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LOSSES MANAGEMENT PROCESS ON THE PRE-DESIGN STAGE OF CONSTRUCTION

Artem Radchenko[1] - Marina Petrochenko[2]

Abstract: *Nowadays construction industry requires new possibilities to decrease costs and time for buildings erection and lean management principles get answers for these requirements. In general, most of lean recommendations for construction are focused only on such stages of construction when building process have started and site managers want to decrease time and costs operatively on site. This article presents conceptually new approach to find possible losses on site before the start of construction and propose the measures for their elimination or impact decreasing.*

Keywords: Lean production, lean construction, quality management system, losses, wastes, improvement

1 LEAN CONSTRUCTION, LOSSES AND RISK MANAGEMENT TOOLS

Losses are the integral part of any construction process during the erection of the building and today there is no construction project that is fully free from them. The work of identification, monitoring and management of losses should be maintained constantly, during the entire life cycle of the project. Also the reassessing procedure should be continuously made for the identified losses and the regular monitoring of the arrival and impact of new ones.

The presence of losses in the production of works does not mean necessarily that there are problems exist, because the problems occur only at the present time. However, we consider losses from the point of view of risk management, so attribute them to the future, and their appearance would be entirely probabilistic in nature (they may not appear). But if not managed, they can become problems during the construction project. Thus, the identification of potentially occurring losses is a positive activity aimed to improve the activities of the construction company, improve efficiency and quality characteristics, increase productivity and reduce costs.

2 THE PROPOSED MODEL FOR LOSSES MANAGEMENT

The successful management of losses is impossible without an adequate model, describing the whole process. The main purpose of its development is to obtain a clear sequence of decision-makers actions in determining the degree of influence of the losses on production processes and identify those whose impact is critical and must be reduced or eliminated altogether. The model should be applicable not only to a certain type (types) of work, but also to fully cover all construction operations at the site first, and then the construction zone, the big complex and up to across the company. In order to achieve this goal it is necessary: to understand the essence of the arising losses at construction site - the probability of their occurrence, the impact on the production processes - to develop the most effective ways each of them impact reducing to acceptable level or completely eliminate them and implement interventions for the processing of losses according to the selected method. Therefore, the process of managing losses should be a set of consistent targeted actions that focus on optimization of the construction process in the framework of maintaining the planned budget, reducing the duration of the works and along with the quality.

Considering a large number of works of predecessors, we can conclude that at present there is no universally accepted course of action for the management of losses while the production of construction works. And on the basis of the tools of risk management the following process was adopted of managing losses on a construction site that includes the main stages:

1. The definition of the situation on the construction site and development of plan, setting goals and objectives of the management of losses.
2. The analysis and documenting of the processes during the execution of construction works.
3. The detection and identification of losses, their distribution into 7 major groups according to the methodology of lean construction, the definition in each of the groups of NVA and NVAR types of losses.
4. The assessment of the impact level of NVA losses on the production works according to the analysis of the opinions of experienced experts.
5. Processing of obtained results, the verification and development of responses on the most influencing losses, the calculation of the losses impact on production processes.

6. Monitoring and control of the activities performed and changes.

2.1 The definition of the situation in the construction process, the development of the plan and analysis of production

At the first stage decision makers should establish the clear structure of the process, to describe the process of losses identification, assessment and processing, as well as how to control these operations. It is also need to know the input data of management process, i.e. the information set out in design and project documentation, calendar plan of construction, the scope of work, the composition of the teams for the implementation of the main types of works, their description, the planned costs for construction, the planned timing of construction of the building and the assigned responsible managers who will be involved in the work.

Based on this data, the project management staff should examine all construction processes which are planned from the normative point of view (the scope of work set forth in the norms and standards) and from the practical view, that means to determine the sequence of all possible operations on the construction of building "in nature". This stage is based on experts experience and observations over the construction of similar facilities.

2.2 Detection and identification of losses

The next stage is the identification of losses, i.e. the identification of the operations having a negative impact on the course of production processes. The purpose of losses identification on the construction site is to detect potential events, which may occur with different probabilities and have different degrees of the consequences that affect the cost of structures erection, construction time, the quality and performance of workers. Moreover, it should be noted that in contrast to risks, losses are not recognized with positive influence on the project and can be recognized only as "threats" in the methodology of risk management.

The results of the analysis form the list of losses, which increase costs and construction time and further grouping by 7 types in accordance with the lean management methodology [1,2,3,4]. Losses are formulated as random events that may not take place; therefore, the probability of occurrence is introduced. The formulation of the single losses (source of loss, event) should have some detailed information about it, and the formulation must be specific and unambiguous [5].

2.3 The loss impact level assessment

The purpose of this procedure is to identify and assess the priority losses, the reducing or removing the impact of which is a priority for the company. This operation includes the procedure of the probability of occurrence estimation for each of certain losses on the construction site and their impacts on manufacturing operations. The next step is to organize losses by priority in accordance with the assessment and identify which ones are the most influencing, taking into account such factors as the time limits and the tolerance to the losses of key stakeholders.

The most preferable for pre-design stage is the method of expert assessment, as the simplest and easiest. The sequence of operations while using this technique is determined on the basis of the existing recommendations [6]. The experts' competence is the key characteristic of this process. Competence can be defined as based of the analysis activity of a specialist, the level and breadth of knowledge in science and technology field, understanding of the studied problems and possible ways of their solution [7]. The consideration of following qualities should be prepared: the work experience; the level and profile of education; the profile of work performed; the level of solved problems; the number and level of projects in which the expert participated.

The assessment is based on the pairwise comparison method [8]. For the further work the certain number of experts should be selected that will provide the necessary level of representativeness of the sampling. Each expert must have a certain set of qualities that are detailed on 4 levels: high, above-average, average and low [9].

After the specialized assessment of expert's competence, the direct estimate of losses using the method of expert assessment is started. By using this method, the expert group makes the estimation by assigning of each indicator's scores on a particular scale. In this case it is possible to estimate the importance of indicators by fractional values or to assign the same value from the selected scale for several indicators [10,11,12]. The processing of assessment should be made taking into account the criteria of competence.

2.4 The obtained assessment result processing

During the work, experts assess the losses from the perspective of their probability P and the level of impact on construction costs and time (the increasing of costs during production and increasing of the erection time of structures) in case of advent I_c and I_t, the index is calculated for each loss according to these indicators.

Index of each loss (in points) is determined by the formulas 1 and 2 [7,13]:

$$R_{it} = P_i \cdot I_{it} \quad (1)$$

$$R_{ic} = P_i \cdot I_{ic} \quad (2)$$

Where: P_i = probability of each loss occurrence; I_{ic} and I_{it} = the impact levels on cost and time of construction respectively.

The average statistic value (in points) is determined by the formula 3:

$$R_{iavc,iavt} = \frac{\sum_{j=1}^{n} R_{ij}}{m} \quad (3)$$

Where: m = the sum of the levels of expert competence.

The scores made by experts for each type of loss are obtained in the table. The index of each loss is determined taking into account the level of expert's competence. Losses assessment is carried out by constructing so called matrix of "probability-losses". The main advantages of this method are shared by the clarity, simplicity and the ability to obtain a detailed view of negative situations and consequences that are possible in the future. The main aspect when using this method is that the dimension of the matrix. The most common, obvious and convenient is the matrix with the dimension five by five, containing five numeric intervals of the probability of occurrence of losses and the degree of losses impact.

2.5 The cumulative integral coefficient of the losses impact

During this stage, experts assess the losses from the perspective of their probability *Pq* and the level of impact on construction costs and time (the increasing of costs during production and increasing of the erection time of structures) in case of advent I_c and I_t, the index is calculated for each loss according to these indicators.

The important aspect of executed operations is the question of the effectiveness of management for carried out changes. For any responsible official decision-maker it is not only important to make any changes aimed at improving productivity, quality of work, lower production costs, but also to evaluate how these changes are effective. This introduces a new characteristic measure: the indicator of the losses impact on construction site. The principles of its formation are based on the methodology of mathematical simulation and economic-mathematical methods. There are 3 main methods of its definition: additive, multiplicative and additive-multiplicative [14,15,16]. The significant drawback of additive and multiplicative transformations is the existence of unlimited opportunities of compensation. In order to decrease restrictions or limits, which define the lowest (highest) acceptable values of particular optimality criteria, and search for optimal alternatives the variety of alternatives is only carried out within these constraints [17,18]. While using the additive method, if one of the individual criteria is equal or close to zero, then the final result does not suffer significantly. But on the other hand, in the additive method, the mutual compensation of the individual criteria can occur. This means that reducing one of them down to zero can be covered by the increase of other criteria. For mitigation of this drawback it is necessary to impose restrictions to the minimum value of individual criteria and their weights[18].

The cumulative coefficient of losses impact can be calculated by the following formula 4:

$$K_{cum} = \sum_{j=1}^{n} K_j \quad (4)$$

Where: Kj = the value of the j-th integral coefficient of each of the identified losses.

At the same time, widely used formula is:

$$K_{cum} = \sum_{j=1}^{n} K_j \cdot \sigma_j \quad (5)$$

Where: σi = the weighting factor of i-th loss index [19,20,21].

There are several options for determining the weights, the most common of which are the method of expert assessment (method of ascribing scores), characteristics of which are outlined above.

The integrated coefficient (indicator) of losses impact on construction site will look like:

$$K_{loss} = \frac{K_{cum}}{z} \quad (6)$$

Where: z = the multiplication of the maximum (minimum) value applied by each expert, respectively, for the probability of loss and impact level.

The maximum (minimum) value of indicator K_{cum} will be calculated according the following formula:

$$K_{cum}^{\max/\min} = \sum_{j=1}^{n} K_j \cdot \sigma_j = R_{c,t}^{\max/\min} \quad (7)$$

The final appearance of the maximum (minimum) value of the integrated losses impact indicator has the following view:

$$K_{loss}^{\max/\min} = \frac{R_{c,t}^{\max/\min}}{z} \quad (8)$$

As the value of the integrated losses impact indicator is closer to 0, the level of losses impact on the construction site is lower and the efficiency of operations and productivity is higher. The approach to the value of 1 gives the decision-maker reason to concern measures of losses reduction and increase efficiency of production work.

2.6 The calculations verification and construction of the matrix (map) of losses

The result of calculations is the ranked list of losses in decreasing order of impact level, indicating the indexes of each loss. For priority response, those that have the highest indexes are selected. However, how to determine which ones has the priority? To do

this, the so-called matrix (map) of the losses impact should be done both in value and in time terms.

Similarly to the definition of the risk matrix from ISO Guide 73:2009, the matrix of losses influence is a tool for the classification and reporting of losses by ranking the degree of impact of consequences and likelihood. It has tabular form. Interpretation of the losses influence matrix, as the risk matrix, in graphic form (map of losses) will enable one to visualize the location of index exposure to losses relative to the level of tolerance. In general sense we can say that losses map visualizes the situation, makes it visible and allows more efficient and faster to interested and involved parties (decision-makers, engineers, etc.) to make the right decisions. It is possible to build, for example, with the standard Microsoft Excel tools or by using the professional software.

For performance of such this evaluation the already available data should be used which has obtained in the survey of experts, as well as the scales of probability and impact. The assessment scores given by experts during the survey are multiplied by the level of competence in a similar way:

$$P_{iL} = P_i \cdot m_j \tag{9}$$

$$I_{iLc} = I_{ic} \cdot m_j \tag{10}$$

$$I_{iLt} = I_{it} \cdot m_j \tag{11}$$

Where: P_{iL} = the probability of loss occurrence taking into account the competence level of experts; I_{iLc} and I_{iLt} = the level of impact on cost and time of construction respectively by expert assessment taking into account the competence level of experts; mj = the level of j-th expert competence.

Further calculations are repeating the statements of 2.4 and reduced to calculating the values of loss index:

$$R_{icav} = P_{iav} \cdot I_{icav} \tag{12}$$

$$R_{icav} = P_{iav} \cdot I_{icav} \tag{13}$$

Where: P_{iav} = is the weighted average of the i-th loss probability of occurrence; I_{icav} and I_{icav} = the weighted average of the impact assessment value on the cost and time of construction respectively taking into account competence of experts.

Weighted averages are applied to the graph of "probability-losses" using already created macros in the Microsoft Office environment. While creation of losses map the required tolerance levels must be installed indicating the maximum values of the losses impact on the cost and time of construction, above which losses are deemed critical and require priority response. Also two tolerance levels can be stated and the assessment results will define the three groups of losses by their impact levels.

2.7 Measures to reduce the impact and/or eliminate identified losses in the works production

The final list of losses on construction site is formed in the end of ranking, where they are divided by degree of impact on groups with the highest indexes, and average the lowest. Losses with low impact indexes can be reduced by the implementation of measures complex on elimination of shortcomings in the organization of construction at the building site by site engineers without interference from the company management.

Losses with average and higher index require more attention, since their reduction or elimination will lead to lower costs of execution of works on the construction site, reduce the production processes time, increase productivity, quality of products and reduce injuries on the site. Measures to eliminate losses should be developed and adopted by decision-makers and included in the enterprise standards for quality management. Thus, the system of the QMS will begin to benefit and not be another "paper" that is necessary only for the sake of appearance for oversight bodies [22,23,24]. Therefore the QMS will be implemented not on paper, but in production.

The visual representation about how to process losses gives a schematic diagram which is shown on Figure 1.

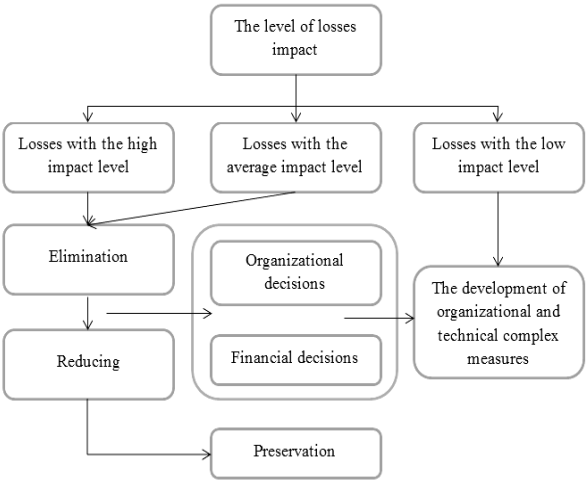

Fig. 1 The principal scheme of losses processing

At the initial stage decision makers should determine whether it is possible to prevent the occurrence of losses prior to the construction of the object. The group must analyze the project and technical documentation, time schedule of work, adopted organizational measures and HSE measures, review the results of the feasibility analysis of the technology of work implementation and possible progressive alternatives. As a result, in the best case the organizational and financial measures should be taken to reduce losses within the existing technology of the construction of the object. However if execution of

these measures is not possible, then there is necessity to change some of its elements of technology for optimal and more advanced options or to adopt alternative methods of works production.

By the results of analysis it can be occurred that taken measures will not lead to the elimination of certain losses. Then decision-maker should move to the next stage: finding ways to reduce the impact of such losses, which implies the adoption of measures aimed at reducing the probability and/or consequences to acceptable (low) values. It is needed to conduct qualitative analysis of each methods of risk management by FMEA, fault trees analysis procedures, bowties, etc. as mentioned in ISO 31000:2011. As the result, decision-maker makes the decision on carrying out additional institutional and financial measures aimed at reducing the occurrence probability of each identified causes and consequences. The preservation of the degree of loss influence at the same level and development of consequences elimination plans is the decision not to evade of any losses. In this case, decision-makers can go by two ways: passive acceptance when nothing will be done in respect of the loss, and in case of its arrival the complex of individual measures is developed aimed to remedying the consequences of its occurrence; the active acceptance when the action plan is developed before the fact of loss occurrence was recorded and is called as the plan of actions in unexpected circumstances. Design principles of these plans are similar to those contained in separate guidance documents on risk assessment, such as ISO 31010:2011 or ISO 17776:2000.

2.8 The processes of monitoring control and documenting

The process of losses management on a construction site is an iterative process. After making the changes, new losses can occur or the degree of influence of the existing ones can increase. Therefore, it is overwhelmed with operations on monitoring, documenting and control of ongoing changes. The main stages of the process are monitored and checked for compliance with applicable methods. It should be noted that monitoring provides more than basic role, as the documenting, though is one of the key processes in managing losses. However, without a process of monitoring and documenting the implementation of effective loss management system is impossible.

3 CONCLUSION

The presented procedure shows the methodology of losses management in the production of construction works which includes all necessary steps for analysis of all probable losses required before starting work on the construction project. This new procedure presents new approaches in lean construction:

1. The assessment of experts' competence level. The implementation of experts' assessment method for evaluation of losses parameters such the probability of occurrence, increasing of the costs and construction time. The method for processing data of the survey of experts has been proposed, which determines the losses impact level in the in-dex form.
2. The technique of calculation of losses impact indicator on works production, which gives decision makers clear understanding about the effectiveness of a construction project from the losses point of view. The values of losses indexes are determining when the calculation of this coefficient, the maximum and minimum values of this indicator has been calculated.
3. The methodology of calculations checking by the matrix (map) of losses which helps to visualize losses and to determine which of them are critical to response. Methods to reduce the impact level and eliminate losses, as well as monitoring of measures.

It should be noted that the finished system of loss management is individual for each project. So measures to reduce and eliminate losses should be developed more carefully and detailed, the probability of successfully company goals achieving will be higher: reducing costs, improving productivity and quality of work, ensuring sustainable development.

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AUTHORS ADDRESSES

[1] Artem Radchenko

Saint Petersburg State Polytechnic University
29, Polytechnicheskaya street
Saint Petersburg, 195251
RUSSIAN FEDERATION

E-mail: katarina.cekanova@stuba.sk

[2] Marina Petrochenko

Saint Petersburg State Polytechnic University
29, Polytechnicheskaya street
Saint Petersburg, 195251
RUSSIAN FEDERATION

E-mail: katarina.cekanova@stuba.sk