- Service delivery time reduction of by up to 50%
- Increase in the volume of work performed by 20% without additional cost
- Decrease of the design cost by 30-40%
- Accomplished projects time reduction by up to 70%.

Summarizing the given above material (Desale & Deodhar, 2013), the key success factors of the Lean Six Sigma methodology application in construction industry are:

1) In the area of design:

- using the IT visualization capabilities to determine the final product from the consumer's point of view;
- an in-depth understanding of consumer needs and focus on creating value for the consumer;
- creation of mechanisms and use of integrated design technologies for achieving close cooperation between architects, project designers, industrial designers, suppliers and contractors;
- availability of product requirements and testing of structural assemblies and other construction processes to ensure high quality, work cost reduction and time saving;

2) In the area of supplier relationships:

- supply chains management and improvement in order to integrate in a single process all parties that contribute to creating value for the consumer;
- transparency of expenditure: eliminating costs and losses in processes, understanding the cost of value creation for the consumer in compliance with targeted confidentiality of costs and cash flows;
- partnership concept: boundaries and barriers between different companies involved in achieving a common goal (value creation for the consumer), should become less pronounced

3) In the area of production planning:

- benchmarking in order to achieve best in class production;
- creating a project implementation program with a clearly defined critical path;
- risk management throughout the project.

4) In the area of logistics:

- The "just-in-time" concept for materials delivery to the place of their use eliminates the need for on-site storage and double processing (for example, movement, and transportation).

5) In the area of construction:

- clear communication of plans and tasks;
- personnel training, teamwork and multitasking;
- daily reporting in order to measure progress;
- motivated and trained workforce.

Conflict of interests

The authors declare no conflict of interest.

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