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Integrated assessment of construction processes on the base of lean production concept

Master thesis

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CONTENTS

ABSTRACT

UDC 69.003.13. The economic effect of construction.
The master thesis contains 141 pages, 41 figures, 21 tables, 5 Annexes.
Keywords: quality management system, total quality management, 6 sigma, lean, lean production, lean construction, building site, risk, risk management, losses, losses management, construction costs, construction time, labor productivity, value stream mapping, decision makers, expert assessment, loss index, expert's competence, coefficient of variation.

This master's thesis presents the research results of new construction organization – lean construction. The main its goal is the detection of all possible losses during execution of works, analysis of their appearance causes and subsequent decreasing of their influence or elimination. The implementation of lean construction systems leads to lower the costs, improve the quality of works, productivity on construction site, reducing the time of construction. This concept applies not only for the construction of residential, but also public and industrial buildings and structures. Unfortunately in most cases the introduction of concept is performed only on separate sites and immediately prior to the beginning of works production, often only within individual projects, but not the whole production system. Therefore it is necessary to provide a system that will allow identifying losses at the pre-investment phase, that paving actions to mitigate losses or to eliminate them even before the beginning of the project, to develop organizational measures for the improvement of production indicators and to identify all deficiencies in work organization. For this purpose the assessment of losses has been proposed arising from the point of risk management view and loss control system has been developed at building site.

The paper discusses currently existing methods of risk assessment in construction projects for this purpose implementation. The improved method of assessment and management the losses on the construction site was developed. The method provides to assemble the expert commission with specialists in the field of industrial and civil construction, compiles the list of qualities that should be possessed by each expert performs a survey on the losses assessment, levels of competence of each expert. The development of universal criteria for evaluation of the project from the losses point of view arising during its implementation has been proposed. The method for the formation and ranking of the losses register has been developed within the allocation in them the most significant and development of elimination measures or the impact reduction on the production process. Recommendations of monitoring process organization, control of made changes and documentation has been provided.

The proposed method of losses management is realized on the example of the in-situ reinforced concrete works. The analysis of processes, identification of losses, their evaluation and ranking has been made, the integral indicator of efficiency has been determined with the verification of results and the measures to prevent and reduce the impact of loss on the works have been proposed. The obtained results show the possibility of reducing the cost of works execution and construction time up to 20-25%.

INTRODUCTION

The actuality of dissertation research theme.

The construction process is a complex system, which values of parameters are constantly changing in time and depend on a huge number of factors. The successful implementation of a construction project is in achieving of its goals: the completion of construction in time, implementation of planned works volumes, the optimal allocation of resources and obtaining high-quality construction products.

The achievement of goals is impossible without clear production control system. The effectiveness of management is influenced by number of participants in the building process, duration of construction and territorial dispersion of objects. Changes in the composition of the participants take place from project to project: designers, contractors, suppliers, requirements of government agencies. However, the failure to apply and to develop new methods of management leads to failures in the work of the participants of construction process, reduce productivity and quality, and consequently to radical gap behind the leading foreign countries.

The researchers define the following chronic problems of Russian construction system:

- systematic exceedance of construction time and cost;
- poor performance;
- low quality of construction products;
- downtimes while performing work;
- low skill level of large numbers of workers;
- working conditions at the workplace;
- non-observance of HSE requirements [1].

One of the main causes of these problems is the gap of the Russian construction industry from other types of industries in the development of advanced management methods of production processes. Today there is necessity to adapt of advanced production management methods that are actively developing abroad, to domestic realities, or creation our own. The modern improvement of managerial activities in construction occurs in several areas: the implementation of innovative technologies; the usage of modern building materials; optimization of financial, production and human resources.

Traditional methods of construction management are focused exclusively on management tasks and consider the production as the transformation of inputs in outputs. However, this is insufficient to ensure the development of construction, which lags behind other industries in the development of methods based on production understanding as process of value creation and flow [1]. One of such methods is the concept of lean construction, the first principles of which was laid by Finnish specialist

Lauri Koskela [2]. Lean construction is the most advanced direction of quality management, designed to eliminate chronic problems of the construction industry by applying the tools of lean production [3-5]. The main idea consists in finding and applying systematic methods to reduce all kinds of losses, which T. Ohno formulated, such as: losses due to overproduction, due to excess inventory, due to waiting, due to unnecessary transportation, due to unnecessary processing steps, due to unnecessary movements and due to the release of defective products [6]. The central tenet of lean construction, like lean production, is the statement that chaos is the natural state of the production process. But in modern practice the approach has developed which says that the end goal can be achieved only with careful organization and planning of the construction process.

The analysis of current researches in lean construction shows that the developed basic tools are applied only before the direct access to the object or the start of production of a particular type of work. For example, the Last Planner system takes place directly on-site and involves the discussion of the upcoming works production on the previously approved project by workmen and foremen. Each participant offers suggestions for the duration of the construction assigned to it processes, linking them to other processes, reduction of production costs, resources and time. The schedule of construction is developed as "in reality", which takes into account all possible nuances in the works production [7]. For each project the process is purely individual and there is no single approach to the management of losses elimination, which could be used for each construction object, regardless of its degree of uniqueness. The development of such methods for losses control causes **the actuality of the topic of this master's thesis**. The proposed system allows the contractor to consider what losses could occur during the construction of each object type, implement in management system required measures to reduce the probability of their occurrence or complete elimination. The main innovation in this process is the usage of risk management tools.

It should be noted that the problem of losses management in construction enterprises in domestic practice has not been raised, fundamental researches on this issue, essentially, haven’t been done yet. However, these researchers such as E. A. Chernykh, I. I. Mazur, V.D. Shapiro, O. Zimina, V.A. Lapidus, A. Baranov and P.I. Gorelik concerned in their works the ideas of lean production and lean construction. It should also be noted researchers engaged in the study of risks in construction projects, such as T.F. Morozova, T.L. Simankina, S.A. Bolotin, S.A. Ershov, Yu.N. Kazansky, A.S. Millerman, M.G. Lapust, F.H. Khayt, J.P. Panibratov, G.N. Chernoff, R.A. Faltinsky, G.V. Kovalenko and etc. Theoretical and practical issues of scientific researches with the help of different mathematical apparatus are dedicated to the works of N.M. Astafyev, N.K. Smolentsev, A.P. Petukhov, A.N. Yakovlev and etc. Among foreign researchers and discoverers of the lean production and construction concepts it should be allocated T. Ohno, P.J. Womack, G. Ballard, A.G. Howell., S. Singo, L. Koskela, J.E. Diekmann, M.Krewedl, J. Balonick, T. Stewart, S. Won, T.D. Jones, D. Roos and etc.

The research goal is the improvement of construction management methods with development of losses management system on the base of lean production principles.

The object of research is the mechanism of the construction process management.

The subject of research is the losses impact while performing the works at the building site on quality, cost and time of construction.

In accordance with the intended objective of work, following **tasks** have been solved.

Scientific and economic research tasks:

1. Analysis and generalization of implementation experience of lean construction in Russia and foreign countries.
2. The development of losses management model of construction processes with risk management tools usage.
3. The definition of construction project efficiency indicators from the possible losses point of view in the works execution.
4. Testing of the obtained model on the example of monolithic frame construction.
5. Processing of the results. The development of preconditions for further work.

Research methods

The methods of expert assessments, the instruments of risk management (risk identification, risk mapping, etc.), the additive method of calculation of the aggregate integrated indicator of efficiency, different statistical and economic-mathematical approaches have been used during of work execution.

The information base of research

Scientific sources in the form of data and information from books, journal articles, research reports, legislative and regulatory acts of the Russian Federation and Europe, methodical recommendations, materials of different organizations and the Internet on management theory, risk management, economic and mathematical methods, lean construction and production.

The most essential scientific results received personally by the applicant:

1) The conceptually new technique for losses management of the construction processes using the tools of risk management has been received.

2) The usage of expert assessments method for losses evaluation at the construction site has been proposed.

3) The approach to determine the level of expert’s competence participating in the survey has been developed.

4) The method of assessment of losses impact on the results of the construction (influence on costs and time of construction) has been implemented within the introduction of such characteristic as the index of losses impact in case of its occurrence.

5) The losses ranking procedure to determine the most influencing construction process has been proposed based on the index of losses impact.

6) Recommendations for the development of measures to reduce the impact level and elimination of losses in case they occur was determined.

7) It is shown that the probability of losses occurrence reduction and prevention of their occurrence can reduce the cost and time of construction by 20-25%.

The evaluation of scientific results and conclusions reliability and validity

The accuracy and practical significance of the results of the study is confirmed by the positive results of the implementation of the proposals for losses management on the example of monolithic reinforced concrete works. Theoretical and experimental results obtained with the use of proven and established practice studies of risk assessment methods, statistical and economic-mathematical methods.

The reliability of scientific results is based on the usage of scientific tools: empirical research methods, systematic approach, statistical and mathematical analysis, graphical methods. The information basis of the study consists of economic and scientific-technical information public funds.

The scientific novelty

The method of losses management on a construction site, the method of the losses impact assessment on construction process are proposed, based on the method of expert assessments, by attracting highly qualified specialists to the design.

Recommendations to reduce impact losses, the probability of their occurrence and the degree of influence on the results of the construction has been developed.

The significance of obtained results for the theory

The developed methods can be used for further research in the field of lean construction. The application of this methodology is reasonable for certain types of work, and for the entire enterprise. The possible implementation of this system can be obtained for the design process, supply and ERP systems in modern construction.

The significance of obtained results for practice

The proposed solutions have practical importance to improve the efficiency of construction, reduce the cost and time of structures erection, and improve work culture and productivity. The process of losses identification and their management takes consistency and increases the degree of harmonization of the construction with the external environment.

Recommendations about the usage of dissertation research results

The results of the work are recommended as a way to manage all the possible losses at the construction site on all stages of the construction project life cycle. The results of the research work are published in various publications, including in the Internet, and are freely available for other researchers of this direction.

Approbation of work

Results will be presented at:

1. ESaT 2016. 2nd International Conference on Engineering Sciences and Technologies. June 2016. The Slovak Republic.

Results are published in print media:

1. Radchenko A.E., Petrochenko M.V. Logistics of processes of building materials warehousing. *Construction of Unique Buildings and Structures*. 2015. No.1 (28). Pp. 32-39.

2. Usoltseva M., Volkova Yu, Radchenko A., Guseva I., Makarova T., Wenkel K.-O. Assessment of Natural Resource Potential of a Territory for Planning of Investment Development and Construction in Suburban Areas. *Advanced Materials and Technologies*. 2016. No. 514.

3. Radchenko A.E., Petrochenko M.V. Implementation of risk management theory for development of lean thinking in construction company. *Advances and Trends in Engineering Sciences and Technologies: Proceedings of the International Conference on Engineering Sciences and Technologies. 27-29 May 2016, Tatranská Štrba, High Tatras Mountains, Slovak Republic*.

4. Radchenko A.E., Petrochenko M.V. Losses management process on the pre-design stage of construction. *International journal of Interdisciplinarity in Theory and Practice*. 2016. No. 10.

1 Analysis of theory and practice of quality management and lean construction issues

1.1 Quality management in Russian construction industry

In modern conditions of Russian economy the big attention is paid to quality issues. The serious competition from foreign manufacturers led to the development of programs of quality improving. In research and practice has arisen the necessity to develop objective indicators for evaluating the capacity of firms in order to produce products of the required quality characteristics. These characteristics are confirmed by the certificates. Many manufacturers all over the world have quality systems that meet international standards (ISO). And the successful implementation of quality product to the consumer is the main source of existence of any enterprise today. The situation in construction industry is the same as in other economy branches: machinery construction, food production, mining and transportation of hydrocarbons and etc. The customer always wants to get products of high quality without additional expenses while manufacturing. So in many countries, including Russia, there was start of implementation of common quality management standards. Today we know them as ISO 9000 standards which introduce Total Quality Management system in production. The quality management system (QMS) as common phenomenon in construction is a set of processes and resources required for the implementation of policies in the field of quality, by managing, planning, ensuring and improving of quality, as well as a set of organizational patterns.

The necessity of introducing the QMS in companies has "external" causes: market entry, competitive advantage among countries and firms. But also the important and "internal" reasons exist [8]:

– greater awareness of quality; reduced defects and rework;

– accelerating of production cycle and increasing of productivity;

– positive cultural change, documentation improving;

– increasing responsibility for the quality of their work;

– problems of corporate culture.

Tactics of QMS [9]:

– preventing the causes of defects;

– involvement of all employees in activities to improve the quality;

– active strategic management;

– continuous improvement of product quality and processes;

– usage of scientific approaches in solving problems;

– regular self-assessment.

One of the forms of quality confirmation is certification process which is determined as the reform carried out by the certification body for the conformity of objects to requirements of technical regulations, provisions of standards or conditions of contracts [10]. In the construction the certification process it is based on international standards ISO 9000. And in accordance with the order of Rosstandart №1575-St dated 22.12.2011 since 1 January 2013 the standard of Russian Federation GOST ISO 9001-2011 "System of quality. Requirements" besides GOST R ISO 9001:2008 [11] has been introduced.

Certification of construction activities is on the one hand proof of the organization's compliance with all professional settings, on the other: it allows talking about the competitiveness of one or another construction company. By analogy with other types of certification, certification of construction should be consistent with the overall objectives and requirements of certification.

Certification of these activities has several specific features. As the construction is varied, then the full picture of production can only be in the totality of all possible activities. Companies may have the equipment and materials of various levels or personnel engaged at construction sites may be more or less prepared. The requirements of the customer are also varied, and the quality of services that construction company can provide depends on the professional training of CEO. Thus, we cannot say that certification gives a complete picture of the competitiveness of a company, but a certificate of compliance can certify that all the declared facilities and materials are typical requests. And from these points our problems starts.

In Russian Federation there are some problems with impeding the implementation of QMS on enterprises. On the first place it was highlighted the most common problems that hinder quality implementation of the system: the lack of interest by the company's management, insufficient knowledge of QMS documents, no changes in internal communication, careful planning and observance of the implementation of the plan, as well as the lack of understanding of customer needs [12].

In the most cases the QMS system is implemented formally, "on paper", and the company does not receive the expected effect of implementation. Also there is a reason for corruption, when the certificate is actually sold for money to allow the company to gain an advantage over its competitors. Worst of all, the product quality and management on the enterprise as a whole is not improving, which casts doubt on the system, and the ISO 9001 standard as such. Our managers want to get profits now and here and they perceive the "quality management" only as an instrument for gaining the money and for compliance with the law of Russian Federation. The ultimate goal is not achieved and the improving of quality is not happening.

So, what should be the appropriate model in order to achieve the best results in quality management? Should we start with the consciousness of employees, managers and are there tools which allow a complex to create the company quality assurance of production system? The developed countries are not staying still and show us the implementation experience of such tools as Total Quality Management, 6 sigma and lean production. These instruments are existed in many companies and prove its effectiveness. So let’s check them and find what are the most progressive and competitive in modern economy

1.2 Main trends of the global manufacturing process

Since the industrial revolution the process of conversion of skills, abilities and competencies of individual masters in the production process had begun. The main component of any manufacturing process is technology. But it involves as a necessary component not only technical knowledge and competence, but also the organization of the technical systems of a single process.

The natural step in the evolution of production systems is the isolation of the subsystems of organization and production management. System of organization of production (production systems) are intended for the organization of production, including procurement of raw materials, operation of workers, placement and maintenance of equipment, quality management, development or introduction of new products and processes [13]. Few production systems are designed for configuration and reconfiguration of various production processes in different industries and under different production parameters (mass, batch, unit).

There are two key goals of production systems, characterized by groups of parameters:

- ensuring the quality of the product;
- minimization of production costs.

Recently added the third goal, supporting and integrating two already indicated, is a constant innovative updating of the process and control by it PS.

The necessity of a clear formulation of the purpose and development of the means of achieving it is dictated by the increasing global competition. Different PS have different reconfigure, "tune in" basic elements of the production process and the modes of their interaction, emphasize to all participants of the production process to different target aspects.

General characteristics of the interaction and interrelationship of the various approaches to the improvement of organizational processes is clearly shown on the Figure 1. This scheme was proposed in 2011 by Dan Lachica [14].

The characteristics of the content and features of various modifications of production systems in sufficient detail described in numerous sources. It is therefore advisable to briefly describe the essence of the basic production systems: total quality management, based on the methodology **"six sigma"** and the concept of **"lean production"**.

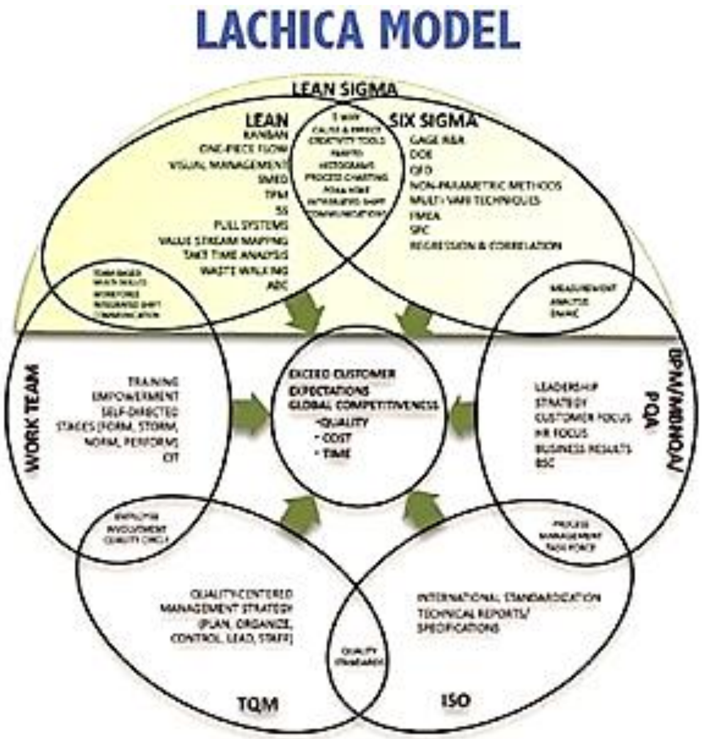

Figure 1.1 The scheme of the interaction and interrelationship of the various approaches in improving of organizational processes.

1.3 Quality management system as a stage in the development of process management towards "lean production"

Today in the Russian practice the quality management system is the translation of the western concept of Total Quality Management (TQM). The statutory definition of TQM: the approach to the management of the organization, focused on quality, based on participation of all its members and aiming to achieve long-term success through customer satisfaction and benefits to all members of the organization and society [15].

As synonyms and/or conceptually closely related approaches, the terms used are: quality management system, six sigma (6 sigma), with an attached modifications associated system of quality management, total quality management.

The modern ideology of quality management systems (see Figure 2) introduces the horizontal management processes of quality in addition to hierarchical management schemes. This is consistent with the actual processes of creating the product, wearing it horizontal in nature.

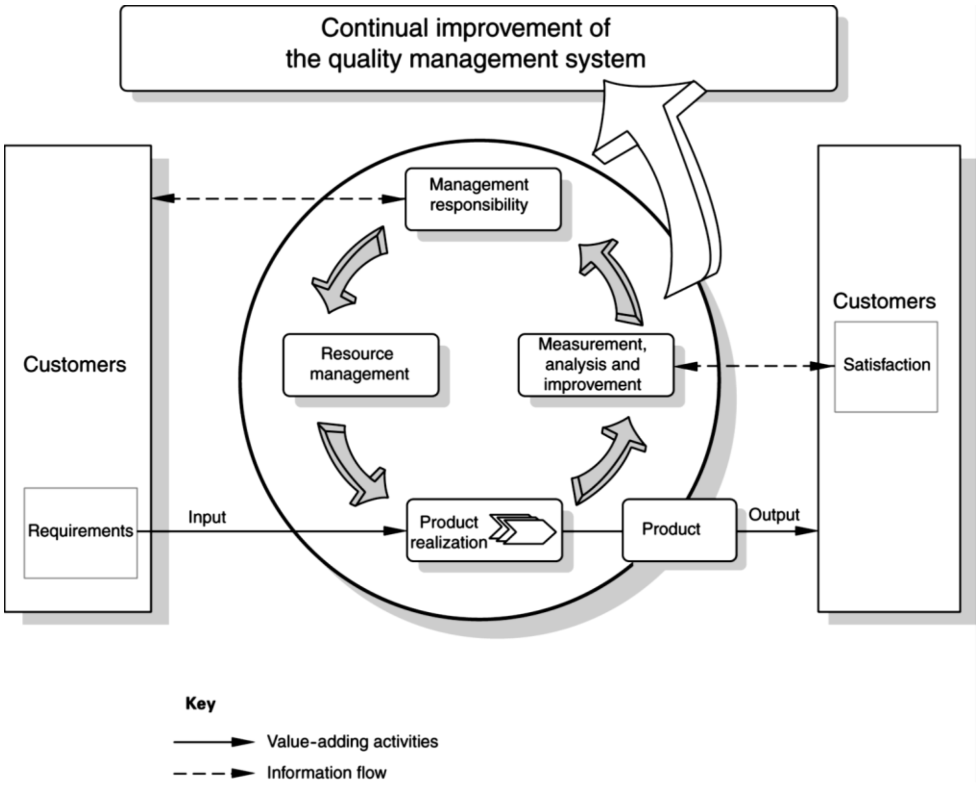

Figure 1.2 The model of quality management system according to ISO 9001.

Manifestations of horizontal management are the following:

- cross-functional teamwork, including collaborative structuring of quality function, operation of quality circles;
- statistical process of control as a common language and tools to describe and improve production processes;
- development of organizational links of the chain between the consumer and supplier;
- motivational aspects.

From the point of view of the evolution in concepts about quality management in industry, TQM is considered as a foundation to build the next level of quality management approach **"six sigma"**, which focuses on the eradication of defects on the basis of continuous diagnosis using statistical analysis of measurement results and subsequent process improvement. As core and specific tools in "six sigma" are statistical concepts that determine the quality of the production process within the parameters of defects.

The main feature of this management approach is to build according to the classical scheme of continuous improvement based on continuous application of the DMAIC cycle [16].

Table 1.1 The content of the stages in the DMAIC system.

D	Define: to define the goals necessary improvements. Objectives are defined at several interconnected levels: the company as a whole (ROI, market share), improving the process (productivity, lower reject rate). Searching information about possible ways of improvements

M	Measure: measurements in existing systems for accurate identification of the existing situation. The application of statistical methods to interpret the accuracy and relevance of measurement results. Introduction of metrics to describe the goals set in the previous step
A	Analyze: analysis of system/process to identify opportunities to bridge the gap between the existing condition and the expected goal. The application of statistical methods for analysis
I	Improvement: the improvement of the system. Creative searching to find ways to do better, cheaper or faster. The use of project management and other managerial techniques for planning and implementation. The use of statistical methods to justify performance improvements
C	Control: the management of the updated system. Institutionalization of the updated system with the regulations. The use of system standards such as ISO: 9000 to ensure the correctness and completeness

For newly created processes there is approach, aimed for anticipating of the consumer expectations. The focus here is on preventing defects in processes.

Design of a new process (or redesign of the existing one) is also carried out in five steps. Method for design (redesign) in the concept of 6 sigma method is called DMADV [17].

Table 1.2 The content of the stages in the DMADV system.

D	Define: this step defines the goals of a new process subject to the requirements of consumers. Creates a project team six sigma for design (redesign) process.
M	Match: the team develops and defines the set of technical characteristics on the basis of which can determine the achievement of the objectives of the process
A	Analyze: the analysis of characteristics of the designed process and developed preliminary versions of the process.
D	Design: during this step generates the detailed specifications of the new process and carried out its implementation in the work organization improvements
V	Verify: at this stage, the project team of six sigma design process performs validation of process to achieve goals based on specific characteristics.

One of the important elements of the methodology of 6 sigma is the process management, because very often in the organization the simultaneously improving of existing processes and designing new ones are going on. Management is constantly changing processes becomes quite a challenge.

The main controls on the methodology of 6 Sigma are:

- defining processes, key customer requirements and process owners;
- measurement of indicators characterizing the compliance of customer requirements and key performance indicators of the processes;
- analysis of the results of measurements and improving management processes;
- control of the processes execution based on the monitoring of "inputs" of processes, execution of operations, and "outputs" of processes and the adoption of measures to address problems or deviations from established requirements.

At the present stage of development of the concept of six sigma became widely known and popular brand. Promotion of the brand contributes to the training of specialists in various levels of "ownership" methodology and 6 sigma certifications [18].

1.4 Lean thinking and lean production

1.4.1 Overall characteristic of lean production system

Lean Thinking is a concept that is based on the Toyota Production System (TPS). It was ultimately developed in a manufacturing environment, more specifically in the automotive industry. The main pioneers and promoters of lean thinking is Toyota’s chief engineer Taichii Ohno and the CEO Eiji Toyoda. They were dedicated to eliminate both hidden and obvious loss. The system drew huge attention after Toyota’s striking competitive advantage over its American and local rivals especially during the 1973 oil crisis [19].

The term “lean production”, first used in the book “The Machine that Changed the World”, was coined by a member of the International Motor Vehicle Program (IMVP) team [20, 21]. The team was led by James P.Womack and Daniel T. Jones at the Massachusetts Institute of Technology (MIT). It was a collective synonym for the Toyota Production System.

The IMVP team completed a five-year international research study, concluding in the book that introduced the term “lean” to the rest of the world. The study compared the mass production system, created by Henry Ford, extended exponentially at General Motors, and practiced by virtually every major industry in the world up to that time (except Toyota), to the production system developed by Ohno and Toyoda. It is again the IMVP team that called Toyota’s production system as “lean production”, referring to reducing inventories, being flexible and decreasing loss. Therefore, in essence, lean production is the Toyota Production System. Just like any manufacturing system, the lean production system is implemented to produce the highest quality products, in the shortest lead time possible, with the least amount of resource investment at the lowest possible cost. Hobbs [22] states that although lean production offers some new concepts, it is basically a consolidation of proven techniques into powerful methodologies. The basic concepts of lean production are [19]:

- Pull-driven production.
- Minimizing the loss by eliminating non-value adding activities.
- Doing things right at the first time by identifying and resolving
- Defects instantly at its source.
- Continuous improvement (Kaizen).
- Building long-term relations with suppliers.

- Being able to produce various goods of various quantities.
- Team work.

1.4.2 History of the development of lean production

The beginning of the development of the TPS system was started after the Second World War, when Japan faced the task of rebuilding the economy and industry, as well as international automotive market. TPS was preceded by mass production, the ancestors of which were Ford's and Sloan in the 1920s. Mass production was actively spread in the world. However, in 1950, future originators of the concept of TPS Eiji Toyoda and Taichi Ohno after visiting the Ford factories in the United States came to the conclusion that in Japan mass production will not work, because:

- the local market has been demanding for variety of vehicles;
- the lack of inflow of foreign workers, the development of trade unions and new labor laws have strengthened the position of workers, which made it almost impossible to use cheap labor to unskilled repetitive operations;
- after the war Japan didn't have enough free money for lending, and the law was limited to the inflow of foreign investments in the automotive industry, whereby it was impossible to Finance the production, based on large stocks.

After the revise of obtained on plants in the USA information, Toyota had its own way of development. The employees received a guarantee of lifetime employment, with the right of use of the social benefits. The company had begun to actively invest in training employees so that new knowledge and skills remain in the company. Unlike mass production in the USA, Toyota company is responsible for the results of the work began to spread far down the hierarchy, which stimulated the development of the worker, and his feeling of belonging to a common cause.

After the completion of the process of motivating employees has been made a number of technological changes at the factory:

- Lower of changeover process of machines from hours to minutes (this approach is called SMED - single-minute exchange of dies).
- The introduction of a compulsory stop of the line if found any defect in the car or in components (Jidoka), which contributed to significant reduction of defective products at the final stage.
- Preparation of tools and equipment directly by employees (general maintenance of production equipment - TPM), organization of personal work space (5S method). The need for auxiliary workers and engineers had lost.

- Workers should have full responsibility for quality of products, passing from their areas of responsibility in following what was the basis for the mechanism of continuous improvement at every stage of product creation and putting forward ideas for universal quality improvement - "Kaizen".
- Intermediate warehouses and a system of "just in time" (just-in-time) were eliminated - the details were delivered on the conveyor as needed through a system of cards "Kanban" in the image and likeness of system in American supermarkets.

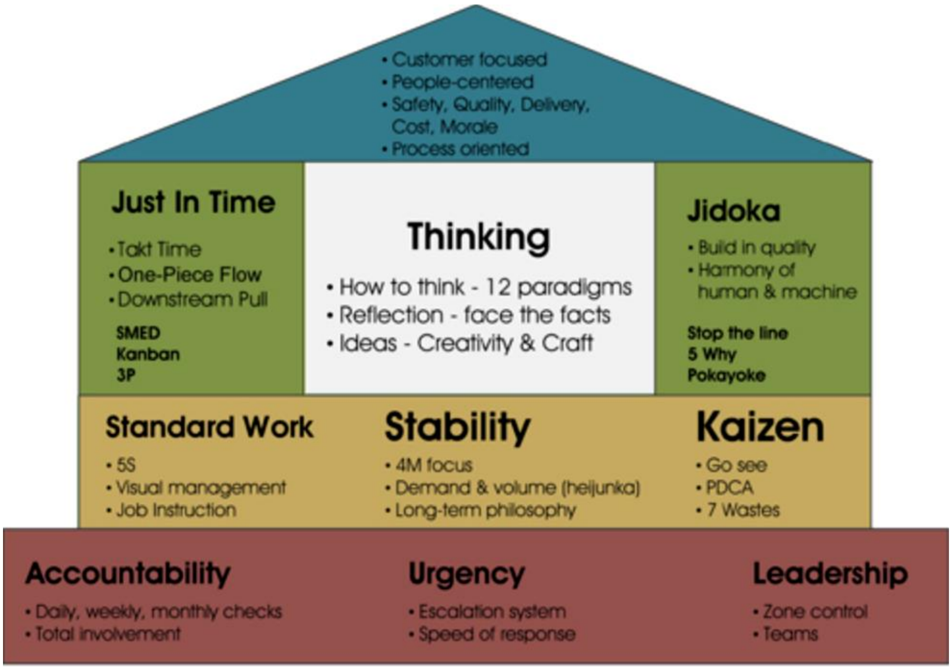

Figure 1.3 General architecture of TPS - Lean Production.

After the solving of some organizational issues for own assembly plant there was a question about procurement [21]. In the company of Toyota the building a system mutually interested manufacturers of component parts began, which were conditionally divided into levels. The first level was the suppliers, which produced large blocks of the car and met the requirements of Toyota for the price, quality and technical parameters in the best way. As each was responsible for the release of his block, between them there was no competition and they can freely share with each other new solutions, both technical and organizational.

The final step was the creation of a distribution system. Unlike mass production with its "push" system of production, it was about building what the experts call a "pull" system of production. In this system the signal "produce" comes from the end of the chain, interacting with the customer, i.e. the sales department and dealers.

The construction of all circuits and its debugging took about 20 years. By the mid-1960s a new production system TPS was introduced at all plants and offices of Toyota. In 1965 Toyota won for its system TPS the Edward Deming prize. By the mid-1970s, the TPS system was introduced in component suppliers. One example is the Turkish plant TMMT (Toyota Motor Manufacturing Turkey) in Adapazari beneath the city of Istanbul, which works since 1994. Now the full production cycle employs 3,600 people, on learning which Toyota spent a record for Turkey $10 million, i.e. an average of $2800 per worker [24].

The TPS system gained prominence after the oil crises (1973-1979), when Toyota showed in the financial statements net profit, unlike most companies in the international car market and the USA market was invaded by Japanese cars (83% of Toyota) and in a few years took up to 30% of the domestic car market. American automakers began to explore the reasons behind such developments with the aim of finding a way out of this situation. The special fund was established and organized for research project with a budget of more than $5 million in the framework of the International program "Cars" by the Massachusetts Institute of technology, the head of which was James Womac, founder and President of the Lean Enterprise Institute [25].

Currently, there is a widespread use of elements of LP in the world. According to experts of the company Orgprom today the 80-90 % of Japanese enterprises have introduced the lean production system, in the USA such firms are two-thirds, in the EU more than half. Russia on this background looks quite modest: 5-10 % of companies use LP. Moreover, the General Director of "Center for Orgprom" Alexey Baranov claims that in 2009 "from the Russian companies, 68 % knew nothing about Lean, only 2 % are familiar with Lean and theory, and in practice"[18].

The main trend is its final transition to managing the entire lifecycle of a product with the active use of professional software. Programs of online management resources and commodity flows, virtual mathematical models of production processes, remote control systems for equipment, etc. implemented. For example, the tool Kanban, as one of the main elements of the LP, is a card that workers at the enterprise pass each other, with the aim of informing about the need of any particular commodity. The process is now automated by using the software. Moreover, to that date, the less corporate vertical integration is becoming, and relationships with suppliers that underlie the concept of LP are becoming increasingly important. In turn, the software is most suitable tool to support planning and execution across the supply chain [28].

Specific examples development trends within the production system LP justify its use and effectiveness in the implementation:

- The implementation of systems and simultaneous optimization of production planning, combined with the "pull" lean production methods, ensures optimum loading of equipment, subject to production constraints and minimizes the excess volume of production accounting.

- Usage within LP systems the MES systems and bar-coding integrated with APS and ERP systems, allows real-time to consider the state of the production process (production, spoilage, downtime, etc.) and to take into account the data obtained in the calculation of production plans and the analysis of deviations in production processes.

- More common system of production planning MRP II, as well as systems of simultaneous optimization and scheduling APS, allowing using production capacity given the external demand with minimal inventory and reduced lead times.
- In the implementation of LP tools, the emphasis shifts to more simple and obvious "5S" and "visual management" to "human factor": developing an organizational culture of continuous improvement, search and detection of losses; creating Kaizen teams; implementing and improving the effectiveness of supply systems and implementation of proposals.

1.4.3 Basic elements of lean production system

The domestic and foreign scientific literature reflects different perspectives on the concept of lean production, as well as mechanisms and instruments of implementation of this concept in various sectors of the economy, including the industry. Most authors characterize this concept primarily from the perspective of limiting losses in the production process: the concept of lean production saves the labor of workers at the time due to elimination of losses, the use of advanced and most effective methods of labor. Close in meaning definition is given by J. Womack [26], believing that lean is a management concept, which is based on the principle of universal reduction of possible losses, involving in process of optimization of business of each employee.

Specialists define the lean manufacturing as a set of managerial and production technologies which include: VSM, "Kanban", "5S", the system JIT, TPM system and system of "Kaizen".

Similarly, the company Thomas Group uses the concept of lean production as a system of value creation - what the consumer is willing to pay. All other aspects of the production process are considered as useless and unnecessary. Hence, lean manufacturing is a tool designed to focus resources and capacity on the production of products with added value, while eliminating foods that do not have this value [28].

Interesting point of view was expressed by K. Novikov, considering lean production as a new industrial relations system, an evolutionary method which replaced the old system of industrial relations in the era of mass production, completely corresponding to the modern level of development of productive forces of human civilization of the 21st century [29].

As we can see, now the certain consensus about the content of the concept of lean production has not developed. Some authors define it as a system of losses elimination; the other is as a system of value creation for the consumer, and others - as a kind of industrial relations system, adequate to the achieved level of development of the productive forces of society. Each point of view reflects one or another important aspect of the analysis.

Whatever the point of view was not taken by us as the basis, the main point of implementing the concept of lean manufacturing is the identification and classification of losses associated with inefficiency of production and commercial activity of the enterprise. So it has allocated 7 types of losses, which are presented in table 3.

Table 1.3 The main types of losses in lean manufacturing [19].

Losses are fixed in lean manufacturing		
Common	Based on the human factor	Taking into account technological factors
– losses from overproduction – losses due to waiting – losses due to unnecessary transportation – losses due to unnecessary processing steps – losses due to excess inventory – losses due to unnecessary movements – losses due to the release of defective products	– uneven performance – fluctuating schedule due to production system – uneven pace of works	– overloading of equipment – overloading of operators when they work with greater speed or tempo and with great efforts for a long period of time compared to estimated load

Point of view of Taichi Ohno on the classification of the losses was shared by other researchers experience of Toyota company: J. Liker, J. Womack and D. Jones, but they felt the need to highlight the eighth type of loss: unrealized creative potential of employees, including ideas, skills, improvements and learning experiences and etc. [30]

The increasing role of value for the consumer in improving the efficiency of production has altered the perception of the objectives of lean manufacturing. The main objectives are defined as:

1. Organization of a continuous production process by determining the value of products.
2. Products are out to the buyer according to specific requirements of quantity and quality.
3. Production according to highest quality standards that exist at this moment.
4. Harmonization of the demand for the product between the market and production.
5. Formation of the parity interactions of producers, suppliers and buyers.

Changes in the management idea and the objectives of lean production could not affect the choice of instruments of implementation of the concept.

During the review of the Lean concept, the view has formed that this concept is a set of elements, which a particular approach, method or tool, revealing its contents.

1.4.3.1 Kaizen

Of course, the central role in the system of lean production tools has the Kaizen, the greatest degree reflects the philosophy of this concept of governance: continuous improvement of production processes and management, and all aspects of life of the employees. "Kaizen" in business is continuous improvement, ranging from the workplace to executive leadership. The main objective of the Kaizen is the production without losses.

In the context of the system of Kaizen is considered as a rule, two key functions of management: the providing of dynamics - actions according to the criteria of adaptability, organization and application of standards through training and discipline, and improvement - activities aimed at improving of the existing standards. While improvements are continuous and gradual in nature, and though not distinguished by magnitude, reduce risks and gain significant long-term benefits.

Extremely important is also that the heart of the system Kaizen is the format of thinking, process of nature, without which it is impossible to improve the result. In turn, the work with processes is carried out in the framework, continuously renewable cycles of SDCA (standardize and maintain processes) and PDCA (plan-do-check-act). Continuity of cycles is explained by the need to improve any processes even when actions for improvement.

Any work from the viewpoint of Kaizen, is a chain of processes, each with its suppliers and customers. In this case, the transfer of material resources in the chain of processes between suppliers and buyers has interconnections and interdependencies that provide direct control over the quality and timeliness of delivery of resources and information that will result in the production of specified high quality that satisfies the end user.

An integral part of person-centered system of Kaizen is to encourage the participation of all employees in the process improvement activities of the company. Its main objective is the formation of the consciousness of employees, is built on a commitment to the ideals of the company through the Kaizen philosophy, and unlike the most popular in many countries of Europe and the United States approaches the classical school of management.

The study of the system of Kaizen allows us to formulate the fundamental principles of its functioning, including:

– focus on customer requests;

– the continuity and the gradualness of change in all spheres of activity (procurement, production, marketing, interpersonal relationships);

– acknowledgement of problems, the promotion of openness;

– low degree of isolation between departments and work places in comparison with western companies;

– create cross-functional working teams and associated quality circles;

– management of improvement type project management on the basis of allocation of cross-functional teams;

– the formation of a "supportive relationship" where the organization is important not only with financial results, but with the involvement of people in its activities and a good relationship between them;

– the development of self-discipline, the ability to control himself and respect himself and other employees, and the organization as a whole.

– awareness of each employee about the changes in the activities of the company;

– delegation of authority for each employee in full volume, which is possible by the possession of diverse skills and abilities.

Kaizen continues to develop rapidly. The important improvements made by such companies as Matsushita, Canon, Nissan, Honda, Komatsu, Ricoh, and many others. Its success has allowed M. Imai in 1985 to found the Institute of Kaizen (KAIZEN Institute), which is now an international consulting company with offices in all regions of the world [31].

1.4.3.2 Just-in-Time

One of the most important instruments of implementation of the modern concept of lean manufacturing is the system of "just in time". The basic idea of the JIT system is manifested in the use of logistic tools, as a method of control of material flows when the components of these flows in the form of raw materials, individual components and links of products will be supplied in the production process according to the technologies of production planning, strictly observing the quantity, quality and time parameters.

The terms of the implementation of the JIT system are as follows:

1. Placing an order for the products should be regulated by parameters of production capacity.
2. Stocks of material resources must be optimal in accordance with the progress of the production process.
3. Compliance with the production cycle should characterize the organization of production.
4. The mentality of all employees is subject to change.

According to B.A. Anikin [32], the basic components of the principle of JIT are:

– balance of production;

– system Kanban as the driving system;

– production of optimal quantities of necessary quality control with the minimum cost and others.

1.4.3.3 Kanban and Total quality control

The principle of "just in time" also allows you to implement the system of organization of production and supply Kanban, developed by T. Ohno for Toyota. In this case, once optimized supply system of material resources in production remains a long time in the enterprise. It is clear that the introduction of the Kanban system requires a restructuring of the warehouses: the warehouse should be one, as close to the conveyor; it is formed according to the principle of self-service store - the transporter moves through the warehouse and collects itself into the cart the necessary parts and assembly units; parts and accessories in the right quantity should be produced for transporter storekeeper; transfer of parts and components from a transporter operator should not to be recalculated on the basis of trust; for rational use of working time it is necessary to simplify the workflow system (such as the usage of bar coding).

The system Kanban is a system of iterated interaction of the regulations of the total quality control (TQC) in all stages of production process [32].

In general the problem of quality control has received considerable attention in the concept of lean production and as the instruments for its implementation there is the Total quality control system (TQC), which is a complex of "means of economical production of goods or services that satisfy customer requirements". The main focus in this system is paid to quality control using statistical methods.

Subsequently TQC developed into a system of "total quality management" (TQM), covering all aspects of management. In TQC/TQM it is necessary to identify key processes, to carry out continuous monitoring during the operation. Moreover, the role of management is to plan and verify the process, not the result, and also in the improving of process, not to criticize the basis of its result.

The natural supplement of quality control systems is the system of QFD (Quality Function Deployment) [33]: structuring (deployment) of quality function that contributes to the transformation of customer requirements to consumer properties of products, placing the priorities for the manufactured products or performed work. The basis of QFD is a scheme that reflected the information component of a manufactured product and make decisions.

1.4.3.4 5S system

Another core tool of lean production is the system of the workplace rationalization (5S), involving the following elements:

– "sort" (seiri), i.e. the distribution of objects of labor in the workplace by the degree of suitability;

– "the maintenance of order or tidiness" (seiton);
– "cleaning" (seiso);
– "standardization" (seiketsu);
– "improvement and development of production of culture" (shitsuke).

System 5S, as with other elements of the concept of lean manufacturing requires continuous improvements. The identification of shortcomings to be overcome, is carried out during continuous compliance with the rules and standards of organizational behavior of workers in places of production, and audits to assess the effectiveness of the implementation of 5S [34].

1.4.3.5 SMED system

A significant role in saving time and increasing productivity plays the system of rapid changeover/re-tool of equipment (SMED - single minute exchange of dies), which is a set of special theoretical and practical methods. Initially this system was developed to optimize the operation replacement of stamps, but it turned out that the principles of "quick changeover" can be applied to all production stages. The founder of the system was Shigeo Shingo, who in the course of studying the operations of changeover in many plants discovered two important things:

First, the surgical repair during the manufacturing process as well as on the planned dates.

Secondly, the transformation of the largest possible number of internal operations in external changeover allows reducing the time of changeover [35].

One of the first systems SMED was implemented by Toyota, whose experience showed that thanks to the SMED the changeover time of machines was reduced from four hours to three minutes.

More and more manufacturing companies in Japan and abroad are used in the practice of management systems the total productive maintenance (TPM), assuming the main task is to implement a preventative maintenance for the future continued operation of the equipment.

1.4.3.6 OEE system

Lean production cannot be done without efficient operation of the equipment, which is responsible by the OEE system (Overall Equipment Effectiveness).

OEE is a very popular system considering the influence of different manufacturing variables on the effectiveness of the implementation of the production process using modern production technologies.

For the performance of the equipment meets the system automation, also known as automation with elements of intelligence, which does not allow defective products in a production task.

The special system that ensures the reliability of the production process, is the system of protection against errors (not competence). It is the protection of using subjects (especially technics), software from obviously incorrect human actions, both when using and during maintenance or manufacturing. The concept was developed, and then refined by Shigeo Shingo [36].

1.4.4 Modern problems of development of lean production in Russia

The concept of lean production, which has the foreign experience, appeared in Russia only after the collapse of the USSR, namely in the early 2000-ies. At the same time, due to customer requirements and competitive advantage on international markets, the mass introduction of ISO quality standards and its Russified version of the standard (based on ISO:9000) began.

In particular, the desire to integrate into the international chains is reflected in the growth of additional volumes of the Russian industry certification providers (for example, JSC "Helicopters of Russia") according to the quality requirements of the global OEM. However, due to a small time period of adoption of foreign experience, QMS and LP compliance in the logic of the market are case studies of individual companies and not the elements of state industrial policy. Companies that implement this paradigm are in the situation of entering into the global markets (automotive, shipbuilding, petrochemical, metallurgy, military industry).

The most known in Russia examples of companies with its production system based on the concept of LP are: GAZ Group, Sberbank, Irkut, Rosatom, KAMAZ, RUSAL, EvrazHolding, EuroChem, VSMPO-AVISMA, KUMZ, Sollers (ex. Severstal-auto).

As noted by the majority of heads of the enterprises, the main obstacle for the implementation of LP is the reluctance of staff, primarily factory workers, to learn and to apply elements of LP. The question arises from the personnel motivation, which is usually solves by methods, preserved from Soviet times: piecework wage system; the motivation of production managers on the implementation of the plan in time or volume of production (in rubles), delivered to the warehouse; the punishment to the ordinary staff for the initiatives; "identifying" the actual situation and hidden reserves of the enterprise, when, on the contrary, should be encouraged. However, it is much worse when the company's management not involved 100 % and only "in words" ready to learn and implement LP. This perspective is evident in the weak of organizational and financial support of initiatives to improve the production process, lengthy and ineffective process of decision making, waiting for too quick results without serious efforts, ending by pointing ostentatious external order or repairing the equipment.

Another problem is misunderstanding of the whole concept of LP that takes more than just a set of tools to reduce the cost of production, and is the global approach to manage the enterprise, to reduce unnecessary losses and increase quality. The reason for this is insufficient information base to misinterpretation, the original of which can come only from foreign authors describing their experience in the context of a different economy. As a result a situation arises, especially in large industrial complexes, when the management is not solved to global changes, and to be content with separate LP solutions.

Systematization of quite deep and extensive modern problems of production management in Russia has allowed generating a limited list of the main reasons for the inefficiency of Russian companies. This list contains only the factors relevant to the quality management of products and services related to low productivity:

- low moral level and cynicism of a large part of the workers.
- the gap of understanding between management, employees and workers;
- loss of a sense of fairness and faith;
- inadequate by market the structure of industrial enterprises, hyperhierarchy, the concentration of authority at top management levels;
- inefficient management:
- lack of control from the owners (shareholders), low culture of management (repressive management), lack of knowledge and experience of management in market conditions, lack of effective mechanisms for the nomination and selection of senior managers;
- undeveloped marketing;
- misunderstanding of the essence of competition and the role of quality in competition;
- long terms of development of new products;
- misunderstanding of the role of education and training;
- misunderstanding of the role of information and data;
- anti-intellectual and anti-innovation industry;
- high level of conflict, intrigue;
- pagan mentality (heroes, enemies, isolation and secrecy, the hostility to dissent, teenage syndrome, inconsistent and unsystematic).

The situation for corporations and businesses, slowly included in the process of development of new technologies for the management of the PS, will continue to remain the same as in the second half of the last century, when the gap means a threat of existence in the market conditions of global competition.

The last on the queue, but not on the importance of the specifics of the Russian situation is as follows. If the existing in Russian enterprises technological processes and manufactured products apply the most flawless production techniques, implement them to the fullest extent possible and to achieve all the advertised representative results, it is difficult to assume that this will lead to their inclusion in the pool of world leaders in the international arena. Many existing technological solutions irreversibly archaic, and at the heart of their pack should lie with modern technical solutions. Therefore, we need an elaborate and ongoing process of technological and marketing audit prior to the adoption of the decision to introduce organizational and management improvements. After this, absolutely necessary, stage the significant effect can be fully expected from improvement of production management systems.

1.5 Lean construction as concept of lean production in construction industry.

The lean production philosophy that had contributed to the manufacturing industry took the attention of the people in the construction industry as well. Especially, since the early 1990s, a “lean construction” concept has been tried to be created and promoted by means of institutes, governmental reports, construction management scholars, some occupational organizations and so on. The most notable of the organizations that have been working solely for the development of the lean thinking in the construction industry are the Lean Construction Institute (LCI) of the US and the International Group for Lean Construction (IGLC). Louri Koskela was the first to introduce the lean movement in manufacturing to the construction industry. He hosted the first conference of the IGCL in Espoo, Finland in 1993. A group of researchers at the conference adopted the name “lean construction”.

The LCI, founded in 1997, has been publishing an international refereed journal devoted to lean construction practice and research since 2004. The journal is called the Lean Construction Journal (LCJ). The journal includes papers, reports and book reviews from industry practitioners and academia. The IGLC has been organizing yearly academic conferences, hosted by local universities from all over the world, since 1993. The 15th conference will be held in-between the 17th and the 22nd of July, 2007 in East Lansing, Michigan, U. S.

1.5.1 Theoretical background of concept

The lean construction efforts are aimed at contributing to the construction industry via the lean motives and methodologies. This is not to say the direct copying of the applications from the manufacturing industry though. It would not be feasible due to the differences between the industries. Ballard and Howell [37] explained the theoretical background of lean construction as follows: “We understand projects to be temporary production systems linked to multiple, enduring production systems from which the project is supplied materials, information and resources.”

Koskela [38], underlining the fundamental goals of a production system as maximizing value, minimizing losses and delivering the product, explained the framework in which a production system is applied to construction. This pyramidal structure is made of, from bottom to top, methodologies/tools, concepts and principles.

The Lean Construction Institute in 2004 defined the term lean construction as [39]:

Lean Construction is a production management-based approach to project delivery – a new way to design and build capital facilities. Lean production management has caused a revolution in manufacturing design, supply and assembly. Applied to construction, Lean changes the way work is done throughout the delivery process. Lean Construction extends from the objectives of a lean production system - maximize value and minimize losses – to specific techniques and applies them in a new project delivery process.

Lean construction can be defined over a new production management based project delivery system that challenges the trade-off between time, cost and quality. Up to now, there are two important application channels of lean construction that have been utilized by companies around the world. One of them is a new project delivery system developed by the LCI to design and build capital facilities. This delivery system is called the Lean Project Delivery System (LPDS). Howard and Ballard's Last Planner Production Control System is the other important application of the lean construction concepts and methodologies. Today, the researchers who are interested in lean construction have increasingly brought its concepts, principles and methodologies to the construction management departments of the universities and the construction industry of the U.K, the U.S., Finland, Denmark, Singapore, Korea, Australia, Brazil, Chile, Peru, Ecuador and Venezuela.

According to Howell [40], managing construction under lean is different from the current practice because it;

- has a clear set of objectives for the delivery process.
- is aimed at maximizing performance for the customer at the
- project level.
- designs concurrently product and process.
- applies production control throughout the life of the project.

As the primary goal of the lean production system is to enable continuous flow of value creating activities with eliminating non value adding identities (losses), it would be appropriate to explain the main concept of lean construction from the perspective of construction losses.

1.5.2 Construction's production value stream

In order to understand where value is added in a production process, one must first learn the steps or phases a product goes through to reach a finished state. Mapping out all of the steps of a production process allows one to focus on eliminating steps that are not required. Relating this to the construction industry, value stream mapping allows each party involved in the construction process to understand where value is generated. Tapping and Luyster [41] defined a value stream as "everything - including non-value adding activities - that makes the transformation possible." For construction, a transformation is the process of converting raw materials and labor into a finished product (building, bridge, road, etc.). In other words, the value stream represents the channels that material, equipment and workers move through to produce the finished product. Fundamentally, value stream mapping allows one to differentiate between **value adding (VA), non-value adding but required (NVAR)**, and pure **non-value adding (NVA) actions** in a construction process. To highlight areas of losses, work must be defined as VA, NVAR or NVA.

In general terms, inefficiencies are classified as one of three types: inefficiency due to losses (NVA activities), inefficiency due to work that does not directly contribute value (NVAR activities) and inefficiency due to poorly designed work processes (ineffective VA activities) [42]:

1) **VA Definition**. This definition excludes common construction work such as material handling, inspection or temporary structures. Another less precise way of thinking about VA activities is that they are those activities that the client is actually interested in purchasing. For example, one could say that the client is interested in purchasing a steam line for a power plant, but not the temporary support or testing activities that are needed to produce a finished pipeline. The VA action in this process is the physical welding of the pipe spools into their final position (as an example). This strict definition for VA activities has been adopted in this report to provide pinpoint focus on the customer value equation.

2) **NVAR Definition.** This category can be separated into three subcategories that are required for construction operations, yet have no permanent effect on the finished product. These subcategories include material positioning, in-process inspection and temporary work and support activities (TWSA):

- **Material Positioning**. This subcategory includes all activities that involve the movement of a structural steel member, concrete member or pipe spool, or other types of details into its final position. For example, flying a column into its final position in the structure is a required action, but it does not actually change the physical characteristic of the finished product. The structure is physically changed only when bolts are tightened around the baseplate. (Note: one must be careful when labeling an activity as material positioning. Material positioning does not include moving a steel member from the lay-down yard to a staging area. This action should be labeled as "transport," which is an NVA activity.)

- **In-Process Inspections**. This subcategory includes actions such as the leveling, plumbing and/or final field measurements of installed material. It also includes in-process or production inspections that are required in accordance with individual project specifications. This subcategory accounts for current construction requirements of inspecting ongoing and finished products to ensure quality to the customer. For example, continually plumbing and leveling the structure as steel members are erected would fall under this subcategory.

- **Temporary Work and Support Activities (TWSA).** This subcategory includes all actions that must occur while activity-specific equipment is being used to erect and secure a member into its final position. Attaching or adjusting rigging, setting up temporary supports or wrapping a steel member with the hoist line to lift it into its final position would fall under the TWSA subcategory. It also includes those actions needed to ensure that equipment in use during the activity continues to work in the most optimal manner, such as replacing welding rods when they are too short or refueling a scissors lift with gas.

3) **NVA (Losses Definitions).** Interest in lean construction has increased academic and industry interest in loss reduction in construction. Loss reduction and elimination is one of the core principles of lean production, and although it is not the only benefit of lean implementation, it does provide a logical starting point. The potential cost and time savings achieved by eliminating or reducing NVA activities are significant. To develop the construction production value stream, Ohno's concepts of production should be modified to more closely conform with construction production as follows:

- **Overproduction.** Products being produced in excess quantities or products being made before customers need them. This implies that production on a late-start schedule is the ideal. Indeed, from the client's viewpoint, if a late-start schedule could be guaranteed in the face of weather, supplier schedules and other uncertainties, a late-start schedule would minimize WIP and cash flow requirements.

- **Waiting.** Products, equipment or people that must wait because of poor scheduling, production control or unbalanced crew size. Changing work tasks in the course of a typical construction sequence make establishing a proper crew composition difficult.

- **Transport.** Unnecessary movement of materials. Material handling and transport necessitated by the relocation of work are unavoidable in construction. This type of losses includes excessive, multiple and suboptimal movements of material.

- **Extra Processing.** Rework, rehandling or storage that is caused by defects in design, fabrication or construction activities. This type of losses occurs within crews.

- **Inventory.** Extra raw or fabricated materials, excess construction equipment.
- **Motion.** Extra movement by employees or movement of equipment caused by inefficient layout, remote lay-down areas or improper work sequences.
- **Defects.** Errors or deficiencies in finished products that require a crew to return to a work item or require a follow-up crew to perform added work (punch list items). This type of losses occurs between crews.

Table 1.4 compares the seven major classifications of losses in both manufacturing and construction contexts.

Table 1.4 Comparison of Lean Production to Lean Construction Losses.

Type of loss	Manufacturing	Construction
1. Overproduction	Production of too many units or pails due to push nature of manufacturing.	Overbuilding a particular aspect of a project, either because it was overengineered or a process was started before it was really needed.
2. Waiting	Time spent waiting for the next batch of parts to arrive from the previous conversion process. Time spent waiting for a machine to finish.	Time spent waiting for other work crews to finish then particular conversion process so that the next conversion process may begin. Tune spent waiting on crew members of a specific team. Tune spent waiting for parts or instructions.
3. Transport	Wasted effort to transport materials, pails or finished goods into or out of storage between processes.	Wasted effort to transport building components or tools into or out of job trailers or storage between processes.
4. Extra Processing (Operations)	Doing more work than is required.	Losses associated with rework, rehandling or storage caused by defects in design, fabrication or construction activities.
5. Inventory	Maintaining excess inventory of raw materials, parts in process or finished goods.	Maintaining excess inventory of construction components, equipment or tools.
6. Motion	Losses associated with unnecessary worker/equipment movement between work stations.	Losses associated with unnecessary worker/equipment movement around the construction site.
7. Defects	Repair or rework.	Deficiencies in the finished product that require additional work or rework to correct punch list items.

There are two aspects one must investigate to identify losses on a construction site. The first involves the material required to construct a facility. The second entails the multiple activities required for the installation of material into its final position. Each aspect of the value stream occurs on a different time scale. The material value stream includes all materials that are delivered to the site in a “post” manufactured state, such as structural columns or the bolts required to secure that column into place. Piping material might be a pipe spool or a welding rod. In short, materials include everything that will remain with the facility after the construction phase is completed.

The labor aspect of the value stream encompasses all labor required to erect and install material into its final position. Closely associated with labor is construction equipment. For every piece of equipment on a construction site, there is a human operator. Workers along with machines will bolt, frame and weld components into their final position. Workers, aided by machines, add value to the final product. How much value they are capable of adding depends upon management, work processes, information flow and the skill of the crews.

According to the definitions of losses, waiting, transport, extra processing and motion are most closely related to the actual work process (i.e., labor and equipment). Overproduction, inventory and defects are associated with the material supply chain and production scheduling functions. The observation periods for each case study were brief and focused, which limited the team's ability to quantify losses associated with overproduction, inventory and defects in specific detail.

Review of value stream mapping in manufacturing is a useful starting point for developing value stream mapping in construction. In a typical plant, the material would flow in one side and proceed through the various processes (stamping presses, grinders, paint shops, etc.) to produce the finished product required by the customer. Viewed in its entirety, this model represents a first in first out (FIFO) process. While this idea does accommodate many manufacturing processes, it does not relate as well to a typical construction jobsite. In the Duggan and Liker [43] mixed model production, two new concepts are found that aid in the development and implementation of the value stream on a construction site. The first concept requires one to look at activities in a value stream not at the individual level, but rather at the value stream as a mix of activity groups labeled by Duggan as "product families." The second concept builds on the first by requiring one to focus on the "total" time associated with the product families, rather than on the individual times required for each product. For the purpose of this study, "products" will be considered to be "processes." In other words, the construction value stream at the topmost level will be represented through a series of process families. Duggan and Liker define product family as "a group of products that pass through similar processes or equipment and have similar work content." For construction, it can be said that a process family is a group of processes that require similar crew members or equipment and have similar work content. For example, a process family incorporates all subtasks required to take a structural/piping member from the material lay-down yard on a site, through its final preparation stages and into its final position in the facility.

A construction value stream cannot be represented like a manufacturing value stream. The major difference between the two systems occurs at the project level when material reaches the site. Material on the construction site does not flow past the worker, rather the worker must move (flow) to the material. In manufacturing, the "work station," where a transformation of the final product occurs, never has to move in the "ideal" manufacturing line, yet for a construction process the "work station" continually moves around the jobsite as work progress. Furthermore, the conventional model assumes a linear relationship between its elements, creating what is known as a FIFO process. In construction, several tasks in an activity can and/or must occur simultaneously. The simple manufacturing value stream model does not easily allow for parallel activities.

According to the aim of reducing the losses time and losses processes in construction processes, many investigations and researches have been done. These studies today have provided the conclusions which are basic principles and subprinciples of lean construction process. All of them are required when the customer wants to improve its production to the lean level, reduce construction time limits and increase productivity. We can briefly provide the main of them [44]:

1. **Customer focus** (meet the requirements of the customer, define value from the viewpoint of the customer, use flexible resources and adaptive planning, cross train crew members to provide production flexibility and etc.).

2. **Culture and people** (provide training at every level, encourage employee empowerment, ensure management commitment and etc.).

3. **Workplace organization/standardization** (encourage workplace organization and use 5s's, implement error-proofing devices, provide visual management devices, create defined work processes and etc.).

4. **Losses elimination (aspect 1: process optimization)** (minimize double handling and worker and equipment movement, balance crews, synchronize flows, remove material constraints, use kitting, reduce input variation and etc.).

5. **Losses elimination (aspect 2: supply chain)** (institute just-in-time (JIT) delivery).

6. **Losses elimination (aspect 3: production scheduling)** (use production planning and detailed crew instructions, predictable task times, implement last planner, reliable production scheduling, short interval schedules, use small batch sizes, minimize WIP and etc.).

7. **Losses elimination (aspect 4: product optimization)** (reduce the parts count, use standardized parts, use preproduction engineering and constructability analysis and etc.).

8. **Continuous improvement and built-in quality** (prepare for organizational learning and root cause analysis, develop and use metrics to measure performance, use stretch targets and etc.).

1.5.3 Applying the lean principles to construction industry

Observations of early adopters of lean principles suggest that there is no one prescribed way to become lean. Each early adopter in this study used a different starting point, and each progressed along the path at a different rate. However, based on the totality of the research, the evidence suggests that an engineering, procurement and construction (EPC) company that wants to start a lean process should start with its field operations [44,45]:

- **Identify losses in field operations.** There is historical precedent for starting with production activities; Toyota started its lean work by concentrating on its shop floor. Starting lean activities with field operations also has a good rational basis because value is added (from the customer's viewpoint) during the construction process. Finally, the strict value definition that was used for the field studies provides a lens through which one can start to identify losses in the field processes.
- **Drive out the losses.** After a type of losses has been identified, the next step is to drive it out. A given type of losses (e.g., rework) might have one or several different causes. To drive out the losses, the root cause must be understood. If the root cause is worker training, design errors or tolerance errors from an upstream crew, appropriate steps should be taken to eliminate or reduce the losses on future work. The process of driving out losses leads naturally to many of the other lean principles such as constructability reviews and Just-In-Time (JIT) scheduling. The EPC contractor should start by concentrating on the non-value adding (NVA) (i.e., pure losses) activities. With construction averaging 50 percent NVA activities, there are ample opportunities to reduce these losses before turning to the non-value adding but required (NVAR) or VA activities.
- **Standardize the workplace.** After lean practices have been identified, they should be formalized as company standards. Developing standard practices for construction processes reduces the information burden on the crew members. One early adopter contractor that was studied created identical gang boxes so that the crews knew what tools were commonly available and where to find them.
- **Develop a lean culture.** Depending upon how much of the value stream a company controls (i.e., construction only or EPC), the processes should be formalized within the organization and with strategic partners, subcontractors and suppliers. One early contractor spent considerable effort training its entire staff and most of its supplier and subcontractor staffs. Other lean early adopters trained key partners on a project-by-project basis. A key difference between manufacturing and construction is the rapidity with which construction partnerships and alliances change with time and location.
- **Get the client involved with the lean transformation.** After a company has experience with lean principles, its clients should be educated about the benefits, costs and risks of going lean. The company should start defining value from the customer's viewpoint. In some cases, the impetus for going lean has actually originated with a client organization that had experience with the successes of lean manufacturing.
- **Continuously improve.** With all of the above steps under way, a company can start to improve on improvements. Everyone involved with the project should begin to understand their

responsibility for reducing losses and improving quality. Continuous improvement requires that lean practices and lean culture be the common basis for doing business.

1.5.4 Reasons to apply lean principles in construction industry

Investigations of the construction production process indicated that construction activities are typically only 10 percent value adding (VA). If a contractor could improve the VA portion to just 15 or 20 percent, the lean contractor would have a significant competitive advantage. However, when one looks at construction operations with “lean eyes,” little standardization or preplanning is evident. In fact, the construction process includes little that manufacturing engineers would recognize as production planning or production engineering. Often, the design of construction operations is consigned to the individual crews. While the crew members often have the skill and experience to design specific construction operations, typically they do not have the training or the mind-set that will lead to a lean operation.

Some will contend that construction is too different from manufacturing to expect “manufacturing-like” lean results. While acknowledging that manufacturing and construction operate in different environments and that lean in construction will be more difficult than lean in manufacturing, interviews with early adopters of lean construction principles cited increased quality, increased safety, better schedule performance and decreased costs as some of the benefits of starting the lean journey [45].

1.6 Application of risk management methodology in the implementation process of lean construction

The presence of production losses in the traditional approach to design and construction is everywhere, therefore, the interest of all project participants should be while the performance improving.

However, contractors do not always share these priorities, and often harsh conditions of their contracts do not motivate them. The existing methods of performance enhancement that are written in volumes of scientific papers provide their effectiveness only locally, on certain types of work, and often are used to meet the needs of the administration willing of the supervisory authorities requirements, or in the case of various certification activities of the QMS, but not correct the problem.

One of the key obstacles in the implementation of lean construction is the axiom adoption of the current production workers working "on the line" that all construction projects are different and the same approach is not applicable on different objects. However, the practice of leading construction firms shows that the introduction of lean construction tools can reduce losses and costs, improve the productivity and quality of work at the building site. The methodology, Toyoda used in the automotive industry, can and should be applied in construction, but with the condition of availability and proper use of critical technologies (techniques, the mastery of which will give a significant increasing in productivity and quality) which are available today.

The production of construction works indicates the presence of factors that hinder the implementation of the concept. First of all, the contract relations focus on the goods and services, but not on the behavior and actions of participants. The second group of problems lies in the apparent effectiveness of the same tools usage for different functions. For example, can the work is fully coordinated within their schedule, which provided updated projections, limited requirements, and can be divided into smaller plans that are relevant to specific activities. The third group of problems is connected with the necessity of simultaneous arrivals of all types of resources (human, technical, material), adherence to acceptable weather conditions and the completion of the previous phases of work, which increases the variability of processes and outcomes as for timing and cost. The simultaneous execution of works by several contractors also contributes to the extension of the interference spectrum.

Lean construction focuses on reducing all kinds of losses; some of them are obvious and foreseeable to the greatest extent, while others are hidden. Identification of all types of losses at the construction site should be the starting stage in the enterprise program of concept implementation. The usage of risk analysis tools helps to identify such types of losses: from losses of materials and movements to resource losses, and as is known, processes that include useless elements and procedures, wasted resources are expensive and, therefore, increase the work costs for the contractor, reducing its operating profit.

The reduction of losses in the construction industry will increase the predictability of the process for shorter period of time. For losses identifying in the specific process, it is first necessary to have precisely data of current processes. Therefore, documenting is required for each process under the principle "as is does" before you make decisions for changes. For reproducing the accurate process display, it is advisable to start the documentation from the final stage and gradually moving to the starting phase. This approach allows capturing the whole process in detail without risk to miss any components. After the process was documented, the map of flow is constructed, which reflects the interaction of different process participants.

The next step after creating the map is changing of processes to "as right" for further losses minimization. Each step should be evaluated in terms of the nature and degree of influence on the process: value adding, contributes to the creation of value, does not value adding (see paragraph 1.5). The first components are defined as critical because they create the value of proposition; the second should be reviewed and modified, because without them it is impossible to implement steps that create value; the rest should be deleted or decreased, because they do not create any value for consumers and do not contribute to its creation. After categorization of all components, activities that do not create value must be eliminated with the result that the period of task execution is reduced. However, the optimization process this is not completed, because it identifies further opportunities to optimize stages that add value.

The implementation of lean construction supposes the existence of systematic quality control with usage of practical tools. Initially the priority for each method needs to be defined, than the order and calendar plan of the evaluation.

The creation of a process on an "as right" allows you to integrate new technologies and to provide the same customer value but with different time parameters (lower). Process analysis additionally allows identifying the tasks that can be performed simultaneously, rather than sequentially, thereby forming a critical path, covering the entire time cycle of the project. The tasks that are required, but not included in the critical path can be completed in parallel with other tasks, without increasing the total cycle time. Integration methods, including definition of critical path allows to identify and enhance the bottlenecks in such a way that they do not create barriers while performing other tasks. Identification of bottlenecks is the most significant task due to their direct impact on the overall duration of works execution. In most cases, Gant charts help to monitor and control the sequence and duration of works.

However, despite these statements, case studies and elaborations of these issues has not made. The analysis of documents describing the results of embedding lean construction processes shows that in most cases, the identification of losses was not made, but mostly performed the implementation of individual tools such as Last Planner or proactive planning. Working with these tools effective for a short time, because main causes – losses of the production process – are not identified and not removed, this means that the processes themselves remain expensive, despite the alleged «declination» of the works production time.

The identification and elimination (or reduction) of losses at the construction site is the starting point from which the company's transition on rails of the lean production is beginning.

The practice of research and regulatory documents such as [53] contains descriptions of large number of methods applied for the identification of events, risk sources, etc. The greatest distribution in practice was obtained by the methods described below:

1) **Analysis of checklists**. Checklists are lists of events or phenomena that can be compiled on the basis of the information and knowledge gathered in the previous similar projects. At the moment, according to estimates of various experts, the frequency of use or prevalence of these methods is around 65-70%.

2) **Brainstorming**. The purpose of this procedure is to create a detailed list of risks or, in our case, of losses during project implementation (execution of processes). The main principle of this approach is the separation of the ideation process from the subsequent processes of analysis, evaluation and systematization. The essence of the first phase of the work consists in the proposal by the group of experts in a short time (1-2 days) as many ideas as possible to solve any tasks, and in the second stage, the thorough analysis of all put forward ideas. The expert group is formed by experts of knowledge different fields that allow the generation of original ideas, the most extensive consideration of the problem and dissemination of knowledge in different areas of experts. The success of brainstorming depends not only on the qualifications of the experts – largely the results of the experts are determined in the preparatory phase, when experts were informed of the nature of the problem and psychologically adjust them on the constructive work. During the brainstorming each offer of experts is recorded, and then, at the end of work, the thorough analysis of the proposed ideas, arguments and assumptions on the basis of which the management decision will be taken. In the end, the participants of the brainstorm are called the risks considered important for the project, but with the exception of the discussion of nominated risks. Further risks are sorted into categories and specified. The prevalence of this method is up to 75 %.

3) **The method of analogy**. This method uses already accumulated knowledge and plans of other similar projects for event identification. The essence of this method is to analyze all available data relating to the implementation by the firm of similar projects in the past, in order to calculate the probabilities of losses. The greatest application of analogies method can be found for the assessment of losses from recurring projects. The method of analogies most often used in the case where other assessment tools are available. The frequency of usage is up to 65 %.

4) **The Delphi method**. This procedure is similar to brainstorming, except that the participants don't know each other. The Delphi method was developed in 1953 by T. Gordon and O. Helmer. The application of the method is to express a verdict of particular issue by group of independent experts. It is anonymous and at its core is built on the principle of feedback. Modern computer technologies has significantly simplified the procedure of carrying out this examination, however, the principles remain unchanged for centuries. The examination is conducted in the form of anonymous written response for questions on any issue: every expert, isolated from others and often even unaware of the size and composition of the expert group, gives his judgment. Isolation of the expert group members to each other provides anonymity of assessment because the experts in this situation are deprived of the opportunity to discuss answers to the questions. With this separation it is possible to avoid the "trap" of group decision-making and dominance of the views of the leader. Then all the judgments are compiled and processed in such a way as to deprive their individual features of the particular expert style. Thus, the possibility of psychological discomfort is removed that is associated with the personification of

each assessment. The results of processing through managed feedback are reported to each member of the expert group for review, and then experts again answer questions asked earlier. The procedure is repeated until all the experts have not come to a consensus. As practice shows that generally consensus is achieved after 3-4 iterations or expert's opinions are polarized around two opposite perspectives. In both cases the examination is stopped and on its basis the decision is made. The prevalence of this method is estimated to 10-15 %.

5) It may be useful **to apply the provisions of GOST IEC 61160-2006**. In this case, at the initial stage of identification for the basis can be taken or the template, obtained while development of previously completed or similar projects, or loss checklist covering all areas related to the project. This is the process of determining the impact of each loss on the objectives of the project. The results of losses identification are transferred to the register (database).

The key problem of losses management on a construction site is the size of the losses list, obtained at the stage of identification. To manage all identified events is impossible in principle, as it requires large financial and personnel expenses. Therefore, it is necessary to establish the significance of losses for the project and come out of this when determining the losses that can, if they occur, have a significant impact on the fate of project, which is determined by two key consequences of the implementation: the cost change and duration of construction. In order to do this, the following methods are used:

1) **Verbal expert assessment**. This method is defined as taking into account the subjective opinion procedure for determination of quantitative relationships between variables in the case when these ratios cannot be establish from theoretical considerations or on the basis of accumulated statistical data. Therefore, the problem is reduced to a common denominator – to obtain the objective result on the basis of individual subjective opinions of the expert group. This method is most simple but has several disadvantages caused by the excessive influence of psychological factors. Recently, however, ways have been developed through which one can overcome these difficulties by eliminating direct communication of specialists with each other, either by taking into account the qualifications of the experts for weighing their opinions. The applicability of this technique is about 75%.

2) **The Monte Carlo Method**. Modeling by the Monte Carlo method is used in establishing the system changes that result from changes in input data, taking into account their distribution and connection with the output. The analysis can be used to model which defines the relationship between input and output data. The input can be described as random variables with appropriate distributions and their inherent uncertainty. For the assessment triangular or beta distribution is used. The level of this method usage is 50-55%.

3) **Influence diagrams**. This statistical procedure uses for estimating the probability of priori data distribution outcomes. The accuracy of the results depends on the accuracy of prior distribution.

Influence diagrams model causal relationships on the basis of the analysis of probability ratios of input data and results. The usage of this tool is around 35%.

4) **Event tree**. The usage of this method employs inductive conclusions for assessing the probability of events and their transition into other events. The applicability is 15-20%.

5) **FMEA** (**Failure Mode Effect Analysis**). It is method of types and processes and development of failures and consequences identification. There are several different variants of FMEA: FMEA of project (or product) and its components, FMEA of system, FMEA of process (for production and assembly process), FMEA of maintenance and FMEA of software. The percentage of the method realization is 15%.

6) **FTA (Fault Tree Analysis)**. This method uses the identification of system failure (main event) and then there is the definition of ways of its occurrence. These ways are represented graphically in a logical tree diagram. Mostly this technique is used for the studies of ways for reducing or eliminating the potential causes/sources of defects.

The verbal method of expert assessment is the simplest and therefore most commonly used. While execution it produces subjective measurements of objects that are not directly measurable. The most using tools are ranking, paired comparison, direct evaluation and serial comparison.

1) **Ranking** is just the row of allocation units of the statistical population in which variations of the characteristic are in the ascending or descending order. Any ranked row consists of ranking numbers (from 1 to n) and the corresponding option for it. The option number in a ranked row, formed on a substantial basis, usually equal to the number of units in the statistical population.

2) **The pairwise comparison** is the process of establishing preference of objects when comparing of all possible pairs. In contrast to the ranking in which the ordering of all objects the pairwise comparison of objects is a simpler task. While comparing the objects pair there is either a relation of strict order or equivalence relation. By comparing a pair of objects, the expert expresses, that the first object is greater than the second, or, contrary, they are equivalent.

3) **The direct assessment** is the process of assigning alternatives to numeric values in the scale intervals. According to each alternative the subject of management should find a point at a certain interval of the numerical axis. This method is also called the numerical score method of or imputation of scores.

4) **The sequential comparison** is a complex measurement procedure, including ranging, and direct assessment.

When applying the method of expert assessment there is a possibility of the use of intuition, life and professional experience of survey participants. It is the most applicable in risk assessment, because the lack or complete absence of information does not allow using other avenues of research. And the direct estimate allows giving a quantitative equivalent of the importance of each of the investigated object.

Thus, the process of introduction of lean construction system should be implemented by constructing the losses control system on the basis of risk management existing methods. Adequate approach to the perception of effective management and control will be one of the components of project success. On this basis, the purpose of losses management in the production of construction and installation works will be as follows:

1) Decreasing the probability of negative events and events that affect the progress of works during construction;

2) The anticipation and prevention of situations that threaten the achievement of the goals and objectives on the construction site;

3) Ensuring the sustainable development of the company, reducing corporate costs and increasing the profitability of projects.

However, the losses management should be based on several principles:

– the organizational legitimacy (all personnel should be interested in this process, starting with staff and ending with the General director of the company; duties and responsibilities of personnel should be differentiated and personalized in the framework of the implementation of each construction project);

– the accuracy and clarity (there should be ensured the understanding of ideas, tasks and specific content of measures to manage losses by all participants, their development and further implementation);

– the adequacy (the compliance is ensured with the accepted ways to handle any losses and develop measures for their elimination of the current conditions and the character of the market situation);

– the efficiency (process management losses should be based on their reasonable practicability, management measures are cost-effective and practicable on site);

– the flexibility (it is possible to adapt measures to control losses without changing the target orientation when changing the external and internal conditions of the project, as well as the emergence of new factors that have an impact on losses);

– the resource security (the company has adequate and accessible resources for implementation of developed measures for managing losses, the cost of monitoring and control is laid in the cost of the work);

– the continuity (losses are mandatory systematically identified, studied and tracked);

– the documentment (losses and their characteristics are fully and promptly reflected in management documentation, operational registry).

The achievement of these goals and principles will enable construction companies to reach a qualitatively new level of business, more perfect compared with existing methods of organization and work management, thus giving a tangible advantage in a competitive market.

1.7 Conclusions chapter. Statement of the research problem

The conducted analysis of the modern project and production management trends showed us that the most appropriate and progressive method of construction management today which is the next step up to the different systems is the lean construction. It combines all of the most effective and applicable methods for construction work organization.

The problems of nowadays construction processes show us the huge value of losses: in time, materials, labor, money and etc. Lean principles are able to solve modern problems on construction site much more than inspections, quality management, usage of 6 sigma’s and moreover the traditional planning which today while the times of development boom in construction and in tendency of reducing construction time makes the modern management system ineffective and weaken.

One of the biggest advantages of lean production on building site is reducing the time of construction and proportion of NVA operations and processes in work. Performed case studies [44] of steel structures erection and piping showed that optimization of value flow achieve the 20-30% decreasing the value of NVA processes. Nowadays the researches of lean construction in West countries is not stays and continues further on the field of another types of constructions and works on building site.

The Russian reality, as has said earlier, is on a step of active quality management system implementation. The huge amount of construction supervision tenders and only “documental” realization of total quality systems which aims not to improve the quality on the building site but only to be in accordance with legislation system shows that quality management in Russia stays on low level. Only few of modern companies with certain share of foreign countries in statutory capital are on lean implementation processes. But there is no one in construction, only in manufacturing. Today’s construction reality based on Soviet experience and methods with the combination of traditional planning tools. As a result it takes huge amounts of money to build the appropriate, comfortable and useful structures in comparison with for example Europe and USA.

The researches show us that nowadays there are no specific methods or algorithm of implementation of lean principles in Russian reality. Thus, for the start of wide usage of lean construction we should study and make the analysis of these methods of implementation for the European, Asian and North American companies and start from the focus on the one type of building processes, for example, the construction of monolithic frame of the building or concrete works. The successful work in this area will provide us in further researches the possibility to share this experience on other processes.

The conducted analysis is allowed to formulate the following objectives of this study:

1. Analysis and generalization of implementation experience of lean construction in Russia and foreign countries.
2. The development of losses management model of construction processes with risk management tools usage.
3. The definition of construction project efficiency indicators from the possible losses point of view in the works execution.
4. Testing of the obtained model on the example of monolithic frame construction.
5. Processing of the results. The development of preconditions for further work.

2 Development of losses management methodology of construction processes based on the tools of risk management and lean construction

Losses are the integral part of any construction process during the erection of the building. Different types of work can be associated with more or less number of losses, 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. External and internal circumstances, in terms of the impact of which the building processes are constantly undergoing and change, and therefore, reassessing 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.

2.1 Model of losses management at the building site

The successful management of losses while the production of construction works 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 (causes, the probability of their occurrence, the impact on the production processes), to develop the most effective ways of reducing the impact of each of them to an 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 is 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.

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 (Figure 2.1):

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 non-value adding and non-value adding but required types of losses;

4) the assessment of the impact level of non-value adding processes 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.

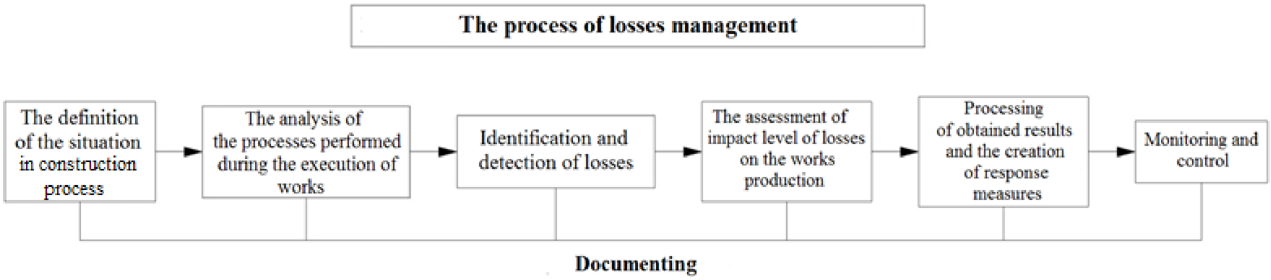

Figure 2.1 The integrated model of losses management.

At the first stage while the definition of situation and development of the management plan the clear structure of the process should be established, 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 (WP – work plan and CMP – construction management plan), 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 rules of the Unified Norms and Prices, State Itemized Cost Estimate Standards, Territorial unit costs, etc. and WP) and from the real, practical view, that is to determine the sequence of all possible operations on the construction of building "in nature". This stage should be based on their own experience and observations over the construction of similar facilities. The obtained data should organize and conduct their distribution by types of constructed structures.

The next stage in the process of loss management is the identification of losses, i.e. the identification of the operations having a negative impact on the course of production processes. The results of the analysis formed the list of losses, which increase costs and construction time, the division between NVA and NVAR and further grouping by 7 types in accordance with the lean management methodology. The result of this work will be the final list of identified losses during construction and installation works.

Next is the direct assessment of the losses impact on the production of construction works on the building site. For this purpose it is necessary to collect data about the causes and consequences of the each of the identified losses occurrence, to determine which techniques should be used in assessment of their impact, to carry out operations of the assessment and to receive the results. While performing this work you should use the techniques outlined in the first chapter. The assessment of the losses impact is made on the basis of 3 indicators: the probability of occurrence of each loss, the impact on cost and the influence on time of construction. For each type of influence the calculations are carried out separately. The data is processed using the methods of mathematical statistics and econometrics.

During the processing phase the ranking of losses is performed according to the degree of their influence on the construction works progress according to the specified criteria. Thus, the ranked list of losses is obtained. Then the results are checked, and calculated integral indicator (coefficient) of the impact of losses on the construction progress. By results of this stage the decision maker receives the output data - the list of losses, segregated by the level of impact on three main groups: loss with the high level impact, medium and low. The first two groups of losses require urgent measures of reducing and elimination. The losses of the third group can be removed by the development of organizational measures, in particular to improve the engagement of employees, improve the existing organization of works production, etc. Measures to reduce the impact of losses or their elimination are developed specifically for each type of operations. If measures have not given expected result, then the decision on development of plans for elimination of the loss consequences or abandon the changes.

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 system loss management is impossible.

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

The extended model of losses control in the works production on the construction site with its major stages is shown on the Figure 2.2. Details of the each step will be explained in this chapter.

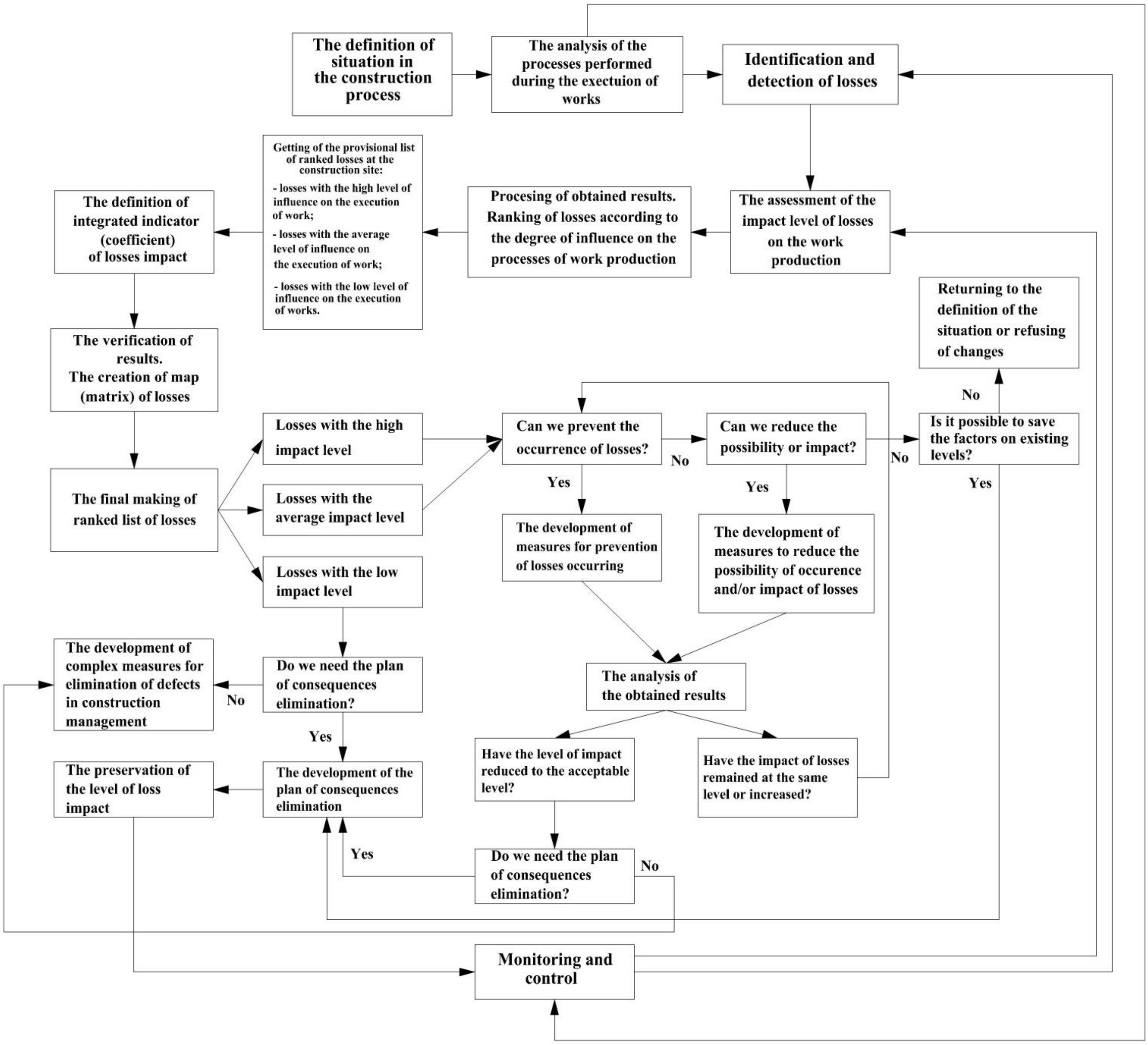

Figure 2.2 The extended process model of losses management of the construction works production.

2.2 Definition of the situation in the construction process of company, the development of the plan and analysis of production processes

If the construction project did not clearly define the situation in which the production is, control and reduction of losses can become economically senseless. Without accurate understanding, what processes need to be assessed, without the schedule of execution of works, without the accepted scheme of production and other factors, the process of determining losses at the building site becomes difficult. Therefore, the work with losses, as work with classical theory of risk management, begins with the identification of interested stakeholders and parties, i.e. persons or entities that directly or indirectly affect the project or, conversely, are subjected to its influence. Here it is necessary to clearly understand the contractor's interests (for example, reduction of costs and expenses), final customer (reduce the final cost and reduction of time of construction of the object), as well as all participants of a construction project.

At this stage there is also necessity of clear understanding what goals must be achieved in the end and how all requirements will be implemented in the process of achieving them. The important aspect is also to determine levels of tolerance to the level of losses impact, as well as the necessary criteria for assessing the effectiveness of project from the loss management point of view at all stages of the production process. The use of these values will allow the company management to further understand the effectiveness of project at the stage of preparation works, what issues should be paid attention when developing plans, process maps, and schedules for execution of works to reduce the cost of construction of the building, increasing productivity, reducing time of standstills, etc.

After conducting this research decision makers shift to the development of losses management plan. This document should include the requirements for losses management, the situation definition and major tasks for implementation. In the course of planning all methods and approaches should be defined that can be used for identifying losses, recommendations for the assessment of their impact, preparation and usage of the losses registry and its renewal. The main criteria for impact of losses is stated here: increasing of construction cost and increasing of erection time. Also it is necessary to appoint responsible persons from among the personnel of building organization for implementing the objectives to losses management.

After the planning procedure decision makers go directly to the analysis of basic production processes. To do this, the data about the future of investment-construction project should be collected: CMP and WP, with schedules, scope of work, plan investments, etc. At this stage a comparison of "idealized" processes outlined in the standards and documents, with actual operations on the construction field. While performing this work you should use your own experience or observation of construction of similar objects. As a result the decision makers get the list of all operations that apply to each kind of works and in the structure of which identifying the losses will be continued.

2.3 Identification (detection) of losses

According to p.4.3.28 [54] the purpose of identifying risks is to identify potential risk events and their characteristics and that, if they occur, can have a positive or negative effect on project aims. For the theory of lean construction can be written the following wording: the purpose of losses identification on the construction site is to detect potential events on the site, which may occur with different probabilities and have different degrees of the consequences that affect the cost of structures erection or construction time or 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. Losses are recurring events or processes, new ones may become known or change during its life cycle. The list of identified possible losses on the construction site can be changed on pre-design and design stages of construction and in the building process. Therefore constant monitoring by the responsible persons at the site (site engineers, headmen, etc.) is necessary from the point of view of changes of losses structure and the arrival of new ones. It is confirmed by the above words about the methodology of lean construction: it is necessary to radically change the thinking about the processes at the construction site to work efficiently and without losses.

The purpose of the identification of losses is to get the list of the sources of losses and events that may affect the achievement of each of established goals of the project.

For the purpose of identifying losses it should be formulated as random events that may not take place, therefore, introduced such a category as the probability of occurrence. The formulation of the single losses (source loss, event) should have some detailed information about it, and the formulation must be specific and unambiguous.

2.4 Assessment of the loss impact level on the processes of construction works

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 further action by the company. This operation includes the procedure of the probability of occurrence estimation for each of certain losses on the construction site and their implications for manufacturing operations, if these losses will still occur. 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. Loss assessment can be a recurring process, because instead of already avoided losses it can be new ones in the work process and in the final stages.

In the conditions of uncertainty, and we are in such conditions, the most applicable 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 [46, 47]:

– Making the decision of the expert survey necessity, formulation and foundation for its purpose.

– The selection and appointment of the basic composition of the working group.

– The formation of the working group and approval of the terms of reference for carrying out expert survey.

– The development by the analytical group of the detailed script of the collection and analysis of expert opinions (assessments).

– The selection of experts in accordance with their competence. Differentiated assessment of the level of scientific expertise is set, which is confidential. The estimation is made on the base of 3-point scale, as follows: experts with a high level of competence assigned 3 points, with the average - 2 and low - 1.

– Data collection of expert information. Experts estimate the risk in terms of occurrence probability of a negative situation (on a scale) and the amount of loss in the event of its occurrence (on a scale), thus the index is calculated for each risk.

– Assessments are marked by experts for each type of risk and summarized in the tables. The risk index is determined taking into account the level of competence of the expert.

– The final analysis of expert opinions and preparation of the final document. The evaluation of risks is carried out by their ranking: the location of risks in accordance with pre-defined criteria, i.e., development of the risks rating. This rating provides the basis for the preparation of measures in order to reduce the degree of risks exposure to acceptable level and the allocation of resources to process them.

– The official end of the group work.

When using the method of expert assessments there is a possibility of intuition, life and professional experience of the respondent’s usage. The usage of this method in this case is the most expedient, because the deficiency or complete lack of information does not allow using other possibilities. The method is based on the survey of independent experts to assess the level of risk (impact of loss). The main limitation of its usage is the difficulty in selecting of appropriate group of experts.

Methods of assessment of losses by analogy with the methods of risk assessment can be divided into the following types: qualitative, quantitative and mixed. The qualitative evaluation can determine the impact, probability and index of each loss on a scale of "high," "medium" and "low", and assessing the consequences and probability may be combined. Comparative evaluation of the level of risk in this case is carried out in accordance with quality criteria. The quantify assessment of the level of losses impact may be based on the reliable statistics in the case, if the latter exists and is available.

The application of methods for quantitative evaluation involves the following:

– methods should use the objective data to identify knowledge indicators;

– from analytics understanding of mathematical calculation and analytical methods and tools is required;

– methods usage changes the level of uncertainty in the project;

– methods should be based on representative data (chronological series, statistical samples, etc.).

Using methods of qualitative evaluation are based on the following principled provisions:

– methods are widely used the subjective values and judgments as the estimation parameters;

– the indicators must be defined in the project settings, i.e. their evaluation must be developed for adequate quantitative or ordinal scale.

Not all losses on a construction site are possible to determine quantitatively. Therefore it is reasonable to allocate resources to assessment of losses on the basis of expert assessments, because obtaining of accurate statistics and sophisticated model of calculations requires disproportionately more resources.

The qualitative assessment implies a wide application of methods for assessing the probability and consequences of risk, in which expert judgement is prevalent, i.e. subjective human opinion, in this case – the opinion of an expert of the subject area. Also it should be awared that the adequacy of the assessments generated by the expert is influenced by the following factors [51]:

– the supporting bias: the tendency to search or interpret information in a way that it was confirming pre-existing expert concepts;

– the bias of blind spot: the tendency of experts to be far less concerned about their own cognitive shifts in the assessments, rather than the same prejudices from other experts;

– the fundamental attribution error: the excessive attention to the effects on people's behavior to their particular personality or character;

– the anchor bias: too strong focus only in one aspect of the analysis or on a single piece of information;

– the representative bias: the judgment about the plausibility of the hypothesis based on its similarity with already available data. This error is similar to the commonly known method of evaluation and argumentation on the principle of "it can't be because it can be never";

– the projective biasedness line of reasoning, obviously assuming that other people share your current feelings, values or thinking.

2.5 Expert assessments method for the losses impact evaluation

The problem of selection of experts is one of the most important in the assessment process. As the experts competency we understand the degree of expert’s qualification in a particular field of expertise. 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 [47].

It should be noted that currently there is no generally accepted single methodology for assessing the qualities of an expert, so opinions about the professional level of specialists often far apart. Therefore, in the absence of possibilities and experience of organization and holding of expertise it makes sense to seek the services of independent assessment centers, information analysis centers, etc., whose main tasks are the analysis of the situation, assessment of objects of examination, preparation and evaluation of alternative solutions.

While assessing the qualities of the expert it is necessary to take into account his professional knowledge, experience of activities, including expert commissions. There are many ways to assess the qualities of the expert, each of them can be successfully used in a particular case. They are divided into three main groups: apriori, aposteriori and testing. When using apriori methods to assess the qualities of the expert, the information on the results of his participation in previous expertise is not using. When performing aposteriori methods, on the contrary, the information about the results of his previous examinations finds immediate application. The testing methods involve the holding of special tests.

In our case we should use the aposteriori methods of assessment that involves consideration of the following qualities:

– 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 first step is to determine the weight of importance of each quality should be possessed by the expert.

Based on the method of pairwise comparisons of qualities the matrix of preferences is formed. Pairwise comparison is, in turn, the procedure of determination of preference of objects when comparing all possible pairs. While comparing any pair of objects it can be strict order attitude or equivalence relation. The results of the comparison of all pairs are collected in table 2.1, in rows and columns which represented quality, and the cells of the table are numerical values of preferences. In the process of filling uses the following numeric representation: if the *i*-th quality is more important than the *(i+1)*-th, then *(i, i+1)*-th cell set the value of 2, otherwise, 0, and if qualities are equally important – 1. After filling the matrix of preferences it is determined the evaluation of each quality and its rank R_{ij}. Assessment *i*-th quality made by this *j*-th expert was determined by summing of all scores in the corresponding row of the preferences matrix of the expert. The total sum of grades equal to n^2, where n is the number of considered qualities [48].

The ranking procedure provides the determining of relative preference of qualities which based on sequencing, as a result, each of them are assigned ranks (1, 2 , 3, ..., n). The most preferred quality, which has the highest score, is assigned a rank equal to one, the second has rank equal to two, etc. The equivalent qualities assigned the same rank.

The importance factor of the *j*-th quality is defined by the formula 2.1:

$$V_i = \frac{x_{ci}}{n^2} \tag{2.1}$$

The results of the evaluation of the importance weight of the *i*–th quality is presented in Table 2.1.

Table 2.1 The formation of preferences matrix.

Quality	Employment period	Level and profile of education	Profile of the work performed	Level of solving problems	Quantity and level of projects…	Assessment of quality	The rank of quality	The weight of significance
Employment period	1	2	1	1	0	5	2	0,2174
Level and profile of education	0	1	1	1	1	4	3	0,1739
Profile of the work performed	0	1	1	0	1	3	4	0,1304
Level of solving problems	1	1	1	1	0	4	3	0,1739
Quantity and level of projects…	2	1	1	1	1	6	1	0,2609
					Total	23		

By preference matrix results it can be concluded that such qualities as "Employment period" and "Quantity and level of projects…" with R = 2 and V_i = 0,2174 and R = 1 and V_i = 0,2609 and are the most significant. [49]

The level of competence of the expert is determined on the second stage. Most commonly used methods are the self-evaluation, peer assessment of expert's competence and professional suitability tests. The independent professionals with similar competencies should be engaged for the assessment of qualities of experts, who will continue to evaluate losses at the construction site. For further work on the assessment, 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 (estimated at 40 points);
– above-average (30 points);
– average (20 points)
– low (10 points).

Specialists-assessors of competence of the experts who will participate in the expert survey, put up scoring in special questionnaire: the table on the basis of data on employment period, level of education, work profile, etc., which was incorporated into consolidated list. The overall score is obtained for each expert and defined by the formula 2.2:

$$A_l = \sum_{j=1}^{m} V_i \cdot a_{ijl}\ , \tag{2.2}$$

where V_{in} is the weight of significance of i-quality;

a_{ijl} is the rating of i-th quality of l-th expert assessing the risks made by j-th expert.

Next, the level of competence of the expert is determined based on the following conditions:

– $A_l < 20$, the level of competence is 1;
– $20 \le A_l < 30$, the level of competence equal to 2;
– $A_l \ge 30$, the competence level is 3.

After the specialized assessment of expert's competence, the direct estimate of losses using the method of expert assessment (method of assigning points) is started. By using this method, the expert group makes the estimation by assigning of each indicator's scores on a particular scale. For example, the group of six experts evaluates some of the indicators on a scale from 1 to 10. 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. It is understood that the experts have equal competency. However, in our case, the experts will be not with equal competency, as they have a different level of experience, tasks, education, etc. So the scores will be stated taking into account the criteria of competence. Then the weight matrix of the estimates is constructed (Table 2.3). The value r_{ik} of weighted estimates is calculated for each integral index of qualification of the i-th expert is given by the formula 2.3 [55, 56, 57]:

$$r_{ik} = \frac{h_{ik}}{\sum_{k=1}^{m} h_{ik}}, \tag{2.3}$$

where h_{ik} is the score of the i-th expert to k-th criteria;

$\sum_{k=1}^{m} h_{ik}$ is the score of the i-th line;

m is the number of private ratings of criteria (the number of experts).

Table 2.2 Scores given by experts.

Experts	Indicators						The total score $\sum_{k=1}^{m} h_{ik}$
	A	B	C	D	E	F	
1	7	8	7	6	5	7	40
2	5	9	10	5	6	5	40
3	6	9	8	10	6	6	45
4	6	10	7	9	4	5	41
5	8	5	8	10	7	6	44
6	9	7	7	9	6	7	45

The next step determines the total score for each criteria which is obtained by summing the values of each column of the matrix (table 2.3) [57].

$$r_i = \sum_{j=1}^{L} r_{ij}, \tag{2.4}$$

where L is the total number of experts participating in the survey.

The values of weight coefficients are calculated according to the formula (2.5) and should satisfy the condition presented in equation (2.6) [57]:

$$\sigma_i = \frac{r_i}{\sum_{i=1}^{L} r_i}, \tag{2.5}$$

$$\sum_{i=1}^{n} \sigma_i = 1 \tag{2.6}$$

where n is the number of the evaluated indicators.

Table 2.3 The weight matrix of the estimates.

Experts	Indicators						The total score $\sum_{k=1}^{m} h_{ik}$
	A	B	C	D	E	F	
1	7/40=0,175	0,2	0,175	0,15	0,125	0,175	40
2	5/40=0,125	0,225	0,25	0,125	0,15	0,125	40
3	6/45=0,133	0,200	0,178	0,222	0,133	0,133	45
4	6/41=0,146	0,243	0,170	0,219	0,097	0,122	41
5	8/44=0,182	0,113	0,181	0,227	0,159	0,136	44
6	9/45=0,2	0,155	0,155	0,2	0,133	0,155	45
The total score r_i	0,961	1,138	1,111	1,144	0,798	0,847	

In the result of the calculation we have:

$$\sum_{i=1}^{n} r_i = 0{,}961+1{,}138+1{,}111+1{,}144+0{,}798+0{,}847 = 6{,}0.$$

Then the following weights for the selected indicators are calculated:

$$\sigma_A = 0{,}961/6 = 0{,}16;\ \sigma_B = 1{,}138/6 = 0{,}19;\ \sigma_C = 1{,}111/6 = 0{,}185;$$

$$\sigma_D = 1{,}144/6 = 0{,}191;\ \sigma_E = 0{,}798/6 = 0{,}133;\ \sigma_F = 0{,}847/6 = 0{,}141.$$

The sum of the values:

$$\Sigma\sigma_i = 0{,}16+0{,}19+0{,}185+0{,}191+0{,}133+0{,}141 = 1.$$

The weights using a ranking method can be calculated similarly, but experts put the indicators in order of importance. The number 1 indicates the most important, according to the expert, indicator, 2 – next important, etc. Then the calculation is performed based on the above algorithm.

2.6 Processing of the obtained assessment results

During the work, experts assess the losses from the perspective of their probability P_q 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 scores made by experts for each type of loss are reduced in the table in which 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 and losses". The main advantages of using 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 of five by five, containing five numeric intervals of the probability of occurrence of losses and five intervals on the scale of possible losses. The degree of losses impact is divided also into five groups, and the level – on seven in accordance with the classification methodology of lean management.

For assessment of the losses probability the scale of five intervals is used: from complete uncertainty with a probability close to zero to full uncertainty with probability close to one. Table 2.6 presents the scale decomposition of the probability of occurrence of losses.

Table 2.4 The scale of assessment of the losses impact on the cost of construction.

Description of the degree of influence on the construction cost (cost increasing in %)	**The rating level in points corresponding to the description**
up to 20%	1
21-40%	2
41-60%	3

61-80%	4
81-100%	5

Table 2.5 The scale of assessment of the losses impact on the construction time.

Description of the degree of influence on the construction time (the increasing of time limits in %)	**The rating level in points corresponding to the description**
up 20%	1
21-40%	2
41-60%	3
61-80%	4
81-100%	5

Table 2.6 The scale of probability occurrence of losses.

Verbal description of probability (qualitative description of the confidence level)	**The rating level in points corresponding to the description,%**
Practically don't occur while performing work, appear rarely and randomly	up to 20%(1)
These phenomena appear at the construction site periodically and disposable in place	21-40%(2)
More frequency of occurrence, mainly because of problems in planning and organization	41-60%(3)
Almost recurring losses, indicate violations in the construction technology, planning and organizing	61-80%(4)
The constant availability of these losses on the construction site, the inability to eliminate	81-100%(5)

Index of each loss (in points) is determined by the formulas 2.7 and 2.8 [47, 50]:

$$R_{ic} = P_i \cdot I_{ic} \tag{2.7}$$

$$R_{it} = P_i \cdot I_{it} \tag{2.8}$$

where P_i is the probability of each loss occurrence;

I_{ic} and I_{it} are the impact levels on cost and time of construction respectively.

For determining the final index of loss it should be taken into account the level of expert competence. In order to do this, the index of loss, stated by particular expert, and the level of expert competence are multiplied.

The average statistic value (in points) is determined by the formula 2.9:

$$R_{iavc,iavt} = \frac{\sum_{j=1}^{n} R_{ij}}{m} = \frac{\sum_{i=1}^{n} R_{ic,t} \cdot m_j}{\sum_{j=1}^{L} m_j} \tag{2.9}$$

where m_j is the level of competence of j-th expert;

L is the expert's quantity;

m is the sum of the levels of expert competence.

Then the degree of coherence of the *i*-th loss is determined by the coefficient of variation [48] according to the formula 2.10:

$$W_l = \frac{\sqrt{\frac{\sum_{j=1}^{m}\left(x'_{ij} - \overline{x'}\right)^2 \cdot m_i}{m}}}{R_{iavc,iavt}} \tag{2.10}$$

where x'_{ij} is the rating of the *j*-th expert for the *i*-th loss in accordance with the result of the survey.

The consistency level can be estimated as follows:

- if $W_i \leq 0{,}1$, the consistency level of the *i*-th loss is considered as high,
- if $0.1 < W_i \leq 0.15$ and above – average,
- if $0.15 < W_i \leq 0{,}25$ – medium,
- if the $0.25 < W_i \leq 0{,}35$ – below average,
- if $W_i > 0{,}35$ – low.

After the calculation of the statistical average index of losses, the results should be analyzed in order to assess which of the losses should be eliminated at first, second, and so on. The procedure of identification and elimination of losses in the future should be included in the enterprise standards to establish and manage quality of work performed at the construction site.

2.7 Formation of integral coefficient of the losses impact on the course of technological processes on the construction site

The important aspect of executed operations is the question of the effectiveness of carried out changes management. 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.

At the present moment there are many different views on the methods of calculating the cumulated criteria or generalized integral indicator. There are 3 main methods of its definition: additive, multiplicative and additive-multiplicative [58-69]. 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 [61, 62].

While using the additive method, if one of the individual criteria is equal or close to zero, then the final result, on the one hand, 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 [62]. If one of the individual criteria are equal or close to zero when selecting the multiplicative method, the factor of one of the criteria "failure" has dramatic influence on the final value of all calculated criteria. All these factors greatly can affect the "stability" of outcome criteria [66].

In this method, the most simple and intuitive method of creating the indicator of efficiency will be used. However, it reflects all the basic parameters that are necessary for a comprehensive assessment of the magnitude of the impact of the losses on production work.

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

$$K_{cum} = \sum_{j=1}^{n} K_j \tag{2.11}$$

where K_j is the value of the j-th integral coefficient of each of the identified losses.

At the same time, widely used formula is:

$$K_{cum} = \sum_{j=1}^{n} K_j \sigma_j \tag{2.12}$$

where σ_i is the weighting factor of i-th loss index.

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. However, as in our case, because the assessments of experts are the random values, it is necessary to apply a number of additional calculations using methods of mathematical statistics to assess their objectivity. For example, coefficients of significance of the assessments, the consistency of opinion of experts are calculated; the coefficient of concordance (consistency) of the opinions is determined [70, 71]. It is also should be noted, that the reliability weights are also significantly influenced by such factors as the composition of the expert group and, as already noted earlier, the level of competence of experts. The ambiguity of all these factors can have a significant impact on the total integral indicator of the impact of the losses.

2.8 Calculation of the integrated indicator of the losses impact on construction site

The initial data for calculation of an impact indicator should have the value of the losses index, taking account of expert's competences. Each expert evaluates the impact of loss on the two exposures: the cost of execution of work and erection of structures. After the procedure of losses identification, preparation of questionnaires, definitions of criteria and scales for scoring by experts, the survey by expert group and processing of data, the results in the form of points should be systematized and presented in the form of weighted averages indexes.

In this case according to the p. 2.5 and 2.7:

$$K_j = R_{iavc,iavt} = \frac{\sum_{j=1}^{n} R_{ij}}{m} = \frac{\sum_{i=1}^{n} R_{ic,t} \cdot m_j}{\sum_{j=1}^{L} m_j} \quad (2.13)$$

For calculation the weight coefficients, the data should be used obtained by the method of expert assessments of competence. The matrix of weight estimates firstly includes the index values of losses calculated on the expert's competence base. Then the computation of required valuesis carried out:

$$h_{ik} = h_{ij} = R_{ic,t} \cdot m_j \quad (2.14)$$

$$\sum_{k=1}^{n} h_{ik} = \sum_{i=1}^{n} h_{ij} = \sum_{i=1}^{n} R_{ic,t} \cdot m_j , \quad (2.15)$$

$$r_{ik} = \frac{h_{ik}}{\sum_{k=1}^{m} h_{ik}} = \frac{R_{ic,t} \cdot m_j}{\sum_{i=1}^{n} R_{ic,t} \cdot m_j} , \quad (2.16)$$

where R_{ic}, R_{it} are indexes of the *i*-th loss (points) defined by the formulas 2.7 and 2.8;

m_j is the level of *j*-th expert competency.

Total values of r_i are determined for each column in the matrix according to the formula:

$$r_i = \sum_{j=1}^{L} r_{ij} = \sum_{j=1}^{L} \frac{R_{ic,t} \cdot m_j}{\sum_{i=1}^{n} R_{ic,t} \cdot m_j} , \quad (2.17)$$

where *L* is the expert’s quantity.

The further procedure is reduced to calculation of weighting coefficients σ_i for each loss according to the formula 2.5, which has the following form:

$$\sigma_i = \frac{r_i}{\sum_{i=1}^{n} r_i} = \frac{\sum_{j=1}^{L} \frac{R_{ic,t} \cdot m_j}{\sum_{i=1}^{n} R_{ic,t} \cdot m_j}}{\sum_{i=1}^{n} \sum_{j=1}^{L} \frac{R_{ic,t} \cdot m_j}{\sum_{i=1}^{n} R_{ic,t} \cdot m_j}} \quad (2.18)$$

The calculations should be checked by the formula 2.6:

$$\sum_{i=1}^{n} \sigma_i = 1 .$$

The cumulative coefficient of losses impact can be calculated by the formula 2.12:

$$K_{cum} = \sum_{j=1}^{n} K_j \sigma_j$$

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

$$K_{loss} = \frac{K_{cum}}{z}, \tag{2.19}$$

where z is the multiplication of the maximum values applied by each expert, respectively, for the probability of loss and impact level.

The important aspect in the application of integrated coefficient (indicator) of losses impact of the works production is the calculation of limit values (minimum and maximum) within which the values of the coefficient lie.

In accordance with accepted standards of calculation, scales for computing the levels of experts competence, the probability of occurrence and impact of losses on construction production, the maximum value of the index is calculated with using the procedure from p. 2.5. Firstly, assume that *L* experts have participated in the survey with the highest level of competence equal to m. They put the maximum values of the losses impact on construction site, respectively I_c и I_t for increasing construction costs and time. Secondly, consider that the experts gave the highest possible values of losses possibilities on the scale of *P*.

Thus, the index of each loss will be equal to $R_{c,t} = P \cdot I_{c,t}$, and the formula for calculation of K_j has the following form:

$$K_j = \frac{\sum_{j=1}^{n} R_{ic,t} \cdot m_j}{\sum_{j=1}^{L} m_j} = \frac{\sum_{j=1}^{n} R_{c,t} \cdot m}{\sum_{j=1}^{L} m} = \frac{R_{c,t} \cdot m \cdot n}{m \cdot L} = \frac{R_{c,t} \cdot n}{L}, \tag{2.20}$$

where *n* is the number of identified losses.

For determining the weights coefficients the matrix with all the scores assigned by experts is created.

Table 2.7 The assessment values given by experts.

Experts	Indexes of losses taking into account the competence level of experts						The total score $\sum_{i=1}^{n} h_{ij}$
	A	B	C	D	……	n	
1	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	……	$R_{c,t} \cdot m$	$R_{c,t} \cdot m \cdot n$
2	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	……	$R_{c,t} \cdot m$	$R_{c,t} \cdot m \cdot n$
3	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	……	$R_{c,t} \cdot m$	$R_{c,t} \cdot m \cdot n$
4	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	……	$R_{c,t} \cdot m$	$R_{c,t} \cdot m \cdot n$
…..	…...	…...	…...	…...	……	…...	$R_{c,t} \cdot m \cdot n$
L	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	$R_{c,t} \cdot m$	……	$R_{c,t} \cdot m$	$R_{c,t} \cdot m \cdot n$

As can be seen from the obtained results, the value of $\sum_{k=1}^{n} h_{ik} = R_{c,t} \cdot m \cdot n$ obtained for each of L rows of the matrix. Table 2.8 contains the matrix of weight estimates.

Table 2.8. The matrix of weight coefficients.

Experts	Indicators						The total score $\sum_{i=1}^{n} h_{ij}$
	A	B	C	D	……	n	
1	$\frac{R_{c,t} \cdot m}{R_{c,t} \cdot m \cdot n} = \frac{1}{n}$	$\frac{1}{n}$	$\frac{1}{n}$	$\frac{1}{n}$	……	$\frac{1}{n}$	$R_{c,t} \cdot m \cdot n$
2	$\frac{R_{c,t} \cdot m}{R_{c,t} \cdot m \cdot n} = \frac{1}{n}$	$\frac{1}{n}$	$\frac{1}{n}$	$\frac{1}{n}$	……	$\frac{1}{n}$	$R_{c,t} \cdot m \cdot n$
3	$\frac{R_{c,t} \cdot m}{R_{c,t} \cdot m \cdot n} = \frac{1}{n}$	$\frac{1}{n}$	$\frac{1}{n}$	$\frac{1}{n}$	……	$\frac{1}{n}$	$R_{c,t} \cdot m \cdot n$
4	$\frac{R_{c,t} \cdot m}{R_{c,t} \cdot m \cdot n} = \frac{1}{n}$	$\frac{1}{n}$	$\frac{1}{n}$	$\frac{1}{n}$	……	$\frac{1}{n}$	$R_{c,t} \cdot m \cdot n$
…..	…....	…....	…....	…....	……	…....	$R_{c,t} \cdot m \cdot n$
L	$\frac{R_{c,t} \cdot m}{R_{c,t} \cdot m \cdot n} = \frac{1}{n}$	$\frac{1}{n}$	$\frac{1}{n}$	$\frac{1}{n}$	……	$\frac{1}{n}$	$R_{c,t} \cdot m \cdot n$
The total score r_i	$\frac{L}{n}$	$\frac{L}{n}$	$\frac{L}{n}$	$\frac{L}{n}$	……	$\frac{L}{n}$	

The total score r_i of each loss has the following view:

$$r_i = \sum_{j=1}^{L} r_{ij} = r = \frac{L}{n}. \quad (2.21)$$

In accordance with the conducted calculations the formula 2.18 has this form:

$$\sigma_i = \frac{r_i}{\sum_{i=1}^{n} r_i} = \sigma = \frac{\frac{L}{n}}{n} = \frac{L}{n^2}. \quad (2.22)$$

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

$$K_{cum}^{max/min} = \sum_{i=1}^{n} K_i \sigma_i = n \cdot \frac{R_{c,t} \cdot n}{L} \cdot \frac{L}{n^2} = R_{c,t}^{max/min}. \quad (2.23)$$

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

$$K_{loss}^{max/min} = \frac{R_{c,t}^{max/min}}{z}, \quad (2.24)$$

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

As it can be seen from the calculation results, the maximum (minimum) value of the integrated losses impact indicator will be defined only ин the maximum (minimum) assessment value of the experts participating in the survey. By using the impact of losses scale on the cost and time of construction from 1 to 5 and probability of losses from 1 to 5 (0-100%), the following results are obtained:

$$K_{cum}^{max} = R_{c,t}^{max} = P_{max} \cdot I_c^{max} = 25,$$

$$K_{cum}^{min} = R_{c,t}^{min} = P_{min} \cdot I_c^{min} = 0.$$

The cumulative indicator $K_{cum}^{min} = 0$, because the minimum value of the probability of loss is 0%. Everything greater than 0 will be number 1 on a scale of probability.

The value of the coefficient $K_{loss}^{max/min}$, is respectively:

$$K_{loss}^{max} = \frac{K_{cum}^{max}}{z} = \frac{P_{max} \cdot I_c^{max}}{z} = \frac{25}{25} = 1,$$

$$K_{loss}^{min} = \frac{K_{cum}^{min}}{z} = \frac{P_{min} \cdot I_c^{min}}{z} = 0.$$

Thus, under all conditions, 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 a reason to concern measures of losses reduction and increase efficiency of production work.

2.9 Verification of the calculations. Construction of the matrix (map) of losses and clarifying of obtained results

The result of calculations is the ranked list of losses in decreasing order of influence 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. This process pursues the goal of clarifying the assessment of losses at the construction site and verification of the calculation results.

Similarly to the definition of the risk matrix from [52], 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 Excel tools (Figure 2.3) or by using professional software.

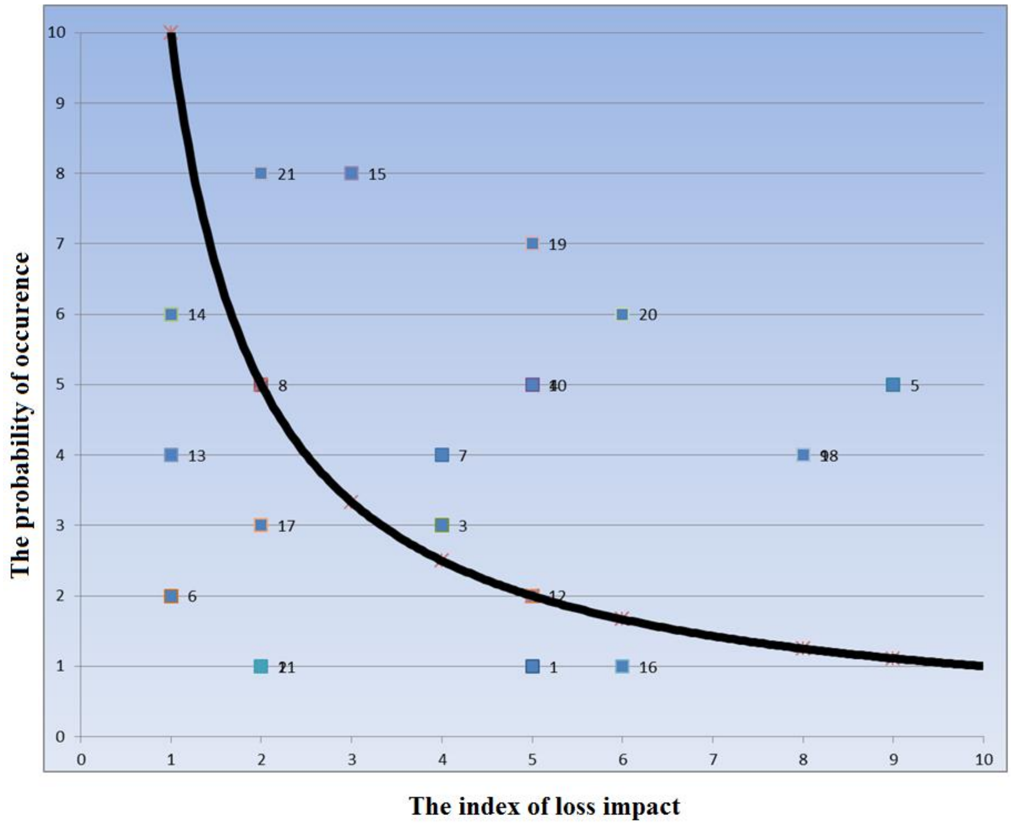

Figure 2.3 The example of losses mapping in Microsoft Excel.

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. It should also be noted that the criteria of competence of experts in this case will play a very important role. The level of competence is taken into account when calculating the probability of occurrence of each loss by multiplying the rating value, set by the expert, on the value of the competence level:

$$P_{iL} = P_i \cdot m_j \,, \tag{2.25}$$

where m_j is the competence level of j-th expert.

The assessment scores given by experts during the survey, also multiplied by the level of competence in a similar way:

$$I_{iLc} = I_{ic} \cdot m_j \,, \tag{2.26}$$

$$I_{iLt} = I_{it} \cdot m_j \tag{2.27}$$

For each loss, the weighted average degree of impact and probability is calculated taking into account the competence level of experts according to the formula 2.9, the results of which bring to the current table. Further calculations are reduced to calculating the values of loss:

$$R_{icav} = P_{iav} \cdot I_{icav} \tag{2.29}$$

$$R_{itav} = P_{iav} \cdot I_{itav} \tag{2.30}$$

where P_{iav} is the weighted average of the i-th loss probability of occurrence;

I_{icav} is the weighted average of the impact assessment value on the cost of construction taking into account competence of experts;

I_{itav} is the weighted average of the impact assessment value on the time of construction 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 which can divide losses on three groups. In the case shown in figure 2.1, the losses numbered 8,3,7,5,12,19,20, etc. lie above the level of tolerance and are the ones that should be paid attention in the first place. The resulting graphs are constructed for both types of effects – the cost and time of construction.

2.10 Definition of 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. In order to do this decision makers should give an order for conducting the training and certification of employees on proper work practices, management of working time, the usage of modern techniques and methods of construction, etc. However, 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. Therefore the QMS will be implemented not on paper, but in production.

According to [53] "the purpose of risk response is to develop options and determine actions to increase opportunities and reduce threats to project objectives. This process addresses the risks by adding resources and operations in the budget and the project schedule. Responding to the risk should be equal to the risk, to be cost-effective, timely and realistic within the project context, understood by all stakeholders and assigned responsible persons". Consequently, the response to losses in the production of construction works must satisfy these requirements and include the following: the elimination of losses, prevention of their occurrence or reduce their impact. Additional measures may be:

– the exception of loss by deciding not to start or continue operation, in the course of or as a result of which you may experience a harmful event;

– the elimination of sources of losses;

– changing in the probability of loss;

– changing the degree of impact on the cost and time of construction;

– the reasonable decision to save the loss, if its removal can lead to new losses or to disrupt of the production process.

The visual representation about how to process losses gives a schematic diagram which is shown on Figure 2.4.

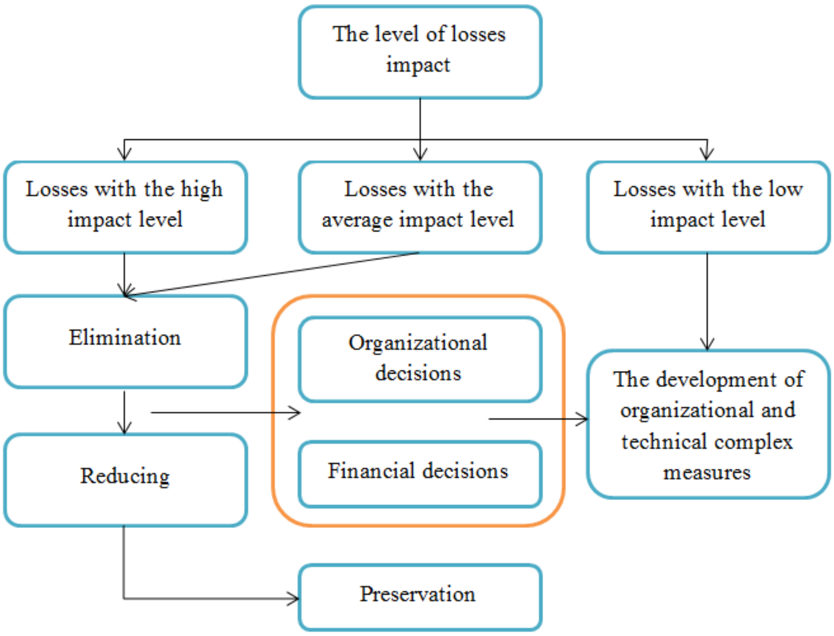

Figure 2.4 The principal scheme of losses processing.

The highest attention should be given to losses with high and average levels of influence, because they have the greatest influence on the construction process. 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. This process should involve specialists from design, production and technical departments and line personnel proposed for involvement in the current construction process (site engineers and team-leaders). The group must analyze the project and technical documentation, time schedule of work, adopted organizational measures and measures on labor protection and industrial safety, 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.

For purpose of this work the great assistance will have the application of Last Planner package as a planning tool. Its essence lies in the discussion of the calendar and parsing it into separate operations by all participants of the project lifecycle. Team-leaders and site engineers offer a specific time frame for each job, process, operation by its own employees, looking for harmonious methods of combining related types of work, propose measures to streamline and increase productivity. Designers and experts in construction management submit proposals and correct ideas of the engineers. The result of these workshops is the completely reworked production schedule, taking into account the real, not idealized and normalized time limits of the construction. Application of this system allows to reduce time of construction by 15-20%.

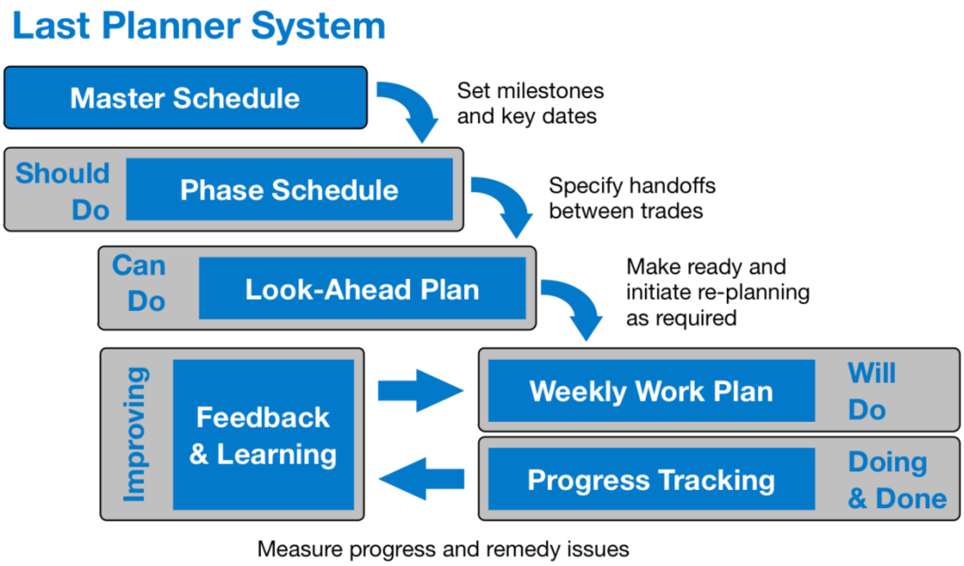

Figure 2.5 The working cycle of Last Planner system.

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. For example, in the construction of the long strip foundations with light laying the option with the least losses may be the usage of bucket wheel excavator instead of the traditionally accepted with backhoe attachment. It is important to take into account the opinions of all construction process participants throughout project life cycle. Only in this case the set goals are achieved.

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 building a tree of causes and faults, bowties, etc. 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. So, for example, to reduce the impact of any delays in the workflow between the field and company management should implement a uniform electronic system of registration and storage of documents, which will be available to every interested person. This is followed by the introduction of these measures into the production process and monitoring of changes. The responsible person at the intermediate stage is carried out new calculations on the impact of related losses in case of registration of their reduction are accountable to decision makers about the results of the measurements. Decision makers build further predictions to reduce the impact of current losses. In the presence of a reverse situation the decision makers develop additional measures or adopt a decision to keep losses at the same level.

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. While passive acceptance, 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. With the active acceptance 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 [53, 72]. The developed plan should be presented for discussion to the company management and taken into account while the development of the company's budget. When financing of such plans it has to be considered:

- potential consequences (in cost and time terms);
- the inability loss treatment before the first effects;
- the cost of developing plans.

The processing option of emerging losses (or combination of options) is selected on the basis of the analysis of the ratio of expected economic benefits and costs associated with the usage of this option.

2.11 Monitoring, control and documenting of losses during the construction

The important phase, which embraces the entire system of loss management, is the monitoring and control of the implemented changes. The undertaken activities are properly documented, the register of operational losses is created that may arise during the construction process, but for some reasons were not taken into account in the previous stages. New losses should be included in the procedure of assessment; however, for identifying the degree of their influence more simplified procedures should be used, based on the observation of current operations. The most appropriate tool in this case is the value stream mapping. Ultimately, we must ensure the continued effectiveness of the losses processing without stopping the construction process. Additional measures for the management of losses should be implemented painlessly without disrupting of already established during the previous stages of the system.

In order to control and monitor the implemented changes, the company's management should designate competent, responsible personnel. It produces the necessary documents, accompanying the processes of monitoring, mandatory reporting to decision makers and systematization of the results of losses management system work. In some cases, when the object dimensions are not large enough (for example, the residential house) the functions of rapid response to emerging loss development and a point of mitigation measures can be assigned for them.

Decision makers have the right to conduct an audit of the management system, both independently and with the help of a third party of relevant competence in this matter. Independent, fresh look at an existing system facilitates the identification of possible problems in the implementation of the system and its improvement.

2.12 Conclusions for the chapter

As a result of the work performed, the methodology of losses management in the production of construction works was obtained. This procedure includes all necessary steps for analysis of all probable losses required before starting work on the construction project:

1) The definition of situation on construction site and the development of plan.
2) The analysis of construction works.
3) The identification of losses.
4) The evaluation of the losses impact level while production processes (increasing the cost of structures erection and construction time) using the method of expert assessment.
5) Receipt and processing of survey results.
6) The calculation of the integrated indicator of the losses impact on building site.
7) Checking of the obtained results.
8) Ranking of losses according to their impact level (the index values).
9) The development of measures to reduce the impact level and/or eliminate identified losses in the production of works.
10) Monitoring changes, control and documentating.

The approach has been developed to assess the level of competence of experts participating in the survey. Experts assess the parameters of losses such the probability of their occurrence, increasing of the cost of works and construction time. The method for processing data of the survey of experts has been proposed, which determines the losses impact level in the index form.

Also the technique of calculation of the integrated indicator of losses impact on works production has been introduced, which gives decision makers clear understanding about the effectiveness of a construction project from the losses point of view arise while its realization. The values of losses indexes are determining when the calculation of this coefficient, the maximum and minimum values of this indicator has been calculated.

The methodology of checking the calculations by constructing the matrix (map) of losses has been prepared, which helps to visualize pictures of losses and to determine which losses are critical to response. Methods to reduce the impact level and eliminate losses were proposed, as well as monitoring of measures.

3 Practical implementation of the developed method for the construction monolithic reinforced concrete structures

3.1 Definition of the situation and analysis of processes occurring while the execution of work

As assessment objects, the processes of construction of monolithic building structures have been selected. In order to assess this type of work, we have selected the model: the typical bay of multi-storey monolithic residential building. Building constructions of this bay include: monolithic columns, monolithic slabs and monolithic walls. The scope of work on this bay includes the following in accordance with technological maps and regulations for the execution of reinforced concrete works [73,74]:

1) Installation of individual rods in the columns.
2) Installation of the column form.
3) Concreting of columns in a travelling shuttering for columns.
4) Technology break for concrete maturing.
5) Dismantling of the column form.
6) Installation of individual rods in the walls.
7) Installation of frames and grids in the walls.
8) Installation of large form wall shutters.
9) Concreting of constructions of external walls with buckets in large form wall shutters, travelling shuttering and the block-forms.
10) Concreting of constructions for internal walls with buckets in the large-area, volume-resettable casing and the block.
11) Technological break for concrete maturing.
12) Dismantling of large form wall shutters.
13) Installation of large form slab shutters.
14) Installation of individual rods in the slab (bottom reinforcement layer).
15) Installation of frames and grids in the slab.
16) Installation of individual rods in the slab (top reinforcement layer)
17) Concreting of slab (by buckets usage) in large form slab shutters.
18) Supplying of concrete mix to the place of laying by concrete pump.
19) Laying of concrete in the slab.
20) Technology break for concrete maturing.
21) Dismantling of large form slab shutters.

However for finding of all possible losses while performing this type of works, this information is not enough. The matter is that processes which are carried out on a building site “in nature” and stated in flow charts and norms often are not correctly correspond each other It is connected with an idealizing of a site conditions in standard and project documentation in comparison with a real situation. Therefore for further work it is necessary to explain in more details all processes happening specifically on a building site.

We will examine the processes of production the following construction elements:

1) Column.
2) Wall.
3) Slab.

The works performed while the construction of columns:

- Marking of locations for installation of columns by geodesist.
- Delivery of reinforcement to the building site.
- Unloading of the reinforcement.
- Receiving inspection of reinforcement.
- Conveyance of reinforcement to the reinforcement shop.
- Preparation of reinforcement for cutting (cleaning of a rust and outer defects).
- Cutting of working reinforcement of a column
- Cutting of auxiliary reinforcement of a column: stirrups.
- Bending of reinforcement (stirrups).
- Column framework tying on the ground.
- Checking of the tied framework on compliance to the project.
- Movement of team of assemblers to the bay.
- Preparation of reinforcement ends of the lower column (cleaning from concrete, rust and correction).
- Suppling of necessary materials: tying wire, cutting of a wire for work.
- Waiting of conveyance of a framework.
- Conveyance of a ready framework by the crane to the bay.
- Installation of a framework in design position.
- Tying of reinforcement of the installed column and reinforcement of column of the previous floor.
- Verification of the plan and high-rise position of reinforcement of a column.
- Checking of correctness of tying on the floor.

- Checking of thickness of a protective layer for the further concreting.
- Preparation of a formwork for concreting: cleaning, concrete removal, check of fasteners.
- Handling of concrete form panels by lubricant.
- Permutation of concrete form panels of column.
- Supplying of missing panels from the ground by the crane.
- Installation of concrete form panels of column.
- Fixing of formwork panels in position.
- Installation of locks, hinges and additional fittings.
- Checking of the installation correctness of formwork panels.
- Installation of ladders.
- Installation of the scaffolding.
- Delivery of concrete to the construction site.
- Transportation of bucket to a discharge zone.
- Selection of concrete for testing samples in compression.
- Rising of teams of concrete workers for unloading of bucket in the column.
- Discharging of concrete into the bucket (1^{st} cycle).
- Supplying of bucket by crane on the bay.
- Lowering of the bucket.
- Unloading of concrete into the column.
- Vibrating by layers.
- Lead of bucket.
- Supplying of bucket by the crane to the place of unloading.
- Discharging of concrete into the bucket (2^{nd} cycle, etc.).
- Supplying of bucket by crane on the bay.
- Lowering of the bucket.
- Unloading of concrete into the column.
- Vibrating by layers.
- Lead of bucket.
- Waiting for delivery of the next batch of concrete.
- End of concreting.
- Technology break for concrete maturing.
- Rising of teams of installers for dismantling formwork.
- Removing of scaffolds and ladders.
- Removing of locks.

- Storage of locks and accessories on the slab.
- Disassembly of the shuttering boards.
- Supplying of formwork to the ground by crane to the storage area.
- Follow-up of concreting by technical supervision.

The works performed during the construction of reinforced concrete walls (diaphragms):

- Marking of locations for walls installation by geodesist.
- Delivery of reinforcement to the building site.
- Unloading of the reinforcement.
- Receiving inspection of reinforcement.
- Conveyance of reinforcement to the reinforcement shop.
- Preparation of reinforcement for cutting (cleaning of a rust and outer defects).
- Cutting of vertical bars of the diaphragm.
- Cutting of horizontal bars of the diaphragm.
- Cutting of end stirrups in reinforced concrete walls.
- Bending of reinforcement (stirrups).
- Column framework tying on the ground.
- Movement of team of assemblers to the bay.
- Preparation of reinforcement ends of the lower diaphragm (cleaning from concrete, rust and correction).
- Supplying of necessary materials: tying wire, cutting of a wire for work.
- Supplying of batches of horizontal and vertical reinforcement on the work front (bay).
- Tying of the diaphragms reinforcement with diaphragms reinforcement of a lower floor.
- Tying of the diaphragms horizontal reinforcement.
- Installation of elements forming openings.
- Installation of cable passages for laying of electric networks.
- Verification of the plan and high-rise position of reinforcement.
- Checking of correctness of tying on the floor.
- Checking of thickness of a protective layer for the further concreting.
- Preparation of a formwork for concreting: cleaning, concrete removal, check of fasteners.
- Handling of concrete form panels by lubricant.
- Permutation of concrete form panels of walls.
- Supplying of panels with adjacent bay.
- Supplying of panels from the ground by the crane.

- Installation of concrete form panels.
- Fixing of formwork panels in design position.
- Installation of locks, hinges and additional fittings.
- Checking of the installation correctness of formwork panels.
- Installation of ladders.
- Installation of the scaffolding.
- Delivery of concrete to the construction site.
- Transportation of bucket to a discharge zone.
- Selection of concrete for testing samples in compression.
- Rising of teams of concrete workers for unloading of bucket in the column.
- Discharging of concrete into the bucket (1st cycle).
- Supplying of bucket by crane on the bay.
- Lowering of the bucket.
- Unloading of concrete into the column.
- Vibrating by layers.
- Lead of bucket.
- Supplying of bucket by crane to the place of unloading.
- Discharging of concrete into the bucket (2nd cycle, etc.).
- Supplying of bucket by crane on the bay.
- Lowering of the bucket.
- Unloading of concrete into the column.
- Vibrating by layers.
- Lead of bucket.
- Waiting for delivery of the next batch of concrete.
- End of concreting.
- Technology break for concrete maturing.
- Rising of teams of installers for dismantling of formwork.
- Removing of scaffolds and ladders.
- Removing of locks.
- Storage of locks and accessories on the slab.
- Disassembly of the shuttering boards.
- Supplying of formwork to the ground by crane to the storage area.
- Follow-up of concreting by technical supervision.

The works performed during the construction of reinforced concrete slab:

- Rising of teams of installers to work front
- Supplying of formwork posts from the adjacent bay.
- Supplying of missing formwork posts by crane on the slab.
- Installation of formwork posts in accordance with the plan.
- Supplying of wooden formwork beams.
- Supplying of beams on the scope of work for installation.
- Installation of beams.
- Fitting of beams to the required dimensions and configuration of floor slab.
- Supplying of panels from the ground by the crane.
- Installation of concrete form panels.
- Resizing of panels for the sizes and configuration of slab.
- Geodetic check of installation correctness of slab formwork.
- Installation of turnover on the edges of the slab in accordance with the project.
- Felling of reinforced concrete walls edges projecting from the plane of the formwork.
- Acceptance of installed formwork by construction supervision.
- Delivery of reinforcement to the building site.
- Unloading of the reinforcement.
- Receiving inspection of reinforcement.
- Conveyance of reinforcement to the reinforcement shop.
- Preparation of reinforcement for cutting (cleaning of a rust and outer defects).
- Rising of steelfixers team on the bay.
- Conveyance of the lower layer reinforcement.
- Laying of the bottom reinforcement layer on the slab.
- Cutting of rods for slab reinforcement.
- Cutting of edge stirrups of slab
- Bending of reinforcement (stirrups).
- Column framework tying on the ground.
- Welding works: preparation of working frames.
- Supplying of necessary materials: working frames, tying wire, cutting of a wire for work.
- Tying of the bottom layer of slab reinforcement with the installation of chairs.
- Supplying of intensive reinforcement on the work front.
- Tying of intensive reinforcement.
- Check of the bottom layer of the reinforcement plate by the construction supervision.

- Delivery to site of the gain frames from the factory.
- Conveyance of the frames by crane on the work front.
- Tying of the gain frames to the reinforcement of the lower layer.
- Installation of elements forming openings.
- Installation of cable passages for laying of electric networks.
- Verification of the plan and high-rise position of reinforcement.
- Installation of working frames.
- Laying of the upper reinforcement layer on the slab.
- Cutting rods for intensive reinforcement of slabs of the upper layer.
- Supplying of intensive reinforcement on the work front.
- Tying of intensive reinforcement.
- Supplying of edge stirrups.
- Tying of edge stirrups.
- Conveyance of thermofillers.
- Installation of thermofillers on the slab.
- Check of the correctness of the reinforcement slab tying.
- Check of the protective layer thickness during further concreting
- Preparation of formwork for concreting: cleaning, inspection of fasteners.
- Installation of a concreting boom on slab.
- Installation and connection of hose.
- Connection of concreting boom.
- Installation of concrete pump to a discharge zone.
- Delivery of concrete to the construction site.
- Selection of concrete for testing samples in compression.
- Rising of teams of concrete workers to the slab.
- Unloading on concrete slab (continuously throughout the concreting cycle).
- Vibrating of layers.
- Waiting for a new ready-mix truck.
- Change of a ready-mix truck.
- End of concreting.
- Technology break for concrete maturing.
- Watering of the concrete during the entire curing process until the dismantling of formwork.
- Rising of teams of installers for dismantling of formwork.
- Removal of formwork posts.

- Storage of formwork posts on the slab.
- Disassembly of the shuttering boards.
- Supplying of formwork to the ground by crane to the storage area.
- Follow-up of concreting by technical supervision.

These processes characterize all possible operations in the process of monolithic reinforced concrete structures construction. The following list indicates the most common processes that occur at the construction site. In the future these works will become the subject of evaluation for identifying and calculating the impact of losses.

3.2 Identification of losses occurring at the building site during the construction of monolithic reinforced concrete structures

After defining of all the processes on the building site which are associated with the construction of monolithic structures is necessary to analyze which of losses in monolithic construction can occur during the construction of structures. The analysis of the production of construction works revealed the presence of a large number of non-value adding (NVA) and non-value adding but required (NVAR) losses. For further classification we should also perform a separation into the groups on a constructive basis, thus for each type of constructions (columns, reinforced concrete walls, floor slabs) we should classify all the losses and systematize them (Table 3.1).

As a result of analysis about 240 different types of losses have been revealed for all kinds of constructions of the bay. For the convenience of further research it was decided to enlarge the group and to generalize these losses for all kinds of structures. Some insignificant losses, as well as those related to the NVAR, was abandoned. After the enlargement for all kinds of structures there are the following types of losses (31):

1) Losses due to overproduction:

– Filling of columns formwork before the end of their complete installation and inspection of the correct execution;

– Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation;

– Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns;

– Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements;

– Production of large quantities of waste (rebar off-cuts, wires, boards, etc.).

Table 3.1 Classification of all losses while the production of concrete structures.

Types of losses	Types of structures		
	Columns	Walls (diaphragms)	Slabs
Losses due to overproduction:	– filling of columns before completing their installation and validation of the performance; – installation of columns shuttering before completing the installation of reinforcement and reinforcement cages; – installation of more quantity of locking devices than provided by method statement or project design; – production of more reinforcement components than required by the task on the installation of this type of construction; – tying of the reinforcement with more quantity of knots than is required for the project; – supplying of more shuttering on the work front than it is required for the current structures of the current floor; – supplying of more concrete than it is required for the task; – production of waste, unused in the future for the construction (fragments of boards, pieces of formwork, bar cuts and etc.)	– filling of walls constructions before completing their installation and validation of the performance; – installation of walls shuttering before completing the installation of reinforcement and reinforcement cages; – installation of more quantity of locking devices than provided by method statement or project design; – production of more reinforcement components than required by the task on the installation of this type of construction; – tying of the reinforcement with more quantity of knots than is required for the project or work performance project; – supplying of more shuttering on the work front than it is required for the current structures of the current floor; – supplying of more concrete than it is required for the task; – production of waste, unused in the future for the construction (fragments of boards, pieces of formwork, bar cuts and etc.) – laying more reinforcement in the walls, rather than the project requires; – excessive vibration of the concrete structure	– slab concreting before the completing of all constructions installation of (including inflatable rubber tubes, elements forming openings and etc.); – supplying of reinforcement for the installation of slabs before the end of the formwork assembly; – installation of floor slab reinforcement before installing of trunking for networks; – installation of formwork struts before dismantling of the walls (in the future may lead to problems with the transfer of the formwork from the lower bay to the upper); – production of more reinforcing products and details than required by the instructions for mounting the monolithic slab; – tying of the reinforcement with more quantity of knots than is required for the project; – supplying of more shuttering on the work front than it is required for the current structures of the current floor; – supplying of more concrete than it is required by the task; – production of waste, unused in the future for the construction (fragments of boards, pieces of formwork, bar cuts and etc.) – laying of more reinforcement in the slab, rather than the project requires; – excessive vibration of construction concrete (can lead to layering); – additional processing of the floor slab formwork (boards and beams) in accordance with the size (wrong delivery and assembly of formwork).
Losses due to	– waiting during validation of columns	– waiting during validation of walls formwork	– waiting during validation of walls formwork installation;

waiting	formwork installation; – waiting while performing the validation column reinforcement installation; – waiting during the acceptance of finished construction products by construction supervision; – waiting for delivery of materials and products for development of structural columns (concrete, reinforcement, details); – waiting for the crane while the related processes execution (for example, when performing of concrete works at the forefront and on the lower bays stone works are carried out, with the such situation the crane work for the reinforced concrete team and masons or finishers; this situation is possible if the absence of other means of supply of materials and products for other teams in the area); – waiting for formwork supplying in the work front; – waiting of cut reinforcement; – waiting for delivery of parts, reinforcing products, etc.; – waiting for concrete delivery on the work front; – waiting for unloading of concrete into the bucket; – waiting while the receiving inspection of materials at the site; – waiting for the selection of concrete samples by site engineer or construction supervision for compression tests; – concrete maturing (technological break);	installation; – waiting while performing the validation walls reinforcement installation; – waiting during the acceptance of finished construction products by construction supervision; – waiting for delivery of materials and products for development of structural columns (concrete, reinforcement, details); – waiting for the crane while the related processes execution (for example, when performing of concrete works at the forefront and on the lower bays stone works are carried out, with the such situation the crane work for the reinforced concrete team and masons or finishers; this situation is possible if the absence of other means of supply of materials and products for other teams in the area); – waiting for formwork supplying in the work front; – waiting of cut reinforcement (vertical and horizontal); – waiting for delivery of parts, reinforcing products, etc.; – waiting for concrete delivery on the work front; – waiting for unloading of concrete into the bucket; – waiting while the receiving inspection of materials at the site; – waiting for the selection of concrete samples by site engineer or construction supervision for compression tests; – concrete maturing (technological break); – smoking breaks during the work; – idle of workers while waiting local work fronts (concrete workers wait until the workers reinforcement workers carry out their part of the	– waiting while performing the validation walls reinforcement installation; – waiting during the acceptance of finished construction products by construction supervision; – waiting for delivery of materials and products for development of structural columns (concrete, reinforcement, details); – waiting for the crane while the related processes execution (for example, when performing of concrete works at the forefront and on the lower bays stone works are carried out, with the such situation the crane work for the reinforced concrete team and masons or finishers; this situation is possible if the absence of other means of supply of materials and products for other teams in the area); – waiting for formwork supplying in the work front; – waiting of cut reinforcement (1 and 2 level of reinforcement); – waiting for preparation and submission of working welded cages required to provide the necessary thickness of the slabs; – waiting for delivery of parts, reinforcing products, etc.; – waiting for concrete delivery on the work front; – waiting during the concrete pipeline installation, installation of distribution boom, concrete pump in the convenient position for the production of works; – waiting for unloading of concrete into the bucket for stairs concreting; – waiting for the selection of concrete samples by site engineer or construction supervision for compression tests; – concrete maturing (technological break); – smoking breaks during the work; – idle of workers while waiting local work fronts (concrete

	– smoking breaks during the work; – idle of workers while waiting local work fronts (concrete workers wait until the workers reinforcement workers carry out their part of the work, for example); – delays because of preparing the necessary documentation (for the supply processes, as well as work permits, issuing tasks, planning meetings, etc.); – delays because of the installation of safety barriers, ladders, assistive devices at the work front (safety guards on formwork of columns, etc.); – losses of time while dismantling the formwork during the removal of the locks because of usage not quick release fasteners.	work, for example); – delays because of preparing the necessary documentation (for the supply processes, as well as work permits, issuing tasks, planning meetings, etc.); – delays because of the installation of safety barriers, ladders, assistive devices at the work front (safety guards on formwork of columns, etc.); – losses of time while dismantling the formwork during the removal of the locks because of usage not quick release fasteners; – losses of time during the cleaning of work front from the waste, garbage, etc.	workers wait until the workers reinforcement workers carry out their part of the work, for example); – delays because of preparing the necessary documentation (for the supply processes, as well as work permits, issuing tasks, planning meetings, etc.); – delays because of the installation of safety barriers, ladders, assistive devices at the work front (safety guards on formwork of columns, etc.); – losses of time during the cleaning of work front from the waste, garbage, etc.
Losses due to transportation (movements of structures and materials):	– moving of the bucket with the concrete mixture to the work front by crane; – supplying of cut reinforcement and products in front of works; – supplying of formwork for concreting from the ground; – delivery of concrete and mortar without organized transport scheme, without the logistical preparation and elaboration; – additional crane movements due to unloading of concrete in the bucket (in those situations where the concrete part of the bucket is required for certain concrete columns, and some for another); – moving the bucket due to the selection of concrete samples for compressive tests; – misplacement of mixture discharge zones that	– moving of the bucket with the concrete mixture to the work front by crane; – supplying of cut reinforcement and products in front of works; – supplying of formwork for concreting from the ground; – delivery of concrete and mortar without organized transport scheme, without the logistical preparation and elaboration; – additional crane movements due to unloading of concrete in the bucket (in those situations where the concrete part of the bucket is required for certain concrete columns, and some for another); – moving the bucket due to the selection of concrete samples for compressive tests; – misplacement of mixture discharge zones that can lead to increased end-time delivery of concrete,	– moving of the bucket with the concrete mixture to the work front by crane; – supplying of cut reinforcement and products in front of works; – supplying of formwork posts and concrete form panels for concreting from the ground; – delivery of concrete and mortar without organized transport scheme, without the logistical preparation and elaboration; – additional crane movements due to unloading of concrete in the bucket (in those situations where the concrete part of the bucket is required for certain concrete columns, and some for another); – moving the bucket due to the selection of concrete samples for compressive tests; – misplacement of mixture discharge zones that can lead to increased end-time delivery of concrete, because in this

	can lead to increased end-time delivery of concrete, because in this case, the driver will have to perform extra movements on the site; – improper placement of reinforcement unloading areas, products and accessories (for the same reason).	because in this case, the driver will have to perform extra movements on the site; – improper placement of reinforcement unloading areas, products and accessories (for the same reason).	case, the driver will have to perform extra movements on the site; – improper placement of reinforcement unloading areas, products and accessories (for the same reason).
Losses due to excess inventory	– excess of reinforcement products on the work front; – delivery of an excessive number of concrete due to incorrect calculations by site engineers (or foremen); – presence of an excess amount of parts, auxiliary materials and products which are not required at this stage of the work, or necessary in the future; – wrong planning of warehouse processes, difficulties in finding the necessary materials and products; – incorrect reinforcement storage conditions, as well as the formwork of walls, slabs, columns, details, supporting products; – storage of auxiliary materials needed for the production of reinforcement, concrete works on the ground; – excess reinforcement products, parts, shuttering of columns on a building site in view of the construction management personnel errors; – waste storage at the construction site, without the removal of at landfills.	– excess of reinforcement products on the work front; – delivery of an excessive number of concrete due to incorrect calculations by site engineers (or foremen); – presence of an excess amount of parts, auxiliary materials and products which are not required at this stage of the work, or necessary in the future; – wrong planning of warehouse processes, difficulties in finding the necessary materials and products; – incorrect reinforcement storage conditions, as well as the formwork of walls, slabs, columns, details, supporting products; – storage of auxiliary materials needed for the production of reinforcement, concrete works on the ground; – excess reinforcement products, parts, shuttering of walls on a building site in view of the construction management personnel errors; – waste storage at the construction site, without the removal of at landfills.	– excess of reinforcement products on the work front; – delivery of an excessive number of concrete due to incorrect calculations by site engineers (or foremen); – presence of an excess amount of parts, auxiliary materials and products which are not required at this stage of the work, or necessary in the future; – wrong planning of warehouse processes, difficulties in finding the necessary materials and products; – incorrect reinforcement storage conditions, as well as the formwork of walls, slabs, columns, details, supporting products; – storage of auxiliary materials needed for the production of reinforcement, concrete works on the ground; – excess reinforcement products, parts, shuttering of columns on a building site in view of the construction management personnel errors; – waste storage at the construction site or the work front without the removal of at landfills.
Losses due to unnecessary processing steps	– preparation of the previous work front to the following (removal of concrete, rust, correcting the structural reinforcement of the lower column) – additional processing of formwork by	– preparation of the previous work front to the following (removal of concrete, rust, correcting the structural reinforcement of the lower column) – additional processing of formwork by lubricant	– preparation of the previous work front to the following (removal of rust) – excessive watering of the concrete in the summer; – preparation of reinforcement for cutting;

	lubricant composition; – excessive watering of the concrete in the summer; – preparation of reinforcement for cutting; – bar cutting at the construction site; – preparation of formwork for concreting (cleaning, straightening, integrity checking); – finishing cutting of the reinforcement during production of reinforcement works already during installation; – lopping of concrete after concreting to the design level.	composition; – excessive watering of the concrete in the summer; – preparation of reinforcement for cutting; – bar cutting at the construction site; – preparation of formwork for concreting (cleaning, straightening, integrity checking); – finishing cutting of the reinforcement during production of reinforcement works already during installation; – lopping of concrete after concreting to the design level; – excessive heating of the concrete, installation of heated enclosure and other structures to ensure normal conditions of hardening in winter.	– cutting excessive amount thermofillers; – cutting of more plastic pipes, boxes, etc. for further electrical works; – preparation of formwork for concreting (cleaning, cutting of boards and beams, integrity checking, rejection); – finishing cutting of the reinforcement during production of reinforcement works already during installation; – lopping of concrete layer from column and wall heads after concreting to the design level; – excessive heating of the concrete, installation of heated enclosure and other structures to ensure normal conditions of hardening in winter; – finishing cutting of the reinforcement on the work front after the laying.
Losses due to unnecessary movements	– unnecessary movements of materials and products at on-site warehouse (shifting, etc.); – unnecessary tripping of various devices for conducting works: formwork panels, vibrators, etc.; – usage of the crane to perform unnecessary and extra work (moving of trash, etc.); – performing of movements in several stages, with the technology of performing fewer etc.; – unnecessary movement of parts, products and constructions by workers on the front of the work (during the tying of reinforcement); – extra columns permutation of formwork.	– unnecessary movements of materials and products at on-site warehouse (shifting, etc.); – unnecessary tripping of various devices for conducting works: formwork panels, vibrators, etc.; – usage of the crane to perform unnecessary and extra work (moving of trash, etc.); – performing of movements in several stages, with the technology of performing fewer etc.; – unnecessary movement of parts, products and constructions by workers on the front of the work (during the tying of reinforcement); – extra reshuffle of wall formwork because of violations of sequence of installation or improper schemes; – additional movements of vertical wall formwork panels, scaffolding, ladders because of unsustainable installation scheme or incorrect sequence.	– unnecessary movements of materials and products at on-site warehouse (shifting, etc.); – unnecessary tripping of various devices for conducting works: formwork panels, vibrators, tools, pipes for the concrete, the distribution boom, etc.; – usage of the crane to perform unnecessary and extra work (moving of trash, etc.); – performing of movements in several stages, with the technology of performing fewer etc.; – unnecessary movement of parts, products and constructions by workers on the front of the work (while tying of slab reinforcement); – extra reshuffle of wall formwork because of violations of sequence of installation or improper schemes; – extra replacements of formwork posts; – additional movements of scaffolding, ladders because of unsustainable installation scheme or incorrect sequence.
Losses due to the release of	– insufficient vibrating of structure during the concreting;	– insufficient vibrating of walls structure during the concreting;	– insufficient vibrating of slab structure during the concreting;

defective products	– non-compliance with standard terms of hardening of concrete; – cracks, cavities and etc. due to violations of concreting technology; – non-compliance with required temperature of concreting; – not maintaining of adequate protective layer of concrete columns; – usage of bars with rust defects; – usage of concrete with water cement ratio below or above the design (or maybe undervibrating or material separation in a body structure); – usage of reinforcement and concrete grades and classes that do not meet the design; – insufficient number of knots in the framework of the column; – incorrect horizontal and vertical installation of frame, the presence of deviations above and below; – incorrect horizontal and vertical installation of columns formwork, formwork deviation during installation; – installation obviously defective formwork for concreting; – usage of a lubricating composition with inadequate quality; – usage use of locks, hinges, clamps and further accessories, fulfilled the normative service life; – working with scaffolding, fencing and usage of personal protective equipment with not a good quality or standard exhaust lifetime; – violation of the integrity of the reinforcement	– non-compliance with standard terms of hardening of concrete; – cracks, cavities and etc. due to violations of concreting technology; – non-compliance with required temperature of concreting; – not maintaining of adequate protective layer of concrete columns; – usage of bars with rust defects; – usage of concrete with water cement ratio below or above the design (or maybe undervibrating or material separation in a body structure); – usage of reinforcement and concrete grades and classes that do not meet the design; – insufficient number of knots in the framework of the walls; – incorrect horizontal and vertical installation of cages, the presence of deviations above and below; – incorrect horizontal and vertical installation of walls formwork, formwork deviations during installation; – installation obviously defective formwork for concreting; – usage of a lubricating composition with inadequate quality; – usage use of locks, hinges, clamps and further accessories, fulfilled the normative service life; – working with scaffolding, fencing and usage of personal protective equipment with not a good quality or standard exhaust lifetime; – violation of the integrity of the reinforcement cage while the performance of works on installation of the formwork, feeding the bucket by mixture, directly	– non-compliance with standard terms of hardening of concrete; – cracks, cavities and etc. due to violations of concreting technology; – non-compliance with required temperature of concreting; – not maintaining of adequate protective layer of concrete columns; – usage of bars with rust defects; – usage of concrete with water cement ratio below or above the design (or maybe undervibrating or material separation in a body structure); – usage of reinforcement and concrete grades and classes that do not meet the design; – insufficient number of knots in the framework of the walls; – incorrect horizontal and vertical installation of formwork posts and sheeting; – installation obviously defective formwork for concreting, the presence of defective formwork; – working with scaffolding, fencing and usage of personal protective equipment with not a good quality or standard exhaust lifetime; – violation of the integrity of the reinforcement cage while the performance of works on installation of the formwork, feeding the bucket by mixture, directly concreting and vibrating; – wrong heat treatment of concrete mode (in the winter); – violation of the integrity of the finished product while dismantling wall formwork; – damaging of the formwork during the work; – violation of concreting process in the production of works (due to the failure of the crane, bucket, shuttering,

	cage while the performance of works on installation of the formwork, feeding the bucket by mixture, directly concreting and vibrating; – wrong heat treatment of concrete mode (in the winter); – violation of the integrity of the finished product while dismantling column formwork.	concreting and vibrating; – wrong heat treatment of concrete mode (in the winter); – violation of the integrity of the finished product while dismantling wall formwork; – damaging of the walls formwork during the work; – damaging of parts (locks, clamps, fittings) of walls formwork during the work; – violation of concreting process in the production of works (due to the failure of the crane, bucket, shuttering, spill of concrete mix at the front of works, etc.).	spill of concrete mix at the front of works, etc.).

2) Losses due to waiting:

– Waiting on delivery of materials and products for construction of structures (concrete, reinforcement, fixings);

– Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example);

– Waiting for the supply of means of production on the work front;

– The breaks of workers in the work process;

– The idles of workers while waiting for work front;

– Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.).

3) Losses in unnecessary transportation (moving of structures or materials):

– Large distances between on-site warehouse and the construction object;

– Damage to structures of formwork when taping of the already built structures;

– Damage to reinforcement units and fixings when applying by the crane;

– Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers);

– Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work).

4) Losses due to excess inventory:

– The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse;

– The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products;

– The mismatch of the terms of materials, structures and products storage to requirements of normative documents;

– Storage of wastes at the construction site, without exporting them to a landfill.

5) Losses due to unnecessary processing steps:

– The production of defective construction products.

– Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc.;

– The usage of materials, structures, products and etc. which are not of appropriate by design while work execution;

– The usage of methods and techniques of work which are not relevant to the project.

6) Losses due to unnecessary movements:

– The lack of discipline in the workplace (in context of materials and units transportation within the building site);

– The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan);

– Additional (unnecessary) handling of materials, structures and products on the construction site.

7) Losses due to the release of defective products:

– The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required);

– The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project);

– The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.);

– The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.).

After the identification of losses there is a necessity to assess their main characteristics: the probability of occurrence and values of the possible consequences in the time (the effect of the increase of performance time) and cost (rise in cost of construction) terms.

3.3 Assessment of the effect of losses on the cost and time of structures erection

The usage of risk assessment methods is applicable for this stage of work. For its implementation we must first write down all the losses in the table, then give them short (indicative) and full name and describe the reasons and consequences.

Table 3.2 The full description of losses at construction site.

No.	Full name	Description of sources (reasons)	Characteristic of the effect (Consequences)
1.	**Losses due to overproduction**		
1.1	– Filling of columns formwork before the end of their complete installation and inspection of the	• The inconsistency in the process of formwork at the project and processes of construction concreting.	• Underreinforcement of structures according to the project.

	correct execution	• Violation of the technology. • Mistakes of construction management personnel. • The lack of inspection by the technical supervision. • Improper organization of work in teams.	• Insufficient structural strength. • The structure is not accepted into operation by the supervision. • The development of measures on elimination of violations (disassembling or gain). • Stop of production works.
1.2	– Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation	• The inconsistency when performing reinforcement and forming processes, during forming it may be that part of the structure which can be underreinforced but validated by the quality assurance. • Violation of the technology. • Mistakes of construction management personnel. • The lack of validation by the technical supervision. • Improper organization of work in teams.	• Underreinforcement of structures according to the project. • Insufficient structural strength. • The structure is not accepted into operation by the supervision. • The development of measures on elimination of violations (dismounting of the formwork, the additional reinforcement and validation)
1.3	– Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns	• Inconsistent implementation of formworks while installing. The formwork walls can be under the formwork of slab. • Violation of the technology. • Mistakes of construction management personnel. • The lack of validation by the technical supervision. • Improper organization of work in teams.	• Remediation (removal of already installed panels and disassembly of the installed formwork at the location of the violation) • Remarks by the quality supervisor.
1.4	– Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements	• Failure of complying with conditions of the project. • Delivery to the construction site of the reinforcement which is not suitable. • Mistakes of construction management personnel. • The lack of validation by the technical supervision.	• Remediation (demolition of already fixed frames, or approval of the works) • The investigation of the causes • Stop work production
1.5	– Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)	• Violation of the technology. • Failure to comply with OSH. • Improper implementation of process. • Mistakes of construction management personnel when issuing assignments. • Improper organization of work in teams.	• Issuance of instructions and remediation (cleaning or disposal of waste in place). • Violations of the ecological and environmental legislation.
2	**Losses due to waiting**		
2.1	– Waiting on delivery of materials and products for construction of	• Logistical problems. • Inappropriate management of	• The increased waiting time of delivery and flow of

	structures (concrete, reinforcement, fixings)	materials delivery to the site. • The selection of suppliers. • Breakdowns for the delivery of goods. • Mistakes of construction management personnel at the site.	materials and products on the work front. • The slowdown in construction. • Disruptions in supplies.
2.2	– Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example	• Disabled lifts. • The lack of a clear scheme of the crane(s) work during the works. • The priority of execution of crane(s) processes is not sustained (first to serve a monolithic work, then masonry and then as a residual). • Violation of the work schedule. • Lack of coordination between the construction management personnel responsible for the production of certain types of work.	• The slowdown in the implementation of monolithic works. • The idle of workers waiting for the crane (s) • Violation of the threading of processes. • Failure to perform daily tasks or increase time of the shift.
2.3	– Waiting for the supply of means of production on the work front	• Breakdown of crane(s). • The inconsistency of work in related processes (masonry and monolithic, for example). Violation of the order of work. • Not sustained the priority of execution of a process valve(s). • Mistakes of construction management personnel and foremen.	• The slowdown in the implementation of monolithic works. • Downtime and breaks. • Increasing the time of erection of structures
2.4	– The breaks of workers in the work process	• The violation of labor discipline. • The time waiting for your processes. • Low speed of execution. • The low complexity of some processes, resulting in part of the crews appears to be vacant. • The lack of proper attention on the part of foremen, technicians and engineers.	• The increase in total construction time. • Low labour productivity. • The slowdown in the construction of structures.
2.5	– The idles of workers while waiting for work front	• The inconsistency of the works production (steel fixers wait assemblers, concrete workers wait assemblers and etc.) due to the difference in the complexity of the processes. • The lack of a detailed schedule of execution of works and measures to prevent downtime of certain parts of a monolithic team. • Violation of the threading process.	• Increasing the time of erection of structures. • Violation of the threading processes. • Reducing productivity and as a consequence the failure of the daily (shift) tasks
2.6	– Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.)	• Mistakes of construction management personnel. • Lack of coordination between the engineers responsible for the production of certain types of work. • The complexity and restraint of workflow on the construction site and at the enterprise..	• Stopping of the process. • The slowdown in the construction of structures. • The increasing of total construction time

3	**Losses in unnecessary transportation (moving of structures or materials)**		
3.1	– Large distances between on-site warehouse and the construction object	• The incorrectness of the organization of on-site areas. • Mistakes of construction management personnel. • Mistakes of the responsible personnel for unloading of materials and products. • Errors in the design (Method Statements for crane operation, work performance project and etc.)	• Increasing of the delivery time of materials and products in the scope of work • Inconsistency of warehousing • The shifting and dragging of materials and products
3.2	– Damage to structures of formwork when taping of the already built structures	• The operator error. • Errors of workers accepting the goods.	• Stop of production at the site. • The declining growth and productivity of works. • Replacement of defective or broken structures or defects rectification in place.
3.3	– Damage to reinforcement units and fixings when applying by the crane	• The operator error. • Errors of workers accepting the goods.	• Replacement of defective or broken structures or defects rectification in place. • The declining growth and productivity of works. • The delay of production at this stage of execution of works.
3.4	– Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)	• The lack of strictly logistics system. • The unreliability of suppliers. • Errors in the design of delivery of materials to the construction site.	• Waiting for delivery of concrete and mortar for production of work. • Disruptions in supplies. • Decline in production work and increase of shift time.
3.5	– Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work)	• Errors in the design. • Mistakes of construction management personnel when placing zones of discharge. • The incorrectness of the organization of on-site areas.	• Increasing of the submission time of the work front. • Moving and shifting from places of unloading to storage sites. • Downtime and increasing the time of construction.
4	**Losses due to excess inventory:**		
4.1	– The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse	• Mistakes of construction management personnel at the organization of storage processes. • The increased volume of ordered materials. • Storage "in reserve".	• Surplus of stock materials. • The violation of storage conditions and condition of materials, structures and products. • The increased percentage of defective materials. • The increased cost of construction due to reordering of materials and products
4.2	– The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products	• Error engineers at the organization of process of storage. • The lack of incoming materials accounting. • The lack of organization of storage	• The lack of a clear organization and planning of warehouse processes. • The difficulty of finding the necessary materials and

		sites.	products at the on-site warehouse. • Additional relocation and shifting.
4.3	– The mismatch of the terms of materials, structures and products storage to requirements of normative documents	• The violation of the technology and storage conditions.	• The violation of storage conditions and condition of materials, structures and products. • The increased percentage of defective materials. • The decline of construction quality. • Reorder of materials and products.
4.4	– Storage of wastes at the construction site, without exporting them to a landfill	• The violation of environmental and ecological requirements. • The violation of safety rules on the site. • Neglecting by the engineers. • The violation of work discipline.	• Issuance of instructions from supervisory authorities. • Cluttering of the site. • The violation of ecological requirements. • Further difficulties in recultivation and the surface infrastructure development of the finished construction project.
5	**Losses due to unnecessary processing steps**		
5.1	– The production of defective construction products	• The violation of production technology. • The use of defective materials, parts and products • The absence of technical supervision. • The illiteracy of workers, foremen, construction management personnel.	• The decline of the construction quality. • Interruption of work because of remarks issued by technical supervision. • The demolition or strengthening of already made or defective structures. • The production of new structures to replace the demolished
5.2	– Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc.	• The violation of technology of work production. • Violations of the processes of installation (dynamic, static exposure). • The usage of materials and products of improper quality. • The lack of sufficient qualified workers.	• The increasing total construction time. • The suspension of production for the correction time. • The slowdown of the work performance.
5.3	– The usage of materials, structures, products and etc. which are not of appropriate by design while work execution	• The selection of suppliers. • Violations of the construction management personnel. • Cheapening of construction directly on the site. • The lack of inspections by technical supervision.	• Verification of performed work for inconsistencies • Stop production until the circumstances are identified. • Investigating and identifying the causes by technical supervision.
5.4	– The usage of methods and techniques of work which are not relevant to the project	• Crude violations by the construction management and foremen.	• Verification of performed work for inconsistencies • Stop production until the

		• Violations of technology of work performance. • The lack of inspection by the engineers and technical supervision.	circumstances are identified. • Investigating and identifying the causes by technical supervision.
6	**Losses due to unnecessary movements:**		
6.1	– The lack of discipline in the workplace (in context of materials and units transportation within the building site)	• The violation of the sequence of works execution. • Violations in the field of HSE. • Not fulfilling the requirements of the instructions, routings, construction management plan and work performance project.	• The decline in productivity. • The increase in construction time. • The decline of construction quality. • The slowdown in the performance of work.
6.2	– The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)	• Not fulfilling the requirements of the instructions, routings, construction management plan and work performance project. • Qualifications of workers and foremen. • Mistakes of construction management personnel at the site. • The lack of a clear system of running the processes directly on the site.	• The decline of productivity. • The slowdown and the increase of production time.
6.3	– Additional (unnecessary) handling of materials, structures and products on the construction site	• The lack of a clear sequence of processes. • The lack of a clear line of movement and supply of materials • Violations in the design of on-site warehouses. • Mistakes of construction management personnel. • The errors of the workers and foremen.	• Downtimes when performing these processes. • The decreasing of performance. • The increasing terms of erection of structures.
7	**Losses due to the release of defective products:**		
7.1	– The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)	• Errors of workers, foremen. • Mistakes of construction management personnel. • The lack of technical supervision. • The usage of defective materials, products, designs, etc. • Violations of technology of works performance. • Violations in the design. • Delivery of materials and products from unscrupulous suppliers.	• The production of defective products. Stop the production and issuance of instructions. • The demolition or strengthening of already made or defective structures. • Production of new structures instead of demolished. • Elimination of defects. • Increasing the time of work.
7.2	– The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project);	• Errors of workers, foremen. • Mistakes of construction management personnel. • The lack of technical supervision. • The usage of defective products, etc. • Violations of technology of works performance. • Violations in the design.	• The production of defective products. Stop the production and issuance of instructions. • The demolition or strengthening of already made or defective structures. • Production of new structures instead of demolished. • Elimination of defects.

		• The supply of accessories and parts from unscrupulous suppliers	• Increasing the time of work.
7.3	– The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)	• Errors of workers, foremen. • Mistakes of construction management personnel. • The lack of technical supervision. • The usage of defective products, etc. • Violations of technology of works performance. • Violations in the design and choosing of the formwork.	• The production of defective products. Stop the production and issuance of instructions. • The demolition or strengthening of already made or defective structures. • Production of new structures instead of demolished. • Elimination of defects. • Increasing the time of work.
7.4	– The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)	• Errors of workers, foremen. • Mistakes of construction management personnel. • Violations of working conditions. • The lack of checks by management personnel, technical supervision. • The lack of strictly reporting on coaching in the workplace. • The lack of PPE issuing system • The violation of labor discipline.	• Violation of the legislation in the field of occupational and industrial safety. • Issuance of instructions and the elimination of violations. • Occupational injuries. • Investigation by HSE service of the company.

In the risk management process there is a big role of expert assessments: quantitative or qualitative evaluations of objects, processes or phenomena that are not directly measurable. Expert assessments are used to find occurrence probabilities of problem situations, assessing the significance of the signs (which are valued solutions), the coefficients of expert's evaluations of alternatives according to various criteria, etc. In our case, expert evaluation will be used to identify the most influencing losses at the construction site.

For expert assessments, a working group is created, which organizes the activities of experts constituting the so-called expert comission [45].

The sequence of operations for expert assessment of risks is determined on the basis of the existing recommendations [46]:

1. Making the decision of the expert survey necessity, formulation and foundation for its purpose.
2. Selection and appointment of the basic composition of the working group.
3. Formation of the working group and approval of the terms of reference for carrying out expert survey.
4. Development by the analytical group of the detailed script of the collection and analysis of expert opinions (assessments).
5. Selection of experts in accordance with their competence. Differentiated assessment of the level of scientific expertise is set, which is confidential. The estimation is made on the base of 3-point scale, as follows: experts with a high level of competence assigned 3 points, with the average - 2 and low - 1.

6. Data collection of expert information. Experts estimate the risk in terms of occurrence probability of a negative situation (on a scale) and the amount of loss in the event of its occurrence (on a scale), thus the index is calculated for each risk.

7. Assessments are marked by experts for each type of risk and summarized in the table, the form of which is given in Annex 2. They determined the risk index taking into account the level of competence of the expert.

8. Final analysis of expert opinions and preparation of the final document. The evaluation of risks is carried out by their ranking: the location of risks in accordance with pre-defined criteria, i.e., development of the risks rating. This rating provides the basis for the preparation of measures in order to reduce the degree of risks exposure to acceptable level and the allocation of resources to process them.

9. The official end of the group work.

By the following procedure the expert assessment of the identified losses is carried out for monolithic construction. Various specialists are taking part in the survey who have experience on the objects of civil and industrial construction in St. Petersburg, Moscow, Krasnodar, Anapa and other cities. The survey attended by engineers of operation and technical department, foremen and site engineers of construction and installation work, chiefs of sites, supply engineers, designers and managers of areas for technical supervision and construction control.

While using the method of expert assessment there is a possibility of using intuition, life and professional experience of all survey participants. The usage of this method in this case is the most appropriate, because the lack or total absence of information does not allow the usage of other features. The method is based on carrying out the survey of independent experts to assess the level of risk (or loss influence). The major limitation in its usage is the difficulty of finding the necessary expert group.

The expert selection problem is one of the most important in this process. Under the competence we need to understand the degree of expert qualification in a particular field of knowledge. Competence can be defined on the base of professional activity analysis, the level and breadth of knowledge of science and technology, understanding of the issues under study, as well as possible solutions to them [47]. In details the process of determining the degree of competence was described in Chapter 2.

As it has been described previously, the registry of qualities that should be possessed by the expert, which assess the risks, with whom it is preferable to operate:

- employment period;
- level and profile of education;
- profile of the work performed;
- level of solving problems;
- quantity and level of projects in which the expert participated.

The first step is to determine the weight of importance of each quality which should be possessed by the expert. The matrix of preferences is formed on the base of pair-wise comparisons of qualities method. Pair-wise comparison, in that turn, is the objects establishment procedure by comparing all possible pairs. While comparing any pair of objects it is may be the strict order relation or relation of equivalence. The results of the comparison of all pairs are collected in Table 3.2. The most preferred quality having the highest score is assigned rank equal 1, the second - rank equal 2, etc. The equivalent quality is assigned by the same rank.

The coefficient of significance or weight of j-quality is determined by the formula 3.1:

$$V_i = \frac{x_{ci}}{n^2} \qquad (3.1)$$

The results of evaluation of the weight of importance of *i*-th quality are presented in table 3.3.

Table 3.3 The formation of the preference matrix.

Quality	Employment period	Level and profile of education	Profile of the work performed	Level of solving problems	Quantity and level of projects…	Assessment of quality	The rank of quality	The weight of significance
Employment period	1	2	1	1	0	5	2	0,2174
Level and profile of education	0	1	1	1	1	4	3	0,1739
Profile of the work performed	0	1	1	0	1	3	4	0,1304
Level of solving problems	1	1	1	1	0	4	3	0,1739
Quantity and level of projects…	2	1	1	1	1	6	1	0,2609
					Total	23		

By preference matrix results it can be concluded that such qualities as "Employment period" and "Quantity and level of projects…" with R = 2 and V_i = 0,2174 and R = 1 and V_i = 0,2609 and are the most significant. [49]

In the second stage the level of competence of experts is determined. The most commonly used methods are: self-estimation, peer assessment of expert competence, as well as tests for professional suitability. 3 experts have done the assessment of the experts qualities, who worked with the questionnaires. 16 experts participated in survey; each of them had a certain set of qualities, detailed on the 4 levels:

– high (estimated at 40 points);
– above-average (30 points);
– average (20 points)
– low (10 points).

The results of the evaluation of experts' properties are shown in Annex 2. The total score obtained by each expert is determined by the formula 3.2:

$$A_l = \sum_{j=1}^{m} V_i \cdot a_{ijl} \qquad (3.2)$$

where V_{in} is the weight of significance of i-quality;

a_{ijl} is the rating of i-th quality of l-th expert assessing the risks made by j-th expert.

Next, the level of competence of the expert is determined based on the following conditions:

– $A_l < 20$, the level of competence is 1;

– $20 \le A_l < 30$, the level of competence equal to 2;

– $A_l \ge 30$, the competence level is 3.

Expert evaluation results are shown in the histogram:

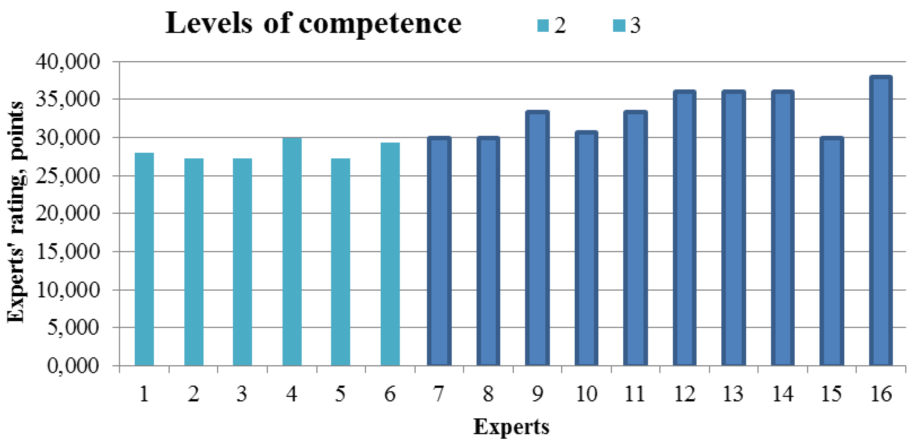

Figure 3.1 – The evaluation of the level of experts' competence.

It can be concluded that in the expert assessment of the impact of losses on the execution of monolithic concrete works 10 experts from the third level of competence and 6 with the second level of competence are involved.

The subjective measurements of objects are produced during performance of expert assessments that are not directly measurable. The most commonly used tools are ranking, paired comparison, direct evaluation and serial comparison.

We should take into account the possibility of communication between experts, because this factor can seriously affect assessment results. In the theory of risk management there are the following methods of communication experts: lack of communication, part-time anonymous communication, correspondence communication without anonymity, face-to-face communication with constraints, face-to-face communication without constrains. In this master thesis personal communication of experts is not present, the questionnaires are carried out individually.

As the object for assessment the bay of 9-three-storey residential building in Voronezh was selected. The floor height is 3 m. Section in plan is conventionally rectangular with the dimensions 20x32 m. Column grid is 6,0x6,0 m. The composition of the one bay constructions:

- concrete columns: 400x400 mm– 24 pcs.
- concrete walls: 6,0x3,0x0,2 m– 14 pcs; 3,0x3,0x0,2 - 1 pc.
- concrete slab: 20x32x0,2 m.

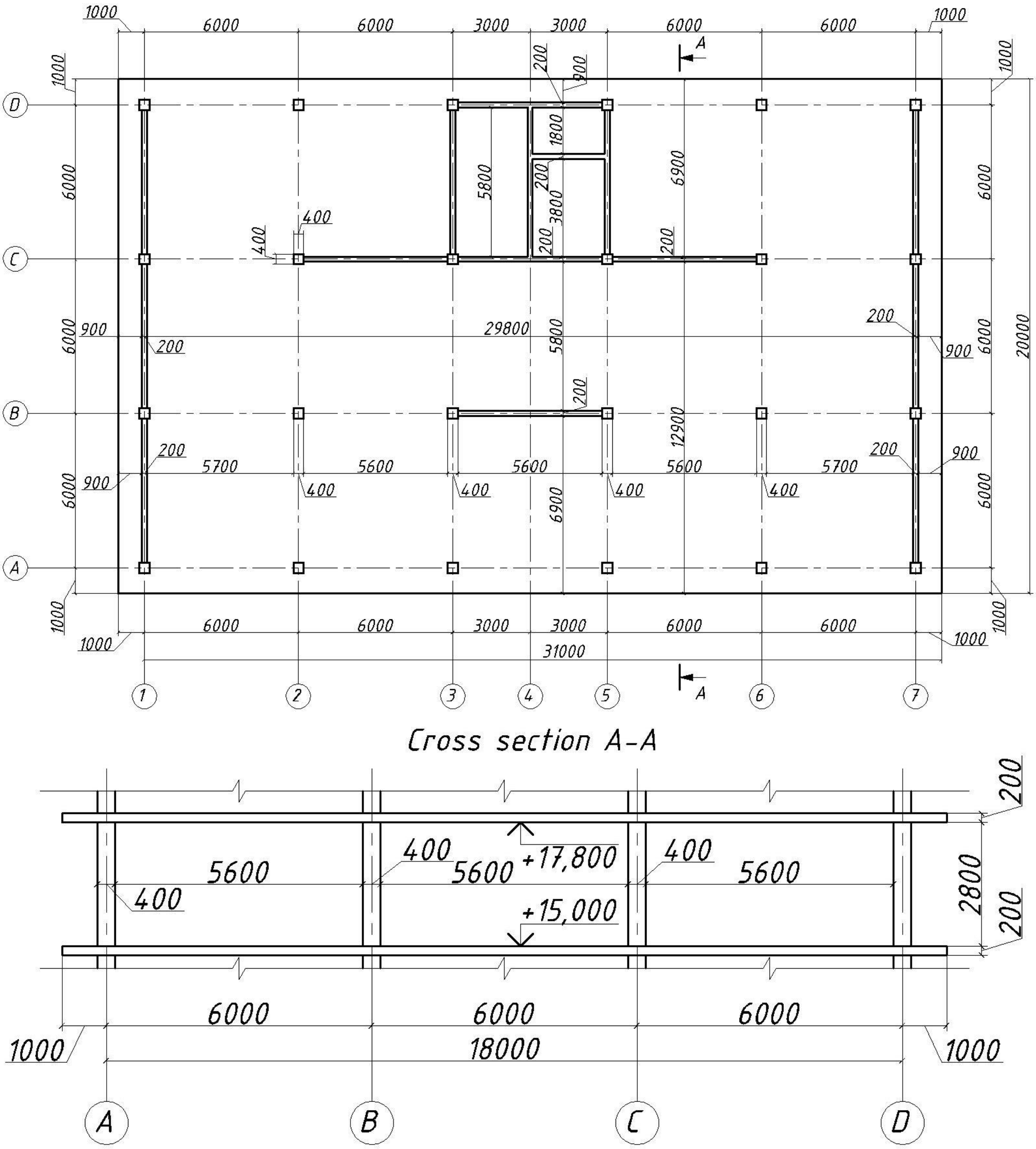

Figure 3.2 – The model of typical bay for estimation.

Experts have estimated losses from the point of view of their probability P_q and the value of the impact on the cost and construction time in case of their occurrence, I_c and I_t, the index is calculated for each risk according to these indicators. The questionnaire completed by each expert is listed in Annex 3.

Assessment marks of experts for each type of loss are in the table, the pattern of which is set out in Annex 3. Then the risk index taking into account the level of competence of the expert is determined.

Assessment of losses is carried out by constructing the matrix of "probability-losses". The main advantages of using this method are shared by the clarity, simplicity and the ability to obtain a detailed view about negative situations and consequences that are possible in the future. While determining the level of loss impact on time and cost of construction the 5-stage scale should be used which is presented in Tables 3.4 and 3.5. In order to assess the probability of losses occurrence, the scale with five intervals is also used: from complete uncertainty with a probability close to 0 to full certainty with probability close to 1. It is presented in Table 3.6.

Table 3.4 The scale of assessment of the losses impact on the cost of construction.

Description of the degree of influence on the construction cost (cost increasing in %)	**The rating level in points corresponding to the description**
up to 20%	1
21-40%	2
41-60%	3
61-80%	4
81-100%	5

Table 3.5 The scale of assessment of the losses impact on the timeline.

Description of the degree of influence on the construction time (the increasing of time limits in %)	**The rating level in points corresponding to the description**
up 20%	1
21-40%	2
41-60%	3
61-80%	4
81-100%	5

Table 3.6 The scale of probability occurrence of these losses.

Verbal description of probability (qualitative description of the confidence level)	**The rating level in points corresponding to the description,%**
Practically don’t occur while performing work, appear rarely and randomly	up to 20%(1)
These phenomena appear at the construction site periodically and disposable in place	21-40%(2)
More frequency of occurrence, mainly because of problems in planning and organization	41-60%(3)
Almost recurring losses, indicate violations in the construction technology, planning and organizing	61-80%(4)
The constant availability of these losses on the construction site, the inability to eliminate	81-100%(5)

Index of each loss (in points) is determined by the formulas 3.3 and 3.4 [47,51]:

$$R_{ic} = P_i \cdot I_{ic}\,, \tag{3.3}$$

$$R_{it} = P_i \cdot I_{it}\,. \tag{3.4}$$

For determining the final index of loss it should be taken into account the level of expert competence. In order to do this, the index of loss, stated by particular expert, and the level of expert competence are multiplied.

The average statistic value (in points) is determined by the formula 3.5:

$$R_{iavc,iavt} = \frac{\sum_{j=1}^{n} R_{ij}}{m}\,, \tag{3.5}$$

where m is the sum of the levels of expert competence.

In Annex 3 Tables 3.1.1-3.1.5 present results of expert assessment of losses due to overproduction, Tables 3.2.1-3.2.6 of losses due to waiting, Tables 3.3.1 - 3.3.5 – losses due to unnecessary transportation, Tables 3.4.1-3.4.4 – losses due to excess of inventory, Tables 3.5.1-3.5.4 – losses due to unnecessary processing steps, in Tables 3.6.1-3.6.3 – losses due to unnecessary movements and Tables 3.7.1-3.7.4 – losses due to the production of defective products. Tables 3.8, 3.9 and 3.10 summarize the results of the expert assessments.

The degree of coherence of the i-th loss is determined by the coefficient of variation [48] according to the formula 3.6:

$$W_l = \frac{\sqrt{\frac{\sum_{j=1}^{m}\left(x'_{ij} - \overline{x'}\right)^2 \cdot m_i}{m}}}{R_{iavc,iavt}}\,, \tag{3.6}$$

where x'_{ij} is the rating of the j-th expert for the i-th loss in accordance with the result of the survey;

m_i is the level of competence of j-th expert.

3.3.1 Results of the assessment of losses due to overproduction

Tables 3.8 and 3.9 of Annex 3 summarize the results of expert assessment of losses due to overproduction. The weight of each loss has been determined; the results are presented on Figures 3.3 and 3.4.

The degree of consistency of expert assessments of losses due to overproduction is presented on Figure 3.5 and 3.6.

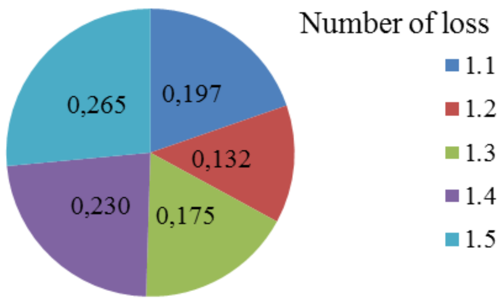

Figure 3.3 The weight of losses due to overproduction which influence on construction cost.

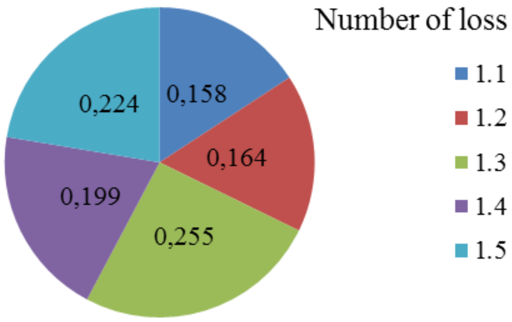

Figure 3.4. The weight of losses due to overproduction which influence on construction time.

According to the charts, the greatest weight in the structure of losses due to overproduction in cost terms have losses 1.4 "Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements" and 1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.). The greatest weight in the structure of losses due to overproduction in the time terms have losses 1.3 "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns" и 1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)".

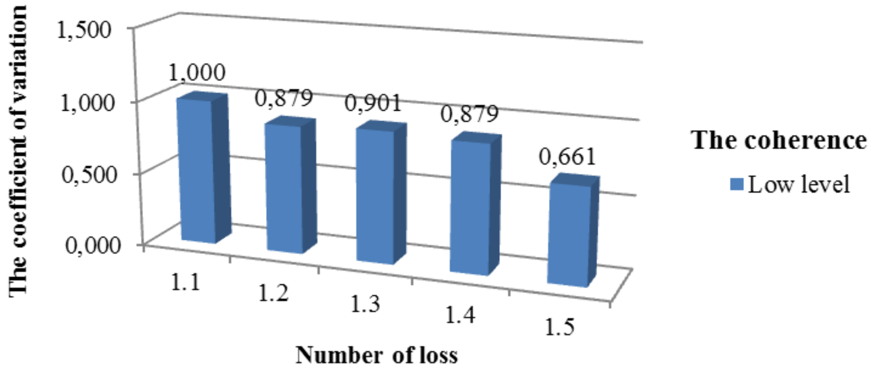

Figure 3.5 The degree of consistency of expert assessments of losses due to overproduction in value terms.

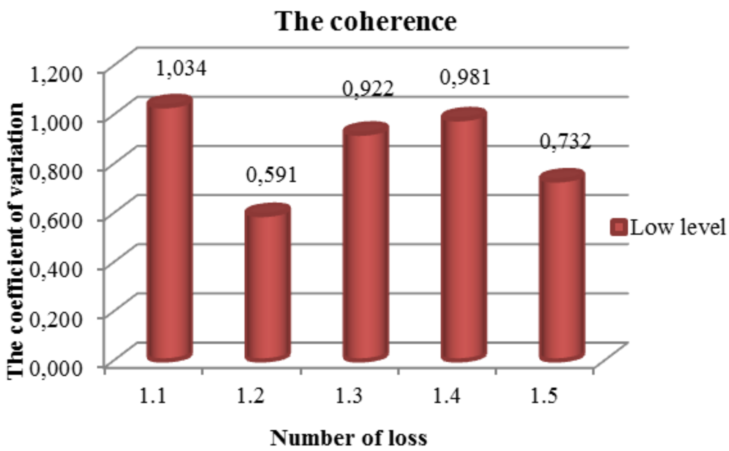

Figure 3.6 The degree of consistency of expert assessments of losses due to overproduction in time terms.

The largest discrepancy of the expert's assessments had observed in the analysis of loss 1.1 "Filling of columns formwork before the end of their complete installation and inspection of the correct execution", the values of the coherence coefficient for which turned out to be 1.000 for impact on cost and 1.034 on time of construction. The experts were the most consistent in assessing of the loss 1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)": 0.661 and 0.732 respectively.

Figure 2.7 presents the results of the average estimation of losses due to overproduction. As it can be seen from Figure 2.7, such losses as 1.4 "Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements" and 1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)" are the most influencing on the cost of construction, and 1.3 "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns" and 1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)" – on the time of construction.

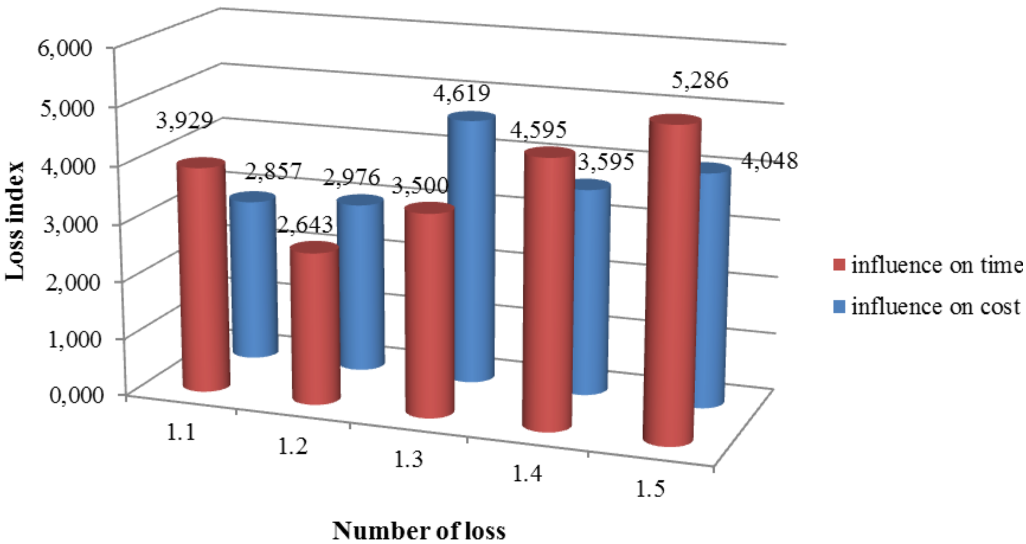

Figure 3.7 The average statistic assessment of losses due to overproduction.

3.3.2 Results of the assessment of losses due to waiting

Tables 3.10 and 3.11 of Annex 3 summarize the results of expert assessment of losses due to waiting. The weight of each loss has been determined; the results are presented on Figures 3.7 and 3.8.

The degree of consistency of expert assessments of losses due to waiting is presented on Figure 3.9.

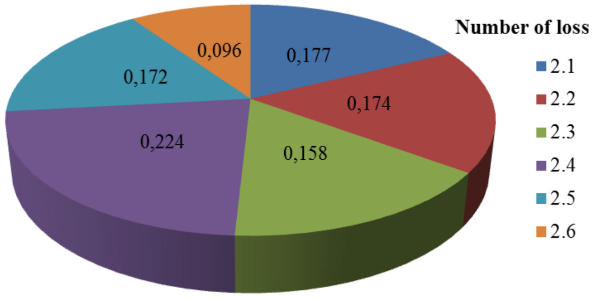

Figure 3.8 The weight of losses due to waiting which influence on construction cost.

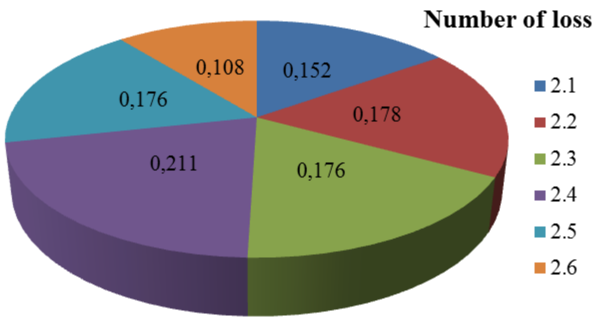

Figure 3.9 The weight of losses due to waiting which influence on construction time.

According to the charts, the greatest weight in the structure of losses due to waiting in cost terms have losses 2.1 “Waiting on delivery of materials and products for construction of structures (concrete, reinforcement, fixings)” and 2.4 “The breaks of workers in the work process”. The greatest weight in the structure of losses due to overproduction in the time terms have losses 2.2 “Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example)” and 2.4 “The breaks of workers in the work process”.

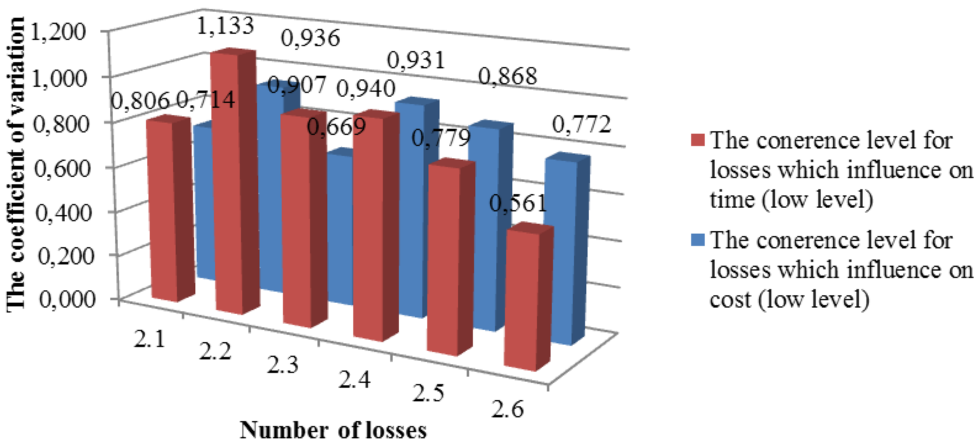

Figure 3.10 The degree of consistency of expert assessments of losses due to waiting.

The degree of consistency between experts in the assessment of losses due to waiting is also low. The largest discrepancy of the experts assessments had observed in the analysis of losses 2.2 “The execution of the related processes by crane (using a crane(s) for the production of monolithic and masonry work at the same time, for example)” with value 1.133 for the construction period and 0.936 for the cost. The lowest values of this indicator are for loss of 2.6 “Outages during the preparation of the documentation (documentation for the supply and preparation of permits, issuing assignments, plans, etc.)” with rates 0,561 and 0,722 respectively.

Figure 3.11 presents the results of the average assessment of losses due to waiting. As it can be seen from Figure 3.11, such losses as 2.1 "Waiting for delivery of materials and products for construction of structures (concrete, reinforcement, fixings)" and 2.4 "The smoke breaks of workers in the work process" are the most influencing on the cost of construction, and 2.3 "Waiting for the supply of means of production on the work front", 2.4 "The smoke breaks of workers in the work process", 2.5 "The idles of workers while waiting for work front " – on the time of construction.

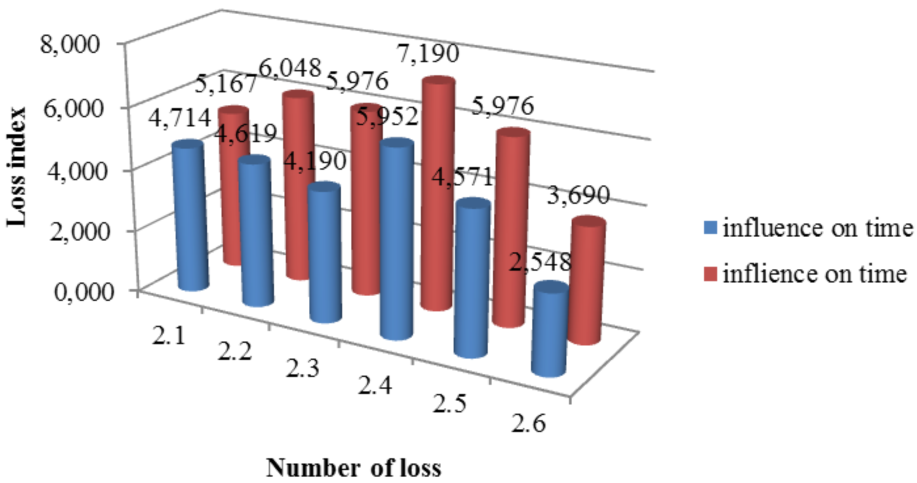

Figure 3.11 The average statistic assessment of losses due to waiting.

3.3.3 Results of assessment of losses due to unnecessary transportation (moving of structures or materials)

Tables 3.12 and 3.13 of Annex 3 summarize the results of expert assessment of losses due to unnecessary transportation (moving of structures or materials). The weight of each loss has been determined; the results are presented on Figures 3.12 and 3.13.

The degree of consistency of expert assessments of losses due to unnecessary transportation is presented on Figure 3.14.

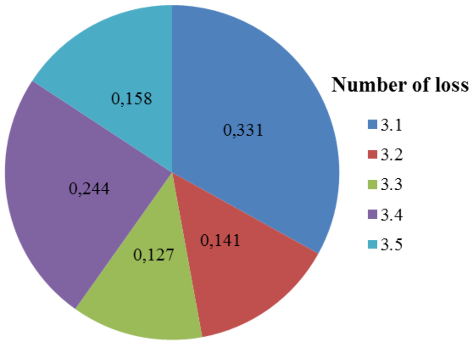

Figure 3.12 The weight of losses due to unnecessary transportation (moving of structures or materials) which influence on construction cost.

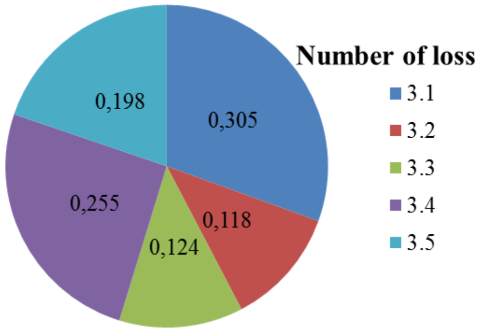

Figure 3.13 The weight of losses due to unnecessary transportation (moving of structures or materials) which influence on construction time.

According to the charts, the greatest weight in the structure of losses due to unnecessary transportation (moving of structures or materials) in cost terms have losses 3.1 “Large distances between on-site warehouse and the construction object” and 3.4 “Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)”.

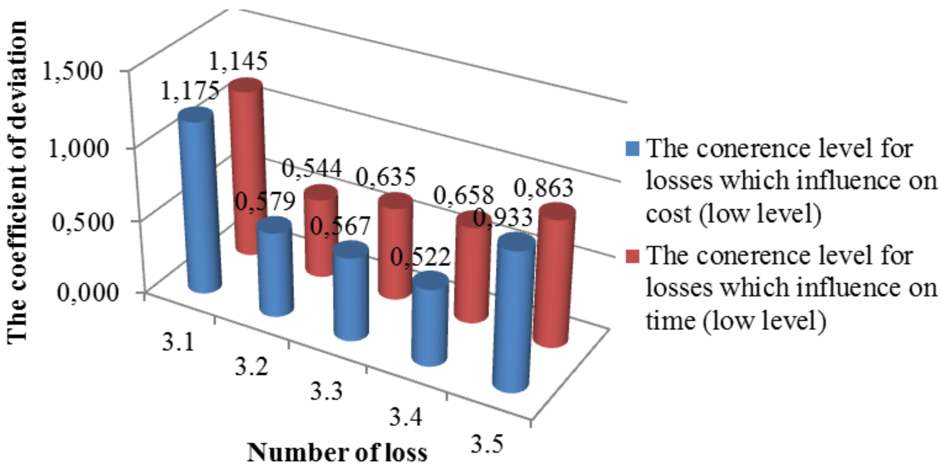

Figure 3.14 The degree of consistency of expert assessments of losses due to unnecessary transportation (moving of structures or materials).

The degree of consistency between experts in the assessment of losses due to unnecessary transportation is low. The largest discrepancy of the experts’ assessments had observed in the analysis of losses 3.1 “Large distances between on-site warehouse and the construction object” with the coefficient 1.175 for the cost and 1.145 for the construction period. The lowest values of this indicator are for loss of 3.2 “Damage to structures of formwork when taping of the already built structures” with rates 0,561 and 0,722 respectively.

Figure 3.15 presents the results of the average estimation of losses due to unnecessary transportation (moving of structures or materials). As it can be seen from Figure 3.15, such losses as 3.1 "Large distances between on-site warehouse and the construction object" and 3.4 "Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)" are the most influencing on the cost and time of construction.

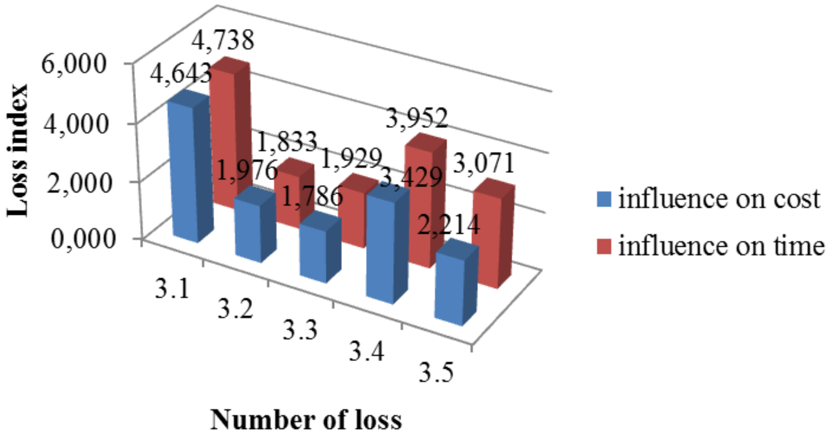

Figure 3.15 The average statistic assessment of losses due to unnecessary transportation (moving of structures or materials).

3.3.4 Results of the assessment of losses due to excess inventory

Tables 3.14 and 3.15 of Annex 3 summarize the results of expert assessment of losses due to excess inventory. The weight of each loss has been determined; the results are presented on Figures 3.16 and 3.17.

The degree of consistency of expert assessments of losses due to excess inventory is presented on Figure 3.18.

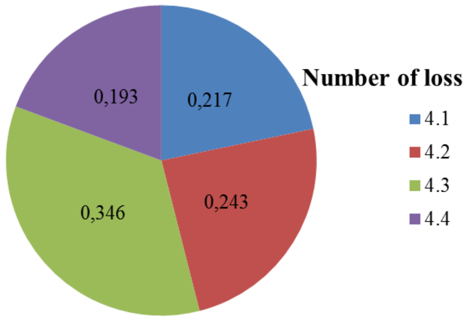

Figure 3.16 The weight of losses due to excess inventory which influence on construction cost.

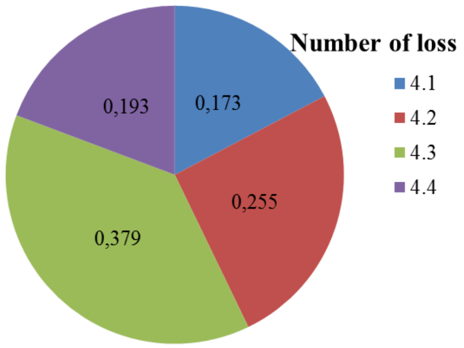

Figure 3.17 The weight of losses due to excess inventory which influence on construction time.

By results of calculations it was obtained that the largest weight in the structure of losses due to excess inventory have losses 4.2 “The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products” and 4.3 “The mismatch of the terms of materials, structures and products to storage requirements of documents” both in time and cost terms.

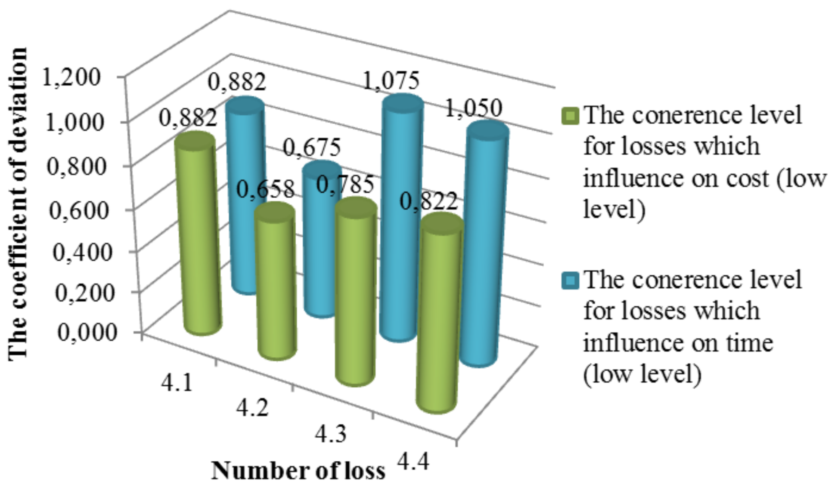

Figure 3.18 The degree of consistency of expert assessments of losses due to excess inventory.

As it can be seen from the charts shown on Figure 3.18, the level of consistency of experts is quite low. The smallest inconsistency in expert estimates show losses 4.4 “Storage of waste on the construction site, without exporting them to a landfill”, the biggest one is for 4.2 “The absence of a system of accounting and planning on the territory of the reserve, the difficulty in finding the necessary materials and products”.

Figure 3.19 presents the results of the average estimation of losses due to excess inventory. As it can be seen from Figure 3.19, such losses as 4.2 "The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products" and 4.3 "The mismatch of the terms of materials, structures and products storage to requirements of normative documents" are the most influencing on the cost and time of construction.

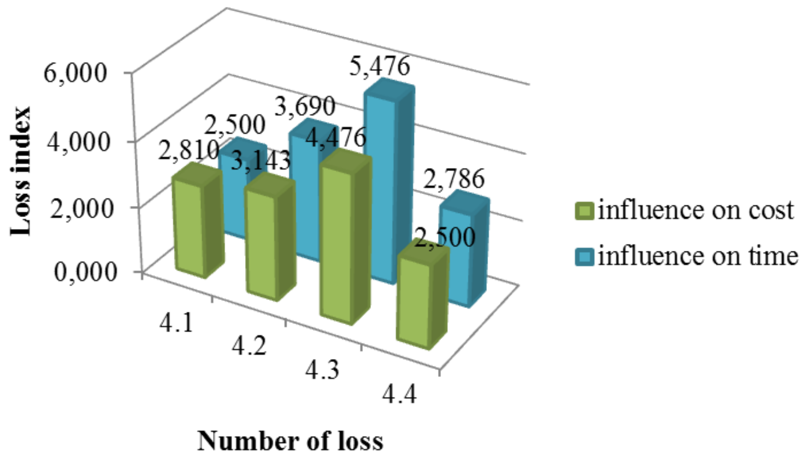

Figure 3.19 The average statistic assessment of losses due to excess inventory.

3.3.5 Results of the assessment of losses due to unnecessary processing steps

Tables 3.16 and 3.17 of Annex 3 summarize the results of expert assessment of losses due to unnecessary processing steps. The weight of each loss has been determined; the results are presented on Figures 3.20 and 3.21.

The degree of consistency of expert assessments of losses due to unnecessary processing steps is presented on Figure 3.22.

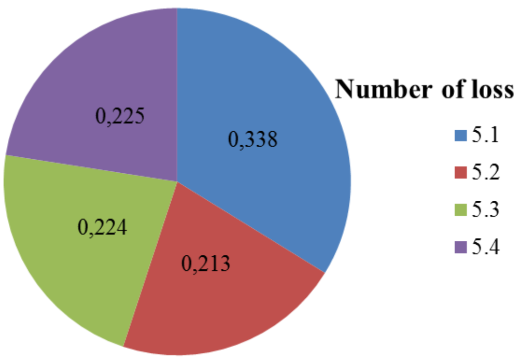

Figure 3.20 The weight of losses due to unnecessary processing steps which influence on construction cost.

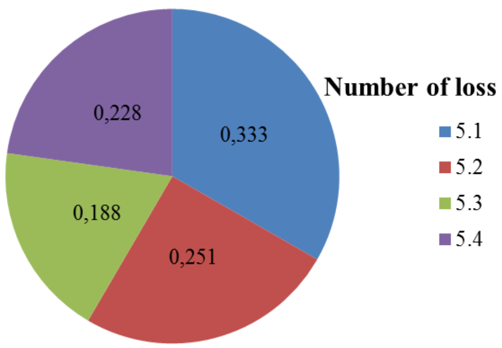

Figure 3.21 – The weight of losses due to unnecessary processing steps which influence on construction time.

As can be seen from the charts on figures 3.20 and 3.21, the largest weight among this type of losses have 5.1 “The production of defective construction products” and 5.2 “Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc.”.

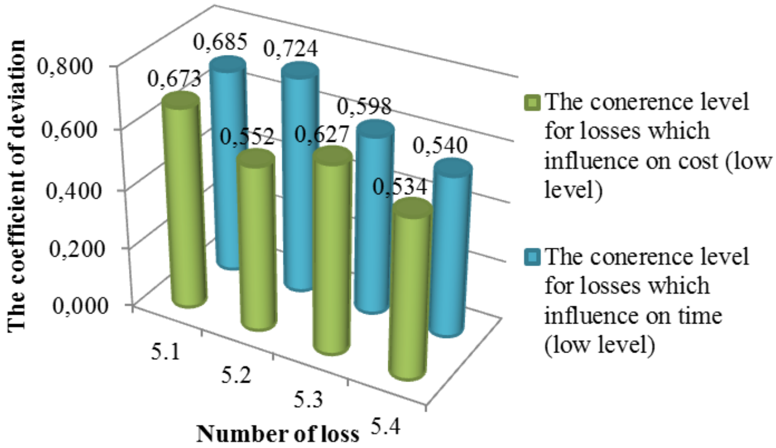

Figure 3.22 The degree of consistency of expert assessments of losses due to unnecessary processing steps.

Figure 3.22 shows that the experts were more consistent in assessing of this type of losses. However, the greatest differences were found when assessing the loss 5.1 “The production of defective construction products” and the lowest – 5.4 “The usage of methods and techniques of work which are not relevant to the project”.

Figure 3.23 presents the results of the average estimation of losses due to unnecessary processing steps. As it can be seen from Figure 3.23, such losses as 5.1 "The production of defective construction products" and 5.4 "The usage of methods and techniques of work which are not relevant to the project " are the most influencing on the cost and 5.1 "The production of defective construction products" and 5.2 "Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc." – on time of construction.

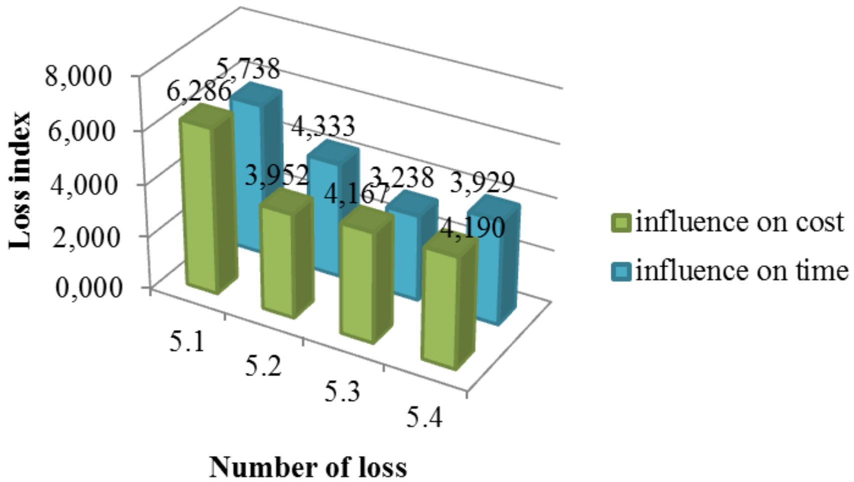

Figure 3.23 The average statistic assessment of losses due to unnecessary processing steps.

3.3.6 Results of the assessment of losses due to unnecessary processing steps

Tables 3.18 and 3.19 of Annex 3 summarize the results of expert assessment of losses due to due to unnecessary processing steps. The weight of each loss has been determined; the results are presented on Figures 3.24 and 3.25.

The degree of consistency of expert assessments of losses due to unnecessary processing steps is presented on Figure 3.26.

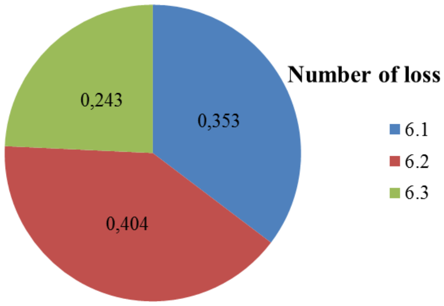

Figure 3.24 The weight of losses due to unnecessary processing steps which influence on construction cost.

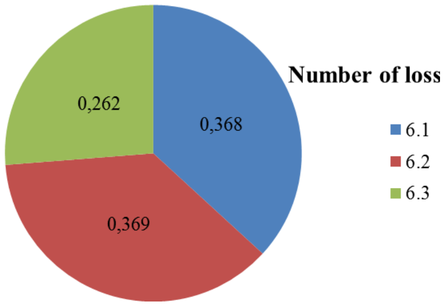

Figure 3.25 The weight of losses due to unnecessary movements which influence on construction time.

As can be seen from the diagrams the weights of the losses due to unnecessary movements in cost and time terms, the largest weight in loss structure has loss with number 6.2 “The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)”, lowest has 6.1 “The lack of discipline in the workplace (in context of materials and units transportation within the building site)”.

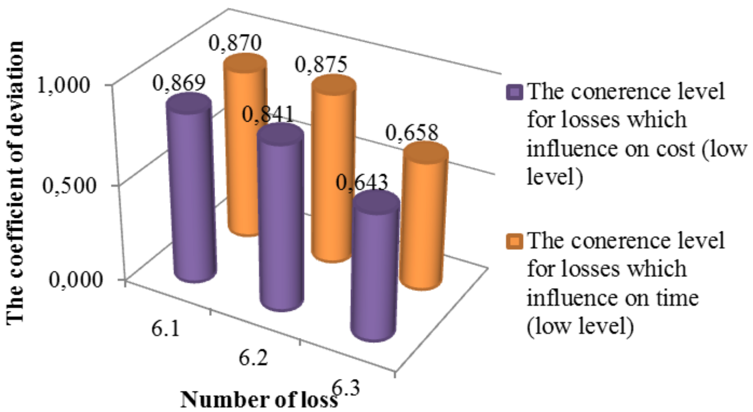

Figure 3.26 The degree of consistency of expert assessments of losses due to unnecessary movements.

The histogram of the degree of expert's coherence in the assessment of losses due to unnecessary processing steps shows low coherence of experts. The highest coefficient of variation was obtained for the loss 6.1 "The lack of discipline on the workplace (in context of materials and units transportation within the building site)", the lowest for 6.3 "Additional (unnecessary) handling of materials, structures and products on the construction site".

Figure 3.27 presents the results of the average estimation of losses due to unnecessary processing steps. As it can be seen from Figure 3.27, such losses as 6.1 "The lack of discipline in the workplace (in context of materials and units transportation within the building site)" and 6.2 "The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)" are the most influencing on the cost and time of construction.

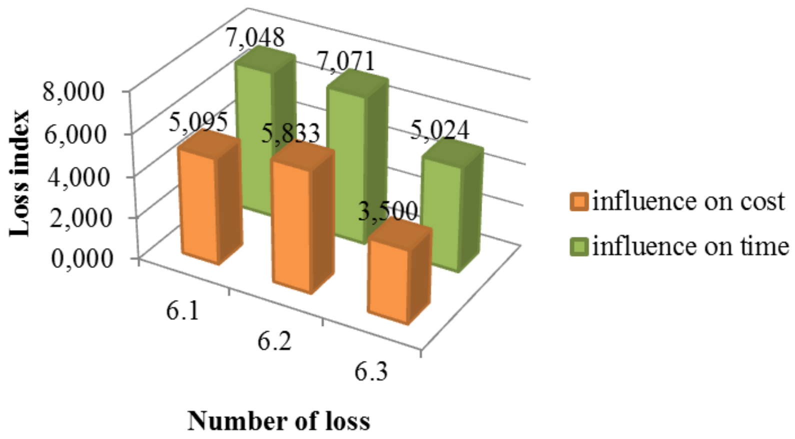

Figure 3.27 The average statistic assessment of losses due to unnecessary processing steps.

3.3.7 Results of the assessment of losses due to release of defective products

Tables 3.20 and 3.21 of Annex 3 summarize the results of expert assessment of losses due to due to release of defective products. The weight of each loss has been determined; the results are presented on Figures 3.28 and 3.29.

The degree of consistency of expert assessments of losses due to release of defective products is presented on Figure 3.30.

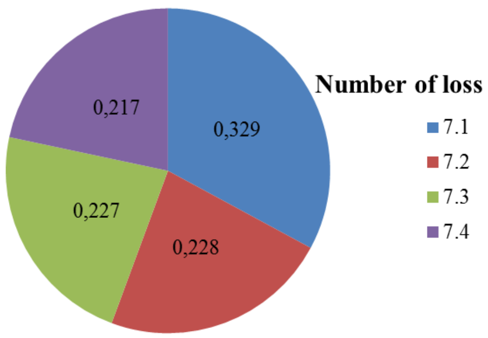

Figure 3.28 The weight of losses due to release of defective products which influence on construction.

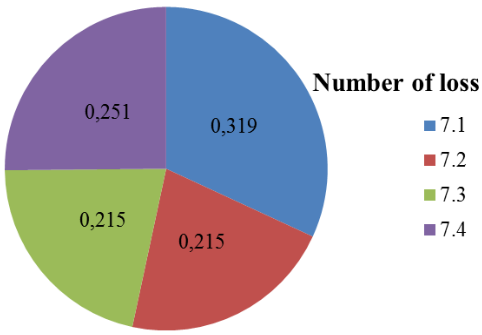

Figure 3.29 The weight of losses due to release of defective products which influence on construction time.

As it can be seen on Figures 3.28 and 3.29, the highest value of weight in structure of losses due to the release of defective products has 7.1 “The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)”. The lowest value of weight in the structure of this type of losses in cost terms has 7.4 “The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)”, and in time terms – 7.3 “The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)”.

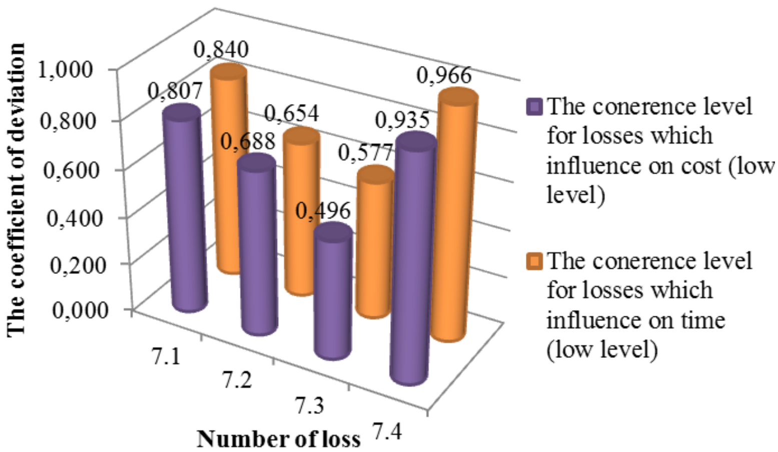

Figure 3.30 The degree of consistency of expert assessments of losses due to release of defective products.

As it can be seen on the Figure 3.30, the highest degree of consistency has the loss 7.3 “The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)” with the values 0.496 and 0.577 for cost and time terms respectively. The lowest has the loss 7.4 "The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)" which has the values 0.935 and 0.966 consistency level.

Figure 3.31 presents the results of the average estimation of losses due to unnecessary processing steps. As it can be seen from Figure 3.31, such losses as 7.1 "The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)" and 7.2 "The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project)" are the most influencing on the cost and 7.1 "The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)" and 7.4 "The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)" – on time of construction.

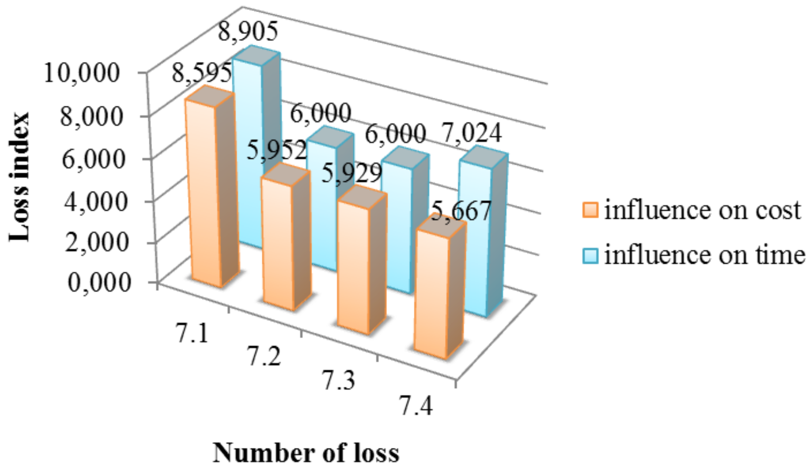

Figure 3.31 The average statistic assessment of losses due to release of defective products.

3.3.8 Preliminary results of the assessment and ranking of losses in terms of impact

As a result of work the statistical approach to assess the level of experts' competence was applied, which showed that the survey included the participation of the persons with the closest competences to theme and the highest level qualifications (level 2 and 3). Experts have conducted assessments of losses with such parameters as the probability of occurrence, increasing of the construction time of the model bay in % and increasing of the construction cost of the model bay in %. The results were adequately statistically treated on the base of the level of experts' competence, graphs and histograms for weight of losses and levels of respondents' opinions consistency have obtained as well as indexes of risk for each loss separately. It should be noted that the value of coherence in all cases was above the level of 0.35, indicating the high differentiation degree of expert knowledge about the ongoing processes on the construction site. Also this indicator is influenced by the level and number of projects in which these persons have participated, years of work and level of problems they solve at the moment.

According to the obtained data, the following losses on the construction site have the highest value of influence index (more than 5.0):

1) With the influence on construction cost:

- 1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)";
- 2.4 "The smoke breaks of workers in the work process"
- 5.1 "The production of defective construction products";
- 6.1 The lack of discipline in the workplace (in context of materials and units transportation within the building site)";
- 6.2 The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)";
- 7.1 "The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)";
- 7.2 "The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project)";
- 7.3 "The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)"
- 7.4 "The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)".

2) With the influence on construction time:

- 1.3 "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns";
- 2.1 "Waiting on delivery of materials and products for construction of structures (concrete, reinforcement, fixings) "
- 2.2 "Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example";
- 2.3 "Waiting for the supply of means of production on the work front";
- 2.4 "The smoke breaks of workers in the work process";
- 2.5 "The idles of workers while waiting for work front";
- 4.3 "The mismatch of the terms of materials, structures and products storage to requirements of normative documents";
- 5.1 "The production of defective construction products";
- 6.1 "The lack of discipline in the workplace (in context of materials and units transportation within the building site)";
- 6.2 "The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)";
- 6.3 "Additional (unnecessary) handling of materials, structures and products on the construction site";
- 7.1 "The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)";
- 7.2 "The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project)";
- 7.3 "The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)"

- 7.4 "The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)".

The losses which have the average degree of impact (index values from 3 to 5) include:

1) With the influence on construction cost:

- 1.1 "Filling of columns formwork before the end of their complete installation and inspection of the correct execution";
- 1.3 "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns";
- 2.1 "Waiting for delivery of materials and products for construction of structures (concrete, reinforcement, fixings) ";
- 2.2 "Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example) ";
- 2.3 "Waiting for the supplying of means of production on the work front";
- 2.5 "The idles of workers while waiting for work front";
- 3.1 "Large distances between on-site warehouse and the construction object";
- 3.4 "Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)";
- 4.2 "The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products";
- 4.3 "The mismatch of the terms of materials, structures and products storage to requirements of normative documents";
- 5.2 "Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc. ";
- 5.3 "The usage of materials, structures, products and etc. which are not of appropriate by design while work execution";
- 5.4 The usage of methods and techniques of work which are not relevant to the project.
- 6.3 "Additional (unnecessary) handling of materials, structures and products on the construction site".

2) With the influence on construction time:

- 1.3 "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns";
- 1.4 "Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements";

- 1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.) ";
- 2.6 "Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.)";
- 3.1 "Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)";
- 3.4 "Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work)".
- 4.2 "The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products";
- 5.2 "Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc.";
- 5.3 "The usage of materials, structures, products and etc. which are not of appropriate by design while work execution";
- 5.4 "The usage of methods and techniques of work which are not relevant to the project".

And, finally, losses that have the least impact (the index values are below 3.0):

1) With the greatest influence on construction cost:

- 1.2 "Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation";
- 2.6 "Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.)";
- 3.2 "Damage to structures of formwork when taping of the already built structures";
- 3.3 "Damage to reinforcement units and fixings when applying by the crane";
- 3.5 "Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work)".
- 4.1 "The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse";
- 4.4 "Storage of wastes at the construction site, without exporting them to a landfill".

2) With the greatest influence on construction time:

- 1.1 "Filling of columns formwork before the end of their complete installation and inspection of the correct execution";
- 1.2 "Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation";
- 3.2 "Damage to structures of formwork when taping of the already built structures";
- 3.3 "Damage to reinforcement units and fixings when applying by the crane";

- 4.1 "The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse".

According to the analysis results it can be said that the losses with middle and high level of indexes of influence prevail in the overall picture. So it is necessary to make the preparation work of measures to counteract them or reduce their incidence. The development of these measures should be entrusted to a project team that will follow the building throughout its duration.

However, it should be noted that due to the low level of consistency together with high levels of experts' competency these estimates may not fully reflect the real picture of the losses impact on construction site. Therefore it is necessary to conduct further evaluation and verification, to construct maps of the losses in time and cost terms, to establish the level of tolerance (levels) based on the mapping [51]. This process has 2 main objectives: to check the results of the approach set out in paragraph 3.3, and, if necessary, to insert additional losses into the existing register, which have an impact on the cost and time of construction. Thus, we conduct additional assessment of losses at construction site.

3.4 Calculation of the integral coefficient of losses impact during the implementation of monolithic concrete works

As it has already mentioned in Chapter 2, the important aspect in the calculation of the degree of losses influence is the question of assessing the effectiveness of the project before and after the changes. For this purpose the new characteristic measure of the impact of losses on construction site was introduced. The calculation of this coefficient uses the tools of economic and mathematical methods and theories of decision-making.

There are many methods of determining this coefficient, however, we will use the most simple and intuitive additive-multiplicative. For the calculation of the parameter uses two formulas, the first of which is used for the cumulative coefficient of losses impact calculation:

$$K_{cum} = \sum_{i=1}^{n} K_i \sigma_i \, , \tag{3.7}$$

where σ_i is the weighting factor of i-th loss index.

The coefficient of losses impact while the execution of monolithic works will look as follows:

$$K_{loss} = \frac{K_{cum}}{z} \tag{3.8}$$

where z is the multiplication of the maximum assessment value applied by each expert, respectively, for the probability of loss and level of its impact.

The calculations of the integral coefficients of losses impact are in Annex 4. For calculation it has been used the data of the losses assessment by the method of expert assessments, given the level of competence of experts involved in the survey. Data for the following losses was recorded in special tables based on the form of tables 2.2 and 2.3 of Chapter 2. For the convenience it was divided into 2 groups by level of impact: influencing the cost of structures erection and the time of construction, for which the rate impact was separately determined. Thus, the values K_{loss}^{c} и K_{loss}^{t} have been calculated.

So, as a result of calculations, the cumulative coefficient of losses impact on the cost of construction amounted to:

$$K_{cum}^{c} = \sum_{i=1}^{n} K_i \sigma_i = 4,730 .$$

The integrated coefficient of the impact of losses on cost of monolithic construction:

$$K_{loss}^{c} = \frac{K_{сов}}{z} = \frac{4,730}{25} = 0,189 .$$

The cumulative coefficient of losses impact on the time of construction amounted to:

$$K_{cum}^{t} = \sum_{i=1}^{n} K_i \sigma_i = 5,266 .$$

The integrated coefficient of the impact of losses on time of works execution:

$$K_{loss}^{t} = \frac{K_{сов}}{z} = \frac{5,266}{25} = 0,211$$

Here z = 25, because the best possible assessment value of the loss occurring probability and impact index are respectively of 5 points according to the adopted scale.

As closer the indicators K_{loss}^{c} и K_{loss}^{t} to 0, than the more efficient works will be performed at the construction site. In the case of monolithic construction processes, we can say that the values of index are close to 0.2 that generally shows a fairly high level of influence of the losses on production work. This fact is demonstrated by the values K_{cum}^{c}= 4,730 и K_{cum}^{t}= 5,266, which show that on average the probability of loss occurring and the degree of their influence exerted at the level of 22-23%. Thus, there is a danger of increasing the cost and time of production of monolithic works.

3.5. Verification of the calculations and creation the matrix (map) of losses.

The losses map provides information about the degree of influence of each loss in graphical form that enables us to show visually the location of losses relatively to the level of tolerance. In general sense it can be argued that losses map visualizes the losses situation arising at the building site and makes it clear that allows more effectively and faster for the interested and involved in situation parties make the right decisions.

The results of the measurements to build a map for each type of loss are set out in Annex 5.

While the creation of losses map, the levels of tolerance were set that allows giving the permissible (acceptable) index value of losses both in value and in time terms (level of loss impact). The losses that require initial processing are on higher level of tolerance. For both categories the levels of tolerance are 3.0 and 5.0 (Table 5.10 of Annex 5).

The results of the assessment and risk maps are shown on Figures 3.32 и 3.33.

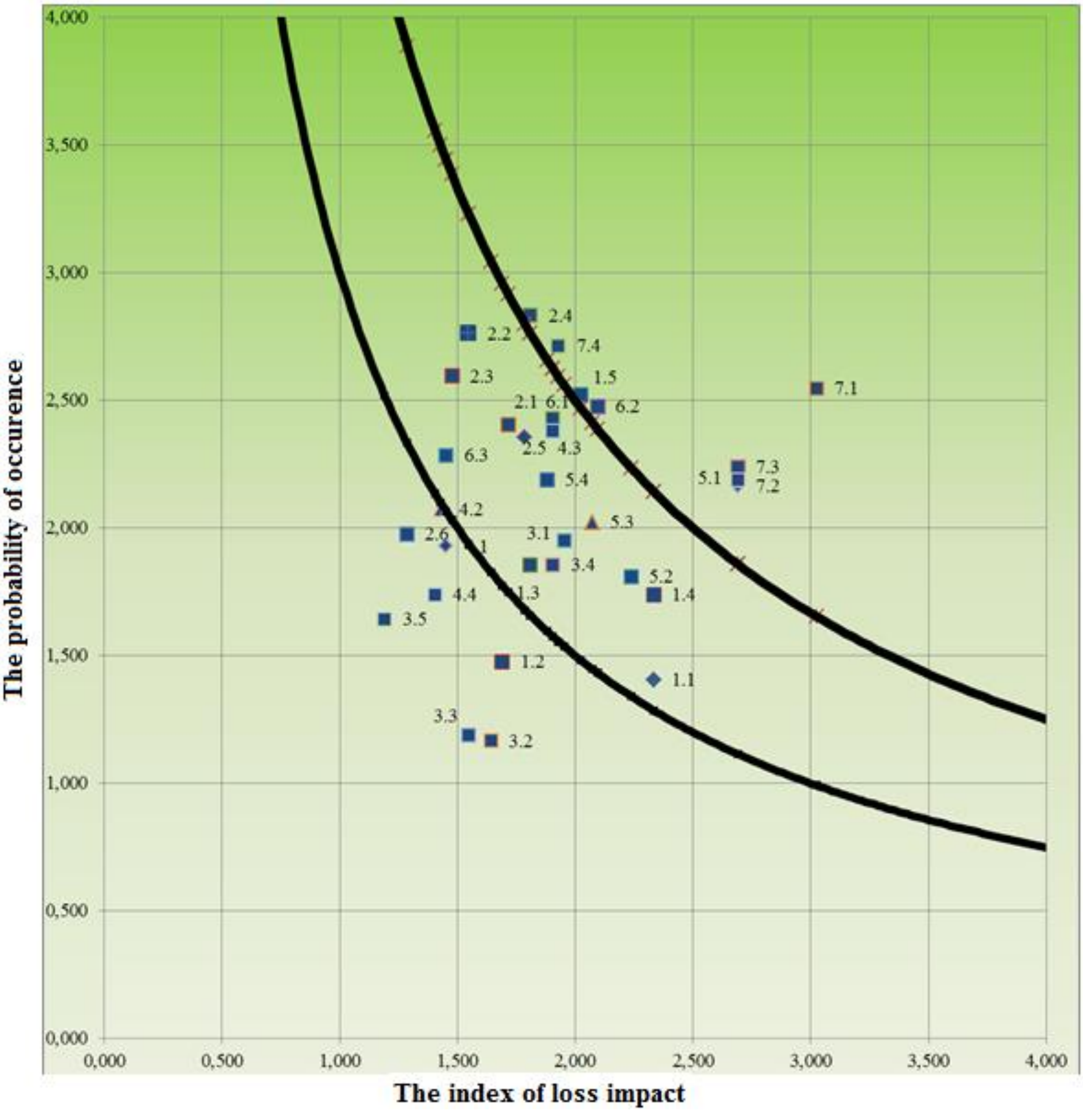

Figure 3.32 The mapping of losses at the construction site in terms of cost (with influence on cost).

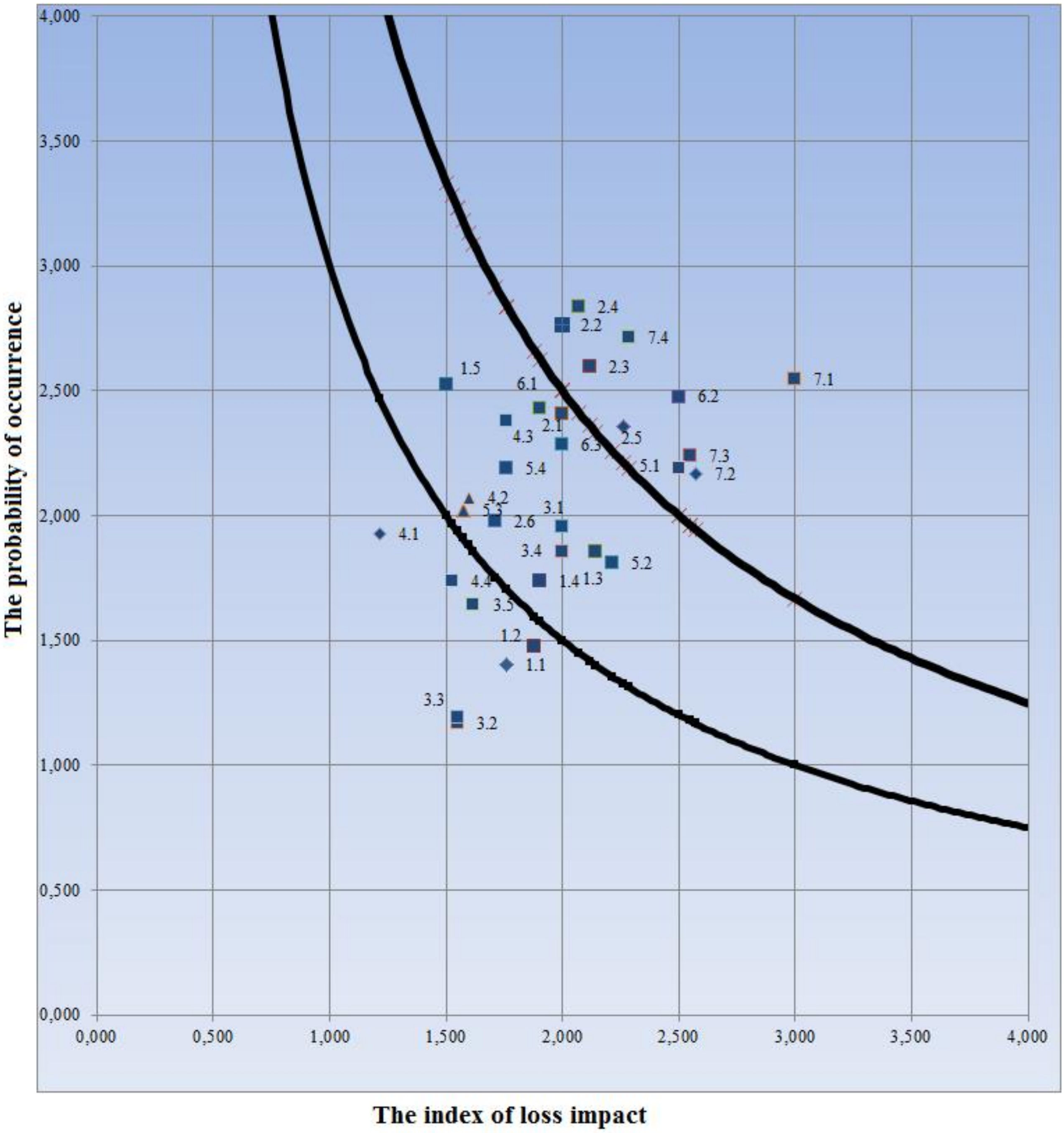

Figure 3.33 The mapping of losses at the construction site in terms of time (with influence on time).

Due to the creation of map it is obtained that the following losses are the upper than the high level of tolerance:

1) With the influence on cost:

- 1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)";
- 2.4 "The breaks of workers in the work process";
- 5.1 "The production of defective construction products";
- 6.2 "The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)";

- 7.1 "The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)";
- 7.2 "The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project)";
- 7.3 "The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)";
- 7.4 "The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)".

2) With the influence on time:

- 2.2 "Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example";
- 2.3 "Waiting for the supply of means of production on the work front";
- 2.4 "The breaks of workers in the work process";
- 2.5 "The idles of workers while waiting for work front";
- 5.1 "The production of defective construction products";
- 6.2 "The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)";
- 7.1 "The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)";
- 7.2 "The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project)";

- 7.3 "The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)";
- 7.4 "The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)".

The losses having an average degree of impact are between the upper and lower boundaries:

1) With the influence on cost:

- 1.1 "Filling of columns formwork before the end of their complete installation and inspection of the correct execution";
- 1.3 "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns";
- 1.4 "Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements";
- 2.1 "Waiting on delivery of materials and products for construction of structures (concrete, reinforcement, fixings)";
- 2.2 "Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example)";
- 2.3 "Waiting for the supplying of means of production on the work front";
- 2.5 "The idles of workers while waiting for work front";
- 3.1 "Large distances between on-site warehouse and the construction object";
- 3.4 "Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)";
- 4.2 "The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products";
- 4.3 "The mismatch of the terms of materials, structures and products storage to requirements of normative documents";
- 5.2 "Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc.";
- 5.3 "The usage of materials, structures, products and etc. which are not of appropriate by design while work execution";
- 5.4 "The usage of methods and techniques of work which are not relevant to the project".

- 6.1 "The lack of discipline in the workplace (in context of materials and units transportation within the building site)";
- 6.3 "Additional (unnecessary) handling of materials, structures and products on the construction site".

2) With the influence on time:

- 1.3 "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns";
- 1.4 "Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements";
- 1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)".
- 2.1 "Waiting on delivery of materials and products for construction of structures (concrete, reinforcement, fixings) ";
- 2.6 "Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.)";
- 3.1 "Large distances between on-site warehouse and the construction object";
- 3.4 "Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)";
- 4.2 "The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products";
- 4.3 "The mismatch of the terms of materials, structures and products storage to requirements of normative documents";
- 5.2 "Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc. ";
- 5.3 "The usage of materials, structures, products and etc. which are not of appropriate by design while work execution";
- 5.4 "The usage of methods and techniques of work which are not relevant to the project";
- 6.3 "Additional (unnecessary) handling of materials, structures and products on the construction site".

Losses with a low degree of influence are below the lower boundary of the tolerance level:

1) Influencing on the cost of structures erection:

- 1.2 "Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation";
- 2.6 "Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.) ";

- 3.2 "Damage to structures of formwork when taping of the already built structures";
- 3.3 "Damage to reinforcement units and fixings when applying by the crane";
- 3.5 "Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work) ";
- 4.1 "The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse";
- 4.2 "The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products";
- 4.4 "Storage of wastes at the construction site, without exporting them to a landfill".

2) Influencing on the time of structures erection:

- 1.1 "Filling of columns formwork before the end of their complete installation and inspection of the correct execution";
- 1.2 "Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation";
- 3.2 "Damage to structures of formwork when taping of the already built structures";
- 3.3 "Damage to reinforcement units and fixings when applying by the crane";
- 3.5 "Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work)";
- 4.1 "The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse";
- 4.4 "Storage of wastes at the construction site, without exporting them to a landfill".

3.6 Results of the assessment and identifying the most affecting losses

The results of the assessment are obtained in the list of losses that arise on the construction site during the construction works and which have the high priority for the organization that wants to implement a system of lean construction. This list is the result of an analysis of all processes occurring at the construction site while production monolithic reinforced concrete works. For this purpose the tools of risk management, mathematical modeling and economic and mathematical methods were used. The results should be further used in the development of policies that reduce the percentage of occurrence of these losses in production or eliminating them altogether.

The list of ranked losses is shown in Tables 3.6 and 3.7.

Losses with high and medium degrees of influence on the work production must be taken into account at the design stage of the organizational part of the project. Losses with a low degree of influence may be taken into account while the drafting process or directly while the production of works.

3.7 Development of measures to reduce the impact of losses on construction site in the production of monolithic reinforced concrete works.

After the creation of ranked losses list in production of monolithic reinforced concrete structures, it is necessary to begin the development of measures to reduce their impact or eliminate them. For the beginning, it should be noted that the loss with low-index of influence can be eliminated on the design phase or while the direct output of the crew to the object. The first option is more preferable, because already at this stage the company can allocate the necessary resources for training its employees by the correct working procedures, management of working time, the usage of modern techniques and methods of construction, etc. and to implement at the brigade level the tools of lean management. For example, the training of the so-called “Pull planning” will help the crew to start preparing for the next stage of work before the time of beginning this work in order to provide it with the necessary tools and resources. In the methodology of lean management it was developed a number of tools that will allow the crew to organize their work without any small-impact losses.

The losses with middle and higher indexes will require increasing influence from decision makers. The reduction of losses within these categories will lead to an overall reduction in the cost of construction works, company expenditures, time of production processes and increase the productivity. The development of measures on reduction of losses with high impact indexes may require a complete revision of the quality management system. They should be developed and adopted by decision makers and included in the enterprise standards, improving the "dead" QMS system, causing it to work.

Table 3.6 The final results of the ranking of losses on construction site affecting on the cost of construction.

Losses group	The degree of influence		
	High	Average	Low
1. Losses due to overproduction	1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)"	1.1 "Filling of columns formwork before the end of their complete installation and inspection of the correct execution"; 1.3 "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns"; 1.4 "Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements";	1.2 "Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation"
2. Losses due to waiting	2.4 "The breaks of workers in the work process"	2.1 "Waiting on delivery of materials and products for construction of structures (concrete, reinforcement, fixings)"; 2.2 "Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example)"; 2.3 "Waiting for the supplying of means of production on the work front"; 2.5 "The idles of workers while waiting for work front";	2.6 "Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.)"
3. Losses in unnecessary transportation (moving of structures or materials)	-	3.1 "Large distances between on-site warehouse and the construction object"; 3.4 "Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)";	3.2 "Damage to structures of formwork when taping of the already built structures"; 3.3 "Damage to reinforcement units and fixings when applying by the crane"; 3.5 "Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work)";
4. Losses due to excess inventory	-	4.2 "The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products"; 4.3 "The mismatch of the terms of materials, structures and products storage to requirements of normative documents";	4.1 "The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse"; 4.4 "Storage of wastes at the construction site, without exporting them to a landfill"

5. Losses due to unnecessary processing steps	5.1 "The production of defective construction products"	5.2 "Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc. "; 5.3 "The usage of materials, structures, products and etc. which are not of appropriate by design while work execution"; 5.4 "The usage of methods and techniques of work which are not relevant to the project"	-
6. Losses due to unnecessary movements	6.2 "The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan) "	6.1 "The lack of discipline in the workplace (in context of materials and units transportation within the building site) "; 6.3 "Additional (unnecessary) handling of materials, structures and products on the construction site"	-
7. Losses due to the release of defective products	7.1 "The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)" 7.2 "The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project)"; 7.3 "The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)"; 7.4 "The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)"	-	-

Table 3.7 The final results of the ranking of losses on construction site affecting on the time of construction.

Losses group	The degree of influence		
	High	Average	Low
1. Losses due to overproduction	-	1.3 "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns"; 1.4 "Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements"; 1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)"	1.1 "Filling of columns formwork before the end of their complete installation and inspection of the correct execution"; 1.2 "Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation";
2. Losses due to waiting	2.2 "Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example"; 2.3 "Waiting for the supply of means of production on the work front"; 2.4 "The breaks of workers in the work process"; 2.5 "The idles of workers while waiting for work front";	2.1 "Waiting on delivery of materials and products for construction of structures (concrete, reinforcement, fixings)"; 2.6 "Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.)";	-
3. Losses in unnecessary transportation (moving of structures or materials)	-	3.1 "Large distances between on-site warehouse and the construction object"; 3.4 "Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)";	3.2 "Damage to structures of formwork when taping of the already built structures"; 3.3 "Damage to reinforcement units and fixings when applying by the crane"; 3.5 "Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work)";
4. Losses due to excess inventory	-	4.2 "The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products"; 4.3 "The mismatch of the terms of materials, structures and products storage to requirements of normative documents";	4.1 "The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse"; 4.4 "Storage of wastes at the construction site, without exporting them to a landfill".
5. Losses due to unnecessary processing steps	5.1 "The production of defective construction products (in terms of additional steps for remaking)";	5.2 "Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc. "; 5.3 "The usage of materials, structures, products	-

		and etc. which are not of appropriate by design while work execution"; 5.4 "The usage of methods and techniques of work which are not relevant to the project".	
6. Losses due to unnecessary movements	6.2 "The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)"	6.1 "The lack of discipline in the workplace (in context of materials and units transportation within the building site)"; 6.3 "Additional (unnecessary) handling of materials, structures and products on the construction site".	-
7. Losses due to the release of defective products	7.1 "The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)"; 7.2 "The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project)"; 7.3 "The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)"; 7.4 "The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)";	-	-

The losses with middle and higher indexes will require increasing influence from decision makers. The reduction of losses within these categories will lead to an overall reduction in the cost of construction works, company expenditures, time of production processes and increase the productivity. The development of measures on reduction of losses with high impact indexes may require a complete revision of the quality management system. They should be developed and adopted by decision makers and included in the enterprise standards, improving the "dead" QMS system, causing it to work.

In case of monolithic construction processes, the elimination of losses or reducing their impact on the cost and time of erection of structures can be made as follows (Table 3.8). For example, consider losses with a high degree of influence on production.

Table 3.8 The development of measures to eliminate losses or reduce their impact in monolithic construction (in terms of cost).

The name of loss	**Measures to reduce or eliminate**
1.5 "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)"	• The development of internal standards for waste management. • Conducting briefings with the staff of the sites on proper handling of waste. • Making clear, specific site measures to reduce waste as set out in the CMP and WP, but not quoting the SP and SNiP (Russian building codes). • Unscheduled inspections of waste management. • The appointment of responsible persons from among the engineers and technicians for on-site waste management.
2.4 "The breaks of workers in the work process"	• The implementation of the Last planner system to ensure continuity of work. • Issue daily assignments to employees in the form of graphics and charts showing the planned works for the day. • The elimination of unplanned downtimes (breaks) by foremen. • The introduction of rewards for fulfilling scheduled daily, weekly, monthly tasks for each worker. • The development of individual target plans for each employee of the site.
5.1 "The production of defective construction products (in terms of additional steps for remaking)"	• The introduction of system of personal responsibility of employees for quality of work. • The regular validation of completed parts, products, methods of work by engineers. • The unscheduled instruction and training of advanced technologies for manufacturing operations. • Conduct an annual unscheduled certification of personnel. Providing of the anonymity. • The introduction of the ban on alcohol and sobriety checks.
6.2 "The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)"	• To detail the CMP and WP, or to upgrade them with all the necessary measures to reduce losses. • Providing the inspection by team-leaders the consistency of its processes, a permanent supervision of works. • Ensuring the conformity of processes adopted in CMP, WP and regulatory documents. • Periodic monitoring by engineers (photo of the day, value stream mapping) to identify weaknesses and improve them. • Issuing clear daily tasks, describing the entire sequence of work performed by each worker with the appointment of a responsible foreman.
7.1 "The violation of the	• To verify the method statements and WP in terms of the concreting for compliance

concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)"	with regulatory documents (SP 48.13330.2011 and 70.13330.2012). • Monitoring of performed works by engineers, compliance verification of works technology and processes occurring "in nature". • The introduction of personal liability for infringement of technology of works (including dismissal). • The diligence technical surveillance of work performed. The supervision for not only the work results but also for the correct execution of the processes. • Responsibility of engineers and technical supervision in case of violation of technology. • Conducting briefings and training of staff performing concreting. • The usage of modern means and tools to perform the work. • The usage of materials with parameters according to norms. Careful choice of suppliers.
7.2 "The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project)"	• To verify the method statements and WP in terms of the reinforcement works for compliance with regulatory documents (SP 48.13330.2011 and 70.13330.2012). • Monitoring of performed works by engineers, compliance verification of works technology and processes occurring "in nature". • The introduction of personal liability for infringement of technology of works (including dismissal). • The diligence technical surveillance of work performed. The supervision for not only the work results but also for the correct execution of the processes. • Responsibility of engineers and technical supervision in case of violation of technology. • Conducting briefings and training of staff performing reinforcement works. • The usage of modern means and tools to perform the work. • The usage of materials with parameters according to norms. Careful choice of suppliers. • Thorough incoming inspection of details and reinforcement. • Monitoring of warehousing and storage processes, ensuring the consistency of these processes to norms.
7.3 "The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)"	• To verify the method statements and WP in terms of the installation of formworks for compliance with regulatory documents (SP 48.13330.2011 and 70.13330.2012). • Monitoring of performed works by engineers, compliance verification of works technology and processes occurring "in nature". • The introduction of personal liability for infringement of technology of works (including dismissal). • The diligence technical surveillance of formwork installation. The supervision for not only the work results but also for the correct execution of the processes. • Responsibility of engineers and technical supervision in case of violation of technology. • Conducting briefings and training of staff performing installation and erection works. • The usage of means and tools to perform the work according to the modern monolithic constructions requirements. • The usage of materials with parameters according to norms. Careful choice of suppliers. • Thorough incoming inspection of details, checking the condition of formwork. • Monitoring of warehousing and storage processes, ensuring the consistency of these processes to norms. • The introduction of personal liability for damage to the equipment
7.4 "The violations in the field of HSE (working	• The development of HSE instructions which are appropriate to advanced industrial practices.

without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)"	• Personal responsibility for violations of industrial safety and labour protection. • Staff training in safe work practices. • The verification by engineers and construction supervision of the HSE system. Unscheduled inspections by senior management of the organization. • To provide personnel with the necessary PPE in accordance with best industry practices and standards. • The verification of the provision of scaffolding and completeness of the fencing, scaffolding, safety belts etc.

Table 3.9 The development of measures to eliminate losses or reduce their impact in monolithic construction (in temporal terms) – in addition to those already described.

The name of loss	**Measures to reduce or eliminate**
2.2 "Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example"	• The clear distinction between cranes, cranes and lifts. • To ensure the technical integrity: the availability of certificates, passports, spare parts for cranes at the site, prompt response to breakdowns. • The availability of responsible person for of cranes at a construction site. • Method Statements for crane operation should contain the specific references, what processes must be performed by a crane on the first place, what on the second, etc. • Ensuring the serviceability of lifts. • The punishment for violation of the production of solid work, when the crane is misused (the descent of waste, the usage in the performance of the masonry works, plastering or other types of works).
2.3 "Waiting for the supply of means of production on the work front"	• The development of measures allowing workers to use during downtime (at the time of filing of the formwork, concrete bucket loading). • Ensuring the continuity of the crane operations. • The consistency crane operations in the production of works by 2 cranes. The development of schemes of interaction of cranes, their communication. • The development of a sequence diagrams of uplifting for each crane, so-called “crane day job task”, the introduction of a system of incentives for its implementation.
2.5 "The idles of workers while waiting for work front"	• The pulling of processes through the introduction of Last Planner. • To discuss daily/weekly tasks in the office of the chief of construction. Planning processes with the participation of foremen. • The introduction of personal liability for breach threading. • The sequence of works should be clearly stated in the company standards, technological cards of the enterprise. • The implementation of Kanban or other system indicating the possibility of transition to the next work front.
For losses 2.4, 5.1, 6.2, 7.1-7.4 measures may be similar, or supplemented.	

3.8 Conclusions for the chapter

As a result of this work the analysis of monolithic construction processes was performed aimed at identifying losses that have an impact on the cost of construction and operations. This work included the monitoring of all possible processes related to monolithic construction, the determination of possible losses for each type of construction, systematization and consolidation of losses, combining them into groups according to the level of influence. Further evaluation was conducted in accordance with the developed method described in Chapter 2:

1) The assessment of the losses impact by the method of expert assessments.

2) Processing of outcomes, the assessment of experts competence, calculation of loss impact indexes on the work.

3) Calculation of the average impact of all losses at construction site in cost and time terms.

4) Checking of the results of calculations by building a map of losses, calculation of tolerance levels.

5) The final ranking of losses by the level of impact on monolithic reinforced concrete works.

6) Proposing of measures to eliminate or reduce the impact of losses on production work.

The introduction of this technique will allow the organization already at the stage of preparation to enter on the object to have in its arsenal the tools to control the quality and process of work, to provide itself with qualified personnel, aims to increase the productivity, reduce the costs of erection of structures. This technique applies both to individual works and to the construction site, the construction zone and possible further enlargement to the systems of interaction between materials suppliers, logistics and building site etc. All this will allow creating the working system and bringing the company to the first steps of lean construction and working QMS.

CONCLUSIONS

The following results and conclusions were obtained in the master thesis:

1) The analysis of modern trends development of quality management systems in construction industry which exist in our country was prepared. It has been received that the existing system of quality management based on the principles of international ISO standards does not fully meet the requirements of modern construction industry. Mostly companies are conducting the certification procedure only to meet regulatory requirements, but not to improve their own management system processes and continue to use traditional methods.

2) The most progressive alternative to the QMS is proposed – lean production, namely lean construction. The development of this area of management systems started relatively recently, in the early 1990-ies, but already today many large foreign companies have fully adopted lean production and prove its effectiveness. The main postulate of the system is detection of so-called losses in the construction process: in time, money, labor, materials, etc., and their subsequent elimination using organizational and technological measures.

3) The concept of lean construction has been investigated, main principles to be followed by the company, which is ready to move to the system, was identified. It is shown that there are no clear methods of this concept implementation, only some tools to improve certain manufacturing processes, such as Pull Planning, Last Planner or 6 Weeks Planning. The usage of these tools is focused only on certain intra-system relationships, but not on the production system as a whole.

4) The absolutely new approach to lean construction has been proposed– the losses management system at construction site. The main idea is to consider the losses in terms of risk management, identifying them as risks while the implementation of investment and construction projects.

5) The algorithm for the losses identification, assessment of their impact in terms of increasing construction costs and time of work production has been developed using the method of expert estimations, processing of measurement results, ranking them by their impact on the production process (high, medium, and low), check the measurement results and development of measures to reduce their impact level, probability of occurrence or complete elimination. Recommendations on the monitoring and control have been proposed and are carried out by the measurements.

6) The new indicator to assess the effectiveness of the project in terms of potential losses while its implementation was developed on the basis of economic-mathematical and statistical methods: the integrated indicator of the losses impact. The maximum and minimum values of this criteria and recommendations for its definition have given. The applicability to various construction processes, building site in general, construction company is proved.

7) The assessment of works production on the construction of monolithic reinforced building frame according to the developed algorithm was done. Approximately 240 potential losses on a building site relating to this type of work were identified during the process. Further processing and consolidation have reduced the number of significant types of losses up to 31. The special questionnaire for assessing the impact of loss on the work was prepared. The survey involved 16 experts of high qualification, with extensive experience in construction both residential and industrial facilities, including hazardous production enterprises. Processing of measurement results is carried out by the proposed method identified the loss of high, medium and low degree of influence on the production process. The integrated indicator of the loss impact on construction work and checking of the obtained results was calculated. Measures to reduce the probability of losses, their impact level and elimination were proposed. It is shown that losses with a low exposure index can be eliminated by introduction of organizational and technical measures on the construction site; the losses with high and average indexes require changes in the management structure of the enterprise. All results and conclusions are supported by calculations and graphs.

The following main scientific results and provisions, obtained by the author in the work, are presented for the public defense:

1. The method of losses management during the construction process, based on the application of the tools of risk management and lean construction has been developed.

2. The integral indicator of losses impact on construction processes was developed in the framework of the losses management system using economic and mathematical modeling methods, which allows to estimate the efficiency of the project prior to its implementation from the emerging losses point of view and after the implementation of measures for losses impact and probability of their occurrence reduction or elimination.

3. The procedure of losses identification on construction site, their evaluation, measurement, and processing of obtained results, the ranking according to the degree of influence on the construction process was proposed. The method of results validation was developed obtained by construction of losses maps and the final determination of the most influencing losses on the construction results.

4. The application of expert assessment method to evaluate the influence degree of arising losses was obtained. The concept of index loss for works execution was introduced.

5. To determine the degree of competence of experts the evaluation procedure from the point of view of their professional skills was developed based on the method of paired comparisons: work experience, job profile, level of tasks running at the moment, level of education, number and level of projects in which they had participated.

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Annex 1.

Survey questionnaire for expert assessment.

Анкета оценки влияния различных видов потерь на процессы строительства при выполнении монолитных бетонных работ.

1. ФИО эксперта____.
2. Дата заполнения___________________.
3. Должность, организация ____.

Данная анкета призвана оценить степень влияния различных видов потерь на строительной площадке применительно к ведению монолитных бетонных работ на условной ярусозахватке, состоящей из следующих типов конструкций: монолитные железобетонные стены, монолитные железобетонные колонны, монолитные железобетонные перекрытия. В дальнейшем результаты опроса будут использованы для выявления наиболее сильно влияющих и наиболее часто возникающих видов потерь при выполнении данного вида работ.

Инструкция по заполнению анкеты:

1) В качестве объекта оценивания выбран условный объект – 9-тиэтажное трехсекционное жилое здание в г. Воронеже. Высота этажа: 3м. Секция в плане условно – прямоугольная, размеры 18х30 м. Сетка колонн: 6,0х6,0. Состав конструкций одной ярусозахватки:

- железобетонные колонны: 400х400 мм– 24 шт.
- железобетонные стены: 6,0х3,0х0,2 м– 14 шт.; 3,0х3,0х0,2 – 1 шт.
- железобетонная плита: 20х32х0,2 м.

2) Для данной ярусозахватки необходимо проанализировать все процессы возведения монолитных конструкций и возможные потери при выполнении данных процессов.

3) Оценить степень влияния каждой потери на производство работ по следующим критериям:

- во временном выражении (увеличение сроков выполнения работ, в %):

1 – до 20%;
2 – 21-40%;
3 – 41-60%;
4 – 61-80%;
5 – 81-100%.

- в стоимостном выражении (удорожание строительства, в %):

1 – до 20%;
2 – 21-40%;
3 – 41-60%;
4 – 61-80%;
5 – 81-100%.

4) Оценить на основе собственного опыта и профессиональной деятельности возможность возникновения данной потери на строительной площадке:

- до 20% - практически не имеют места при выполнении работ, появляются редко и случайно;
- от 21 до 40% - данные явления появляются на строительной площадке периодически, устранимы на месте;
- от 41 до 60% - более выраженная периодичность появления, в основном из-за проблем в планировании и организации;
- от 61 до 80% - практически постоянно возникающие потери, указывают на нарушения в технологии возведения, планировании и организации;
- от 80 до 100% - постоянное наличие данных потерь на строительной площадке, невозможность устранения.

5) Заполнить таблицу в соответствии с критериями, изложенными выше.

Виды потерь	Степень влияния на технологический процесс										Вероятность возникновения, %
	Во временном выражении (увеличение времени выполнения, %)					В стоимостном выражении (удорожание строительства)					
1) Потери из-за перепроизводства											
– заливка конструкций до завершения их полного монтажа и проведения проверки правильности выполнения	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– монтаж опалубки стен и колонн до завершения установки арматуры и арматурных каркасов	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– монтаж стоек и щитов опалубки перекрытия до разборки опалубки стен и колонн	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– переармирование конструкций путем увеличения диаметров или класса применяемой арматуры, количества стержней в элементах конструкций	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– производство большого количества отходов (обрезки арматуры, проволоки, щитов и т.д.)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
2) Потери из-за ожидания											
– ожидание при доставке материалов и изделий для выполнения конструкций колонн (бетон, арматура, закладные детали)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– выполнение краном смежных процессов (при использовании крана(ов) для производства монолитных и каменных работ одновременно, к примеру)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– ожидание подачи средств производства на фронт работ	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– перекуры рабочих в процессе выполнения работ	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– простои рабочих при ожидании фронтов работ	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– простои в процессе подготовки документации (для процессов снабжения, а также для разрешения на ведение работ, выдачи заданий, планерок и т.д.)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
3) Потери при транспортировке (перемещении конструкций или материалов):											
– большие расстояния между приобъектным складом и строящимся объектом	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– повреждение конструкций опалубки при подаче краном об уже возведенные конструкции	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– повреждение арматурных деталей, закладных элементов при подаче краном	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– доставка материалов без организованной транспортной схемы и логистического планирования (большие расстояния доставки бетона, строительных конструкций и изделий от поставщиков)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– неправильное размещение зон выгрузки строительных материалов и изделий на строительной площадке (размещение их на удалении от мест хранения, мест подачи на фронт работ)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
4) Потери из-за лишних запасов:											
– наличие на приобъектном складе избыточного количества материалов, изделий и конструкций, вспомогательных элементов	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– отсутствие системы учета и планирования на приобъектном складе, сложности в поиске необходимых материалов и изделий	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– несоответствие условий складирования материалов, конструкций и изделий требованиям	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	

нормативных документов										
– складирование отходов на строительной площадке, без вывоза их на полигоны	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
5) Потери из-за лишних этапов обработки											
– производство дефектной строительной продукции;	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– исправление поврежденных конструкций опалубки, арматурных изделий, готовых конструкций (брак) и т.д.	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– использование при выполнении работ материалов, конструкций, изделий и т.д. не соответствующих проектным	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– использование методов и способов выполнения работ, не соответствующих проекту	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
6) Потери из-за ненужных перемещений:											
– отсутствие трудовой дисциплины на рабочем месте;	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– отсутствие четкой последовательности выполнения процессов (суета) при производстве монтажных, бетонных, опалубочных работ и т.д. (не выполнение требований инструкций, ППР и ПОС)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– дополнительные (излишние) перемещения материалов, конструкций и изделий по строительной площадке	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
7) Потери из-за выпуска дефектной продукции:											
– нарушения технологии бетонирования (недостаточное уплотнение смеси, не выдерживание нормативного срока набора прочности, температурного режима бетонирования, должного защитного слоя бетона, использование бетона с водоцементным соотношением ниже или выше проектного, неправильный режим прогрева бетона (в зимний период), использование бетона с характеристиками, не соответствующими проектным)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– нарушение технологии арматурных работ (использование дефектных арматурных изделий и закладных деталей, наличие отклонений при установке, нарушение целостности арматурных каркасов при заливке бетонной смеси и вибрировании, использование арматуры с характеристиками, не соответствующими проектным)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– нарушение технологии монтажных работ (неверная планово-высотная установка опалубки колонн, отклонения опалубки при установке, использование фурнитуры, отработавшей свой срок службы, дефектной опалубки, повреждения опалубки, стоек, щитов и т.д.)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	
– нарушения в области охраны труда (работа с подмостей, установка ограждений и использование средств индивидуальной защиты не надлежащего качества, либо отработавших нормативных срок службы, работа без наряд-допусков и т.д.)	до 20	21-40	41-60	61-80	81-100	до 20	21-40	41-60	61-80	81-100	

Annex 2

Assessment of competence level of experts which evaluate losses on construction site.

Table A2.1 Characteristics of the experts involved in the survey.

No.	Date of completion	Name of expert	Title, company	Employment period	The level and profile of education	Profile of the work performed	The level of solving problems	Quantity and level of projects…
1	25.02.2016	Perepelica Ivan	Foreman, Meridian LLC	6	Higher technical education	Practical, work at the construction site	Organization of work for monolithic construction teams on the construction of residential houses, maintenance of reporting documents	4, construction of monolithic residential houses
2	25.02.2016	Savilov Pavel	Construction superintendent, ECSK LLC	9	Secondary technical education	Practical, work at the construction site	Organization of construction process of monolithic apartments consisting of residential complex	6, construction of monolithic residential and civil buildings
3	25.02.2016	Filimonov Ivan	Foreman, Intellektualnye sistemy LLC	5	Higher technical education	Practical, work at the construction site	Organization of work for monolithic construction teams on the construction of residential houses, maintenance of reporting documents	4, construction of monolithic residential houses
4	25.02.2016	Latfullin Ilgiz	Site supervisor, ECSK LLC	10	Higher technical education	Practical, work at the construction site	Construction of the residential complex, supply, documentation, delivery of documents to construction company	7, construction of monolithic residential and civil buildings
5	29.02.2016	Koblev Sergey	Engineer, Anapagrazhdanproekt LLC	8	Higher technical education	Practical, work at the design office and construction site (architectural supervision)	Design, architectural supervision over construction of major construction objects	8, construction of monolithic residential and civil buildings, industrial structures
6	02.03.2016	Khnykin Aleksandr	Construction superintendent, Karkas-Stroj LLC	8	Higher technical education	Practical, work at the construction site	Organization of construction process of monolithic apartments consisting of residential complex	5, construction of monolithic residential and civil buildings
7	02.03.2016	Moiseev Egor	Sourcing manager, engineer, TDS LLC	22	Secondary technical education	Practical, work at the construction site	The organization of supplies the building site with the necessary resources, participation in the organization of construction works	12, residential and civil buildings, industrial structures

8	03.03.2016	Rylov Aleksey	Chief technician Rosneft-Krasnodarneftegaz LLC	12	Higher technical education	Practical, work at the owner service	Preparing of cost estimates for construction, supervision of construction, delivery of reports about the construction process	6, industrial buildings, construction of monolithic foundations
9	09.03.2016	Soldatenko Tamara	Senior lector, Civil Engineering Institute, Saint Petersburg Polytechnic University	20	Higher technical education	Academic and practical, teaching and methodical work, work as the inspector of technical supervision	Disciplines: construction management, economics, building production technology. The work in expert groups as an independent expert in the technology of concrete works, the engineer of technical supervision	20, residential and civil buildings, industrial structures
10	10.03.2016	Kuzmenko Nikolay	Engineer, ArkhCom LLC	20	Higher technical education	Practical, work at the design office and construction site (architectural supervision)	Design, architectural supervision over construction of major construction objects	13, residential and civil buildings, industrial structures
11	10.03.2016	Chigrinskaya Aleksandra	Production and Technical Department Engineer, StrojFasad CJSC	12	Higher technical education	Practical, work at the construction site and office.	Supervision of construction projects, construction management, document verification, confirmation of work values	9, major public facilities, industrial buildings
12	10.03.2016	Luzina Nataly	Head of the division "Non-Destructive methods of control", LLC "TÜV International RUS"	15	Higher technical education	Practical, work at the construction site and office.	Work as Project Manager for construction supervision over erection of buildings. The work of expert groups for the investigation of accidents at hazardous production facilities. Examination of buildings, structures and HIFs	14, HIFs, industrial buildings, oil and gas industry buildings
13	11.03.2016	Kobleva Nataly	Director, ArkhCom LLC	23	Higher technical education	Practical, work at the office of designer.	Architectural supervision, business management, working as expert in the field of organization and technology of construction	23, residential and civil buildings, industrial structures
14	14.03.2015	Majorov Ivan	Director, KaimanDekor LLC	24	Higher technical education	Practical, work at the office of construction company.	Supervision, business management, working as the head of the contractor company	25, residential and civil buildings, industrial structures

15	02.03.2015*	Komarinskij Mikhail	Associate Professor Construction of unique buildings and structures department, Saint Petersburg Polytechnic University	25	Higher technical education	Academic, teaching and methodical work	Disciplines: construction management, economics, building production technology. The work in expert groups and supervision field	18, residential and civil buildings, industrial structures, hydrotechnical constructions
16	15.03.2016	Gubajdullin Danil	Inspection engineer, TekhnoResurs International LLC	22	Higher technical education	Practical, work on the construction site as a certified expert	The work in expert groups for the investigation of accidents at hazardous production facilities. Examination of buildings, structures and the HIFs. The independent inspector of technical supervision	18, HIFs, industrial buildings, oil and gas industry buildings

* The questionnaire was provided 15.03.2016.

Table A2.2 The assessment of competence level of loss assessors by expert No.1

The registry of qualities / Expert No.	Employment period	The level and profile of education	Profile of the work performed	The level of solving problems	Quantity and level of projects…	Expert's rating	The level of expert's competence	Aggregated statistical value of quality rating
1	10	30	30	30	10	22,000	2	110
2	20	20	30	30	10	22,000	2	110
3	10	30	30	30	10	22,000	2	110
4	20	30	30	30	20	26,000	2	130
5	10	30	20	20	20	20,000	1	100
6	20	30	30	20	10	22,000	2	110
7	40	20	20	30	30	28,000	2	140
8	20	30	30	30	10	24,000	2	120
9	40	30	20	30	30	30,000	3	150
10	30	30	20	20	20	24,000	2	120
11	20	30	40	30	20	28,000	2	140
12	30	30	30	40	30	32,000	3	160
13	40	30	40	40	40	38,000	3	190
14	40	30	40	40	40	38,000	3	190
15	40	30	20	20	40	30,000	3	150
16	40	30	40	30	40	36,000	3	180

Table A2.3 The assessment of competence level of loss assessors by expert No.2.

The registry of qualities / Expert No.	Employment period	The level and profile of education	Profile of the work performed	The level of solving problems	Quantity and level of projects…	Expert's rating	The level of expert's competence	Aggregated statistical value of quality rating
1	20	40	40	40	20	32,000	3	160
2	30	30	40	40	30	34,000	3	170
3	20	40	40	40	20	32,000	3	160
4	40	40	40	30	30	36,000	3	180
5	30	40	30	20	40	32,000	3	160
6	30	40	40	40	30	36,000	3	180
7	40	30	30	20	40	32,000	3	160
8	40	40	40	30	30	36,000	3	180
9	40	40	30	20	40	34,000	3	170
10	40	40	30	20	40	34,000	3	170
11	40	40	40	30	40	38,000	3	190
12	40	40	40	40	40	40,000	3	200
13	40	40	20	30	40	34,000	3	170
14	40	40	20	30	40	34,000	3	170
15	20	40	30	20	20	26,000	2	130
16	30	40	40	40	40	38,000	3	190

Table A2.4 The assessment of competence level of loss assessors by expert No.3.

The registry of qualities / Expert No.	Employment period	The level and profile of education	Profile of the work performed	The level of solving problems	Quantity and level of projects…	Expert's rating	The level of expert's competence	Aggregated statistical value of quality rating
1	20	40	40	30	20	30,000	3	150
2	20	20	40	30	20	26,000	2	130
3	10	40	40	30	20	28,000	2	140
4	20	40	40	20	20	28,000	2	140
5	20	40	40	20	30	30,000	3	150
6	20	40	40	30	20	30,000	3	150
7	40	40	40	10	20	30,000	3	150
8	30	40	40	20	20	30,000	3	150
9	40	40	30	30	40	36,000	3	180
10	40	40	40	20	30	34,000	3	170
11	30	40	40	40	20	34,000	3	170
12	30	40	40	40	30	36,000	3	180
13	40	40	40	20	40	36,000	3	180
14	40	40	40	20	40	36,000	3	180
15	40	40	30	20	40	34,000	3	170
16	40	40	40	40	40	40,000	3	200

Table A2.5. Summary assessment of level of competence of experts evaluating the losses.

Expert No.	The assessment of competence level of loss assessors by expert No.			The average expert's rating	The level of expert's competence
	1	2	3		
1	22,000	32,000	30,000	28,000	2
2	22,000	34,000	26,000	27,333	2
3	22,000	32,000	28,000	27,333	2
4	26,000	36,000	28,000	30,000	2
5	20,000	32,000	30,000	27,333	2
6	22,000	36,000	30,000	29,333	2
7	28,000	32,000	30,000	30,000	3
8	24,000	36,000	30,000	30,000	3
9	30,000	34,000	36,000	33,333	3
10	24,000	34,000	34,000	30,667	3
11	28,000	38,000	34,000	33,333	3
12	32,000	40,000	36,000	36,000	3
13	38,000	34,000	36,000	36,000	3
14	38,000	34,000	36,000	36,000	3
15	30,000	26,000	34,000	30,000	3
16	36,000	38,000	40,000	38,000	3

Annex 3

Experts' assessments of losses on construction site.

3.1 Assessment of losses due to overproduction

Table A3.1.1 The expert assessment of loss "Filling of columns formwork before the end of their complete installation and inspection of the correct execution".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	2	2	2	4	4	8	8
3	2	1	1	1	1	1	2	2
4	2	1	1	1	1	1	2	2
5	2	1	1	1	1	1	2	2
6	2	1	1	1	1	1	2	2
7	3	2	4	2	8	4	24	12
8	3	1	3	3	3	3	9	9
9	3	1	2	1	2	1	6	3
10	3	1	1	1	1	1	3	3
11	3	2	3	1	6	2	18	6
12	3	3	5	4	15	12	45	36
13	3	2	4	3	8	6	24	18
14	3	1	1	1	1	1	3	3
15	3	1	2	1	2	1	6	3
16	3	1	3	3	3	3	9	9
Total	42					Total	165	120
The average statistic assessment of loss R_c:								3,929
The average statistic assessment of loss R_t:								2,857

Table A3.1.2 The expert assessment of loss "Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	2	2	2	4	4	8	8
3	2	1	1	1	1	1	2	2
4	2	1	1	1	1	1	2	2
5	2	1	1	2	1	2	2	4
6	2	1	1	1	1	1	2	2

7	3	2	5	2	10	4	30	12
8	3	1	3	3	3	3	9	9
9	3	2	1	2	2	4	6	12
10	3	1	1	1	1	1	3	3
11	3	1	2	2	2	2	6	6
12	3	2	2	3	4	6	12	18
13	3	2	2	2	4	4	12	12
14	3	2	1	2	2	4	6	12
15	3	1	1	1	1	1	3	3
16	3	2	1	3	2	6	6	18
Total	42					Total	111	125
The average statistic assessment of loss R_c:								2,643
The average statistic assessment of loss R_t:								2,976

Table A3.1.3 The expert assessment of loss "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	2	2	4	4	8	8
2	2	3	4	4	12	12	24	24
3	2	4	1	4	4	16	8	32
4	2	1	1	1	1	1	2	2
5	2	4	2	3	8	12	16	24
6	2	1	1	1	1	1	2	2
7	3	2	5	2	10	4	30	12
8	3	1	3	4	3	4	9	12
9	3	3	1	3	3	9	9	27
10	3	1	1	1	1	1	3	3
11	3	2	1	1	2	2	6	6
12	3	2	2	2	4	4	12	12
13	3	1	2	2	2	2	6	6
14	3	1	1	1	1	1	3	3
15	3	1	1	1	1	1	3	3
16	3	2	1	3	2	6	6	18
Total	42					Total	147	194
The average statistic assessment of loss R_c:								3,500
The average statistic assessment of loss R_t:								4,619

Table A3.1.4 The expert assessment of loss "Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	1	1	1	1	1	2	2
3	2	1	1	1	1	1	2	2
4	2	1	1	1	1	1	2	2
5	2	3	2	2	6	6	12	12
6	2	1	1	1	1	1	2	2
7	3	2	5	2	10	4	30	12
8	3	1	2	2	2	2	6	6
9	3	2	3	3	6	6	18	18
10	3	2	2	1	4	2	12	6
11	3	1	3	3	3	3	9	9
12	3	3	5	5	15	15	45	45
13	3	2	4	1	8	2	24	6
14	3	2	1	2	2	4	6	12
15	3	1	1	2	1	2	3	6
16	3	3	2	1	6	3	18	9
Total	42					Total	193	151
The average statistic assessment of loss R_c:								4,595
The average statistic assessment of loss R_t:								3,595

Table A3.1.5. The expert assessment of loss "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)"

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	3	4	4	12	12	24	24
2	2	2	2	2	4	4	8	8
3	2	3	3	3	9	9	18	18
4	2	1	1	1	1	1	2	2
5	2	3	2	1	6	3	12	6
6	2	2	2	1	4	2	8	4
7	3	3	2	1	6	3	18	9
8	3	3	1	1	3	3	9	9
9	3	1	2	1	2	1	6	3
10	3	4	3	2	12	8	36	24

11	3	3	1	1	3	3	9	9
12	3	3	3	2	9	6	27	18
13	3	3	1	2	3	6	9	18
14	3	1	3	1	3	1	9	3
15	3	1	1	1	1	1	3	3
16	3	4	2	1	8	4	24	12
Total	42					Total	222	170
The average statistic assessment of loss R_c:								5,286
The average statistic assessment of loss R_t:								4,048

3.2 Assessment of losses due to waiting

Table A3.2.1 The expert assessment of loss "Waiting for delivery of materials and products for construction of structures (concrete, reinforcement, fixings)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	4	4	4	16	16	32	32
2	2	1	1	1	1	1	2	2
3	2	3	3	2	9	6	18	12
4	2	1	1	1	1	1	2	2
5	2	2	2	2	4	4	8	8
6	2	2	1	2	2	4	4	8
7	3	3	2	2	6	6	18	18
8	3	3	1	1	3	3	9	9
9	3	1	1	3	1	3	3	9
10	3	3	2	2	6	6	18	18
11	3	3	1	2	3	6	9	18
12	3	3	3	2	9	6	27	18
13	3	4	2	3	8	12	24	36
14	3	1	1	1	1	1	3	3
15	3	1	1	2	1	2	3	6
16	3	3	2	2	6	6	18	18
Total	42					Total	198	217
The average statistic assessment of loss R_c:								4,714
The average statistic assessment of loss R_t:								5,167

Table A3.2.2. The expert assessment of loss "Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	5	5	5	25	25	50	50
2	2	1	1	1	1	1	2	2
3	2	3	3	3	9	9	18	18
4	2	1	1	1	1	1	2	2
5	2	1	2	3	2	3	4	6
6	2	2	1	2	2	4	4	8

7	3	5	1	1	5	5	15	15
8	3	4	1	1	4	4	12	12
9	3	1	1	1	1	1	3	3
10	3	4	1	2	4	8	12	24
11	3	4	1	2	4	8	12	24
12	3	2	2	3	4	6	12	18
13	3	5	2	3	10	15	30	45
14	3	1	1	1	1	1	3	3
15	3	1	2	2	2	2	6	6
16	3	3	1	2	3	6	9	18
Total	42					Total	194	254
The average statistic assessment of loss R_c:								4,619
The average statistic assessment of loss R_t:								6,048

Table A3.2.3 The expert assessment of loss "Waiting for the supply of means of production on the work front".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	4	4	4	16	16	32	32
2	2	3	3	3	9	9	18	18
3	2	4	3	3	12	12	24	24
4	2	2	1	2	2	4	4	8
5	2	3	1	2	3	6	6	12
6	2	1	1	2	1	2	2	4
7	3	3	1	2	3	6	9	18
8	3	3	1	1	3	3	9	9
9	3	1	1	2	1	2	3	6
10	3	2	2	2	4	4	12	12
11	3	3	1	3	3	9	9	27
12	3	3	2	3	6	9	18	27
13	3	5	1	2	5	10	15	30
14	3	1	1	1	1	1	3	3
15	3	1	1	1	1	1	3	3
16	3	3	1	2	3	6	9	18
Total	42					Total	176	251
The average statistic assessment of loss R_c:								4,190
The average statistic assessment of loss R_t:								5,976

Table A3.2.4 The expert assessment of loss "The smoke breaks of workers in the work process".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	5	5	5	25	25	50	50
3	2	4	3	3	12	12	24	24
4	2	1	1	1	1	1	2	2
5	2	3	3	3	9	9	18	18
6	2	2	1	2	2	4	4	8
7	3	3	1	1	3	3	9	9
8	3	4	2	2	8	8	24	24
9	3	1	1	1	1	1	3	3
10	3	2	2	2	4	4	12	12
11	3	5	2	4	10	20	30	60
12	3	3	3	2	9	6	27	18
13	3	5	1	2	5	10	15	30
14	3	1	1	1	1	1	3	3
15	3	1	1	1	1	1	3	3
16	3	4	2	3	8	12	24	36
Total	42					Total	250	302
The average statistic assessment of loss R_c:								5,952
The average statistic assessment of loss R_t:								7,190

Table A3.2.5 The expert assessment of loss " The idles of workers while waiting for work front".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	2	2	4	4	8	8
2	2	4	4	4	16	16	32	32
3	2	2	2	2	4	4	8	8
4	2	1	1	1	1	1	2	2
5	2	2	2	2	4	4	8	8
6	2	1	1	2	1	2	2	4
7	3	1	1	1	1	1	3	3
8	3	2	1	2	2	4	6	12
9	3	2	2	4	4	8	12	24
10	3	2	2	2	4	4	12	12
11	3	5	2	4	10	20	30	60
12	3	3	1	1	3	3	9	9

13	3	4	2	2	8	8	24	24
14	3	2	2	2	4	4	12	12
15	3	1	2	2	2	2	6	6
16	3	3	2	3	6	9	18	27
Total	42					Total	192	251
The average statistic assessment of loss R_c:								4,571
The average statistic assessment of loss R_t:								5,976

Table A3.2.6 The expert assessment of loss "Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	1	1	1	1	1	2	2
3	2	1	1	1	1	1	2	2
4	2	1	1	1	1	1	2	2
5	2	2	1	1	2	2	4	4
6	2	1	1	1	1	1	2	2
7	3	4	1	3	4	12	12	36
8	3	2	1	1	2	2	6	6
9	3	2	2	3	4	6	12	18
10	3	2	2	2	4	4	12	12
11	3	2	1	2	2	4	6	12
12	3	2	1	2	2	4	6	12
13	3	3	1	1	3	3	9	9
14	3	2	1	2	2	4	6	12
15	3	1	2	2	2	2	6	6
16	3	3	2	2	6	6	18	18
Total	42					Total	107	155
The average statistic assessment of loss R_c:								2,548
The average statistic assessment of loss R_t:								3,690

3.3 Assessment of losses due to unnecessary transportation (moving of structures or materials)

Table A3.3.1 The expert assessment of loss "Large distances between on-site warehouse and the construction object".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	5	5	5	25	25	50	50
3	2	3	4	4	12	12	24	24
4	2	2	2	2	4	4	8	8
5	2	2	1	2	2	4	4	8
6	2	1	1	1	1	1	2	2
7	3	1	1	1	1	1	3	3
8	3	2	2	1	4	2	12	6
9	3	1	2	2	2	2	6	6
10	3	3	2	2	6	6	18	18
11	3	1	3	3	3	3	9	9
12	3	3	2	2	6	6	18	18
13	3	3	3	3	9	9	27	27
14	3	2	1	2	2	4	6	12
15	3	1	1	1	1	1	3	3
16	3	1	1	1	1	1	3	3
Total	42					Total	195	199
The average statistic assessment of loss R_c:								4,643
The average statistic assessment of loss R_t:								4,738

Table A3.3.2 The expert assessment of loss " Damage to structures of formwork when taping of the already built structures".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	2	2	2	4	4	8	8
3	2	1	2	1	2	1	4	2
4	2	1	1	1	1	1	2	2
5	2	2	2	1	4	2	8	4
6	2	1	1	1	1	1	2	2

7	3	1	1	1	1	1	3	3
8	3	2	2	2	4	4	12	12
9	3	1	1	3	1	3	3	9
10	3	1	1	1	1	1	3	3
11	3	1	3	2	3	2	9	6
12	3	1	3	2	3	2	9	6
13	3	1	1	2	1	2	3	6
14	3	1	1	1	1	1	3	3
15	3	1	2	2	2	2	6	6
16	3	1	2	1	2	1	6	3
Total	42					Total	83	77
The average statistic assessment of loss R_c:								1,976
The average statistic assessment of loss R_t:								1,833

Table A3.3.3 The expert assessment of loss "Damage to reinforcement units and fixings when applying by the crane".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	1	1	1	1	1	2	2
3	2	1	1	1	1	1	2	2
4	2	1	1	1	1	1	2	2
5	2	2	2	2	4	4	8	8
6	2	1	1	1	1	1	2	2
7	3	1	1	1	1	1	3	3
8	3	2	1	2	2	4	6	12
9	3	1	2	3	2	3	6	9
10	3	1	1	1	1	1	3	3
11	3	1	4	3	4	3	12	9
12	3	1	3	2	3	2	9	6
13	3	1	2	1	2	1	6	3
14	3	1	1	1	1	1	3	3
15	3	1	1	1	1	1	3	3
16	3	2	1	2	2	4	6	12
Total	42					Total	75	81
The average statistic assessment of loss R_c:								1,786
The average statistic assessment of loss R_t:								1,929

Table A3.3.4 The expert assessment of loss "Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	2	2	4	4	8	8
2	2	2	2	2	4	4	8	8
3	2	2	1	2	2	4	4	8
4	2	1	1	1	1	1	2	2
5	2	3	2	3	6	9	12	18
6	2	2	2	2	4	4	8	8
7	3	1	2	1	2	1	6	3
8	3	3	2	3	6	9	18	27
9	3	1	2	2	2	2	6	6
10	3	1	1	1	1	1	3	3
11	3	1	4	4	4	4	12	12
12	3	3	1	2	3	6	9	18
13	3	3	2	2	6	6	18	18
14	3	1	2	1	2	1	6	3
15	3	1	2	2	2	2	6	6
16	3	3	2	2	6	6	18	18
Total	42					Total	144	166
The average statistic assessment of loss R_c:								3,429
The average statistic assessment of loss R_t:								3,952

Table A3.3.5 The expert assessment of loss " Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	3	2	3	6	9	12	18
2	2	1	1	1	1	1	2	2
3	2	1	1	1	1	1	2	2
4	2	1	1	1	1	1	2	2
5	2	2	1	2	2	4	4	8
6	2	1	1	2	1	2	2	4
7	3	1	1	1	1	1	3	3
8	3	2	1	2	2	4	6	12

9	3	1	1	2	1	2	3	6
10	3	1	1	1	1	1	3	3
11	3	2	2	3	4	6	12	18
12	3	3	1	2	3	6	9	18
13	3	4	2	2	8	8	24	24
14	3	1	1	1	1	1	3	3
15	3	1	1	1	1	1	3	3
16	3	1	1	1	1	1	3	3
Total	42					Total	93	129
The average statistic assessment of loss R_c:								2,214
The average statistic assessment of loss R_t:								3,071

3.4 Assessment of losses due to unnecessary processing steps

Table A3.4.1 The expert assessment of loss "The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	1	1	1	1	1	2	2
3	2	1	1	1	1	1	2	2
4	2	1	1	1	1	1	2	2
5	2	1	2	1	2	1	4	2
6	2	1	2	1	2	1	4	2
7	3	3	1	1	3	3	9	9
8	3	4	1	2	4	8	12	24
9	3	2	1	3	2	6	6	18
10	3	3	2	1	6	3	18	9
11	3	5	2	1	10	5	30	15
12	3	2	1	1	2	2	6	6
13	3	1	1	1	1	1	3	3
14	3	1	4	1	4	1	12	3
15	3	1	1	1	1	1	3	3
16	3	1	1	1	1	1	3	3
Total	42					Total	118	105
The average statistic assessment of loss R_c:								2,810
The average statistic assessment of loss R_t:								2,500

Table A3.4.2 The expert assessment of loss "The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	2	2	2	4	4	8	8
3	2	2	2	2	4	4	8	8
4	2	1	1	1	1	1	2	2
5	2	2	2	1	4	2	8	4
6	2	1	1	1	1	1	2	2
7	3	2	1	2	2	4	6	12

8	3	4	2	2	8	8	24	24
9	3	2	2	2	4	4	12	12
10	3	3	2	2	6	6	18	18
11	3	4	1	2	4	8	12	24
12	3	3	1	2	3	6	9	18
13	3	1	1	1	1	1	3	3
14	3	1	1	1	1	1	3	3
15	3	1	1	1	1	1	3	3
16	3	2	2	2	4	4	12	12
Total	42					Total	132	155
The average statistic assessment of loss R_c:								3,143
The average statistic assessment of loss R_t:								3,690

Table A3.4.3 The expert assessment of loss "The mismatch of the terms of materials, structures and products storage to requirements of normative documents".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	2	2	4	4	8	8
2	2	4	4	4	16	16	32	32
3	2	3	3	3	9	9	18	18
4	2	1	1	1	1	1	2	2
5	2	3	2	2	6	6	12	12
6	2	1	1	1	1	1	2	2
7	3	2	1	1	2	2	6	6
8	3	2	1	1	2	2	6	6
9	3	4	1	5	4	20	12	60
10	3	3	2	2	6	6	18	18
11	3	4	1	1	4	4	12	12
12	3	3	1	2	3	6	9	18
13	3	1	3	1	3	1	9	3
14	3	1	4	1	4	1	12	3
15	3	1	1	1	1	1	3	3
16	3	3	3	1	9	3	27	9
Total	42					Total	188	212
The average statistic assessment of loss R_c:								4,476
The average statistic assessment of loss R_t:								5,048

Table A3.4.4 The expert assessment of loss "Storage of wastes at the construction site, without exporting them to a landfill".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	1	1	1	1	1	2	2
3	2	1	1	1	1	1	2	2
4	2	1	1	1	1	1	2	2
5	2	3	1	2	3	6	6	12
6	2	1	2	2	2	2	4	4
7	3	1	1	1	1	1	3	3
8	3	2	3	1	6	2	18	6
9	3	1	3	5	3	5	9	15
10	3	1	1	1	1	1	3	3
11	3	3	1	1	3	3	9	9
12	3	3	1	1	3	3	9	9
13	3	4	2	3	8	12	24	36
14	3	1	1	1	1	1	3	3
15	3	1	1	1	1	1	3	3
16	3	2	1	1	2	2	6	6
Total	42					Total	105	117
The average statistic assessment of loss R_c:								2,500
The average statistic assessment of loss R_t:								2,786

3.5 Assessment of losses due to unnecessary processing steps

Table A3.5.1 The expert assessment of loss "The production of defective construction products".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	3	3	3	9	9	18	18
2	2	3	3	3	9	9	18	18
3	2	3	3	3	9	9	18	18
4	2	2	2	2	4	4	8	8
5	2	4	3	2	12	8	24	16
6	2	1	2	2	2	2	4	4
7	3	1	1	1	1	1	3	3
8	3	1	4	4	4	4	12	12
9	3	3	3	2	9	6	27	18
10	3	4	2	2	8	8	24	24
11	3	1	3	3	3	3	9	9
12	3	2	3	3	6	6	18	18
13	3	2	4	3	8	6	24	18
14	3	4	4	4	16	16	48	48
15	3	1	1	1	1	1	3	3
16	3	1	2	2	2	2	6	6
Total	42					Total	264	241
							The average statistic assessment of loss R_c:	6,286
							The average statistic assessment of loss R_t:	5,738

Table A3.5.2 The expert assessment of loss "Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc."

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	1	1	1	1	1	2	2
2	2	2	2	2	4	4	8	8
3	2	3	3	3	9	9	18	18
4	2	2	2	2	4	4	8	8
5	2	2	2	3	4	6	8	12
6	2	1	1	1	1	1	2	2
7	3	2	2	2	4	4	12	12
8	3	1	4	3	4	3	12	9

9	3	3	2	4	6	12	18	36
10	3	4	2	2	8	8	24	24
11	3	1	4	3	4	3	12	9
12	3	2	2	2	4	4	12	12
13	3	1	4	2	4	2	12	6
14	3	1	1	1	1	1	3	3
15	3	1	1	1	1	1	3	3
16	3	2	2	3	4	6	12	18
Total	42					Total	166	182
The average statistic assessment of loss R_c:								3,952
The average statistic assessment of loss R_t:								4,333

Table A3.5.3 The expert assessment of loss "The usage of materials, structures, products and etc. which are not of appropriate by design while work execution".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	2	2	4	4	8	8
2	2	2	2	2	4	4	8	8
3	2	2	2	2	4	4	8	8
4	2	1	1	1	1	1	2	2
5	2	3	1	1	3	3	6	6
6	2	1	1	1	1	1	2	2
7	3	2	1	1	2	2	6	6
8	3	2	5	2	10	4	30	12
9	3	1	2	1	2	1	6	3
10	3	4	2	2	8	8	24	24
11	3	3	1	1	3	3	9	9
12	3	2	3	3	6	6	18	18
13	3	1	3	1	3	1	9	3
14	3	2	3	2	6	4	18	12
15	3	1	1	2	1	2	3	6
16	3	3	2	1	6	3	18	9
Total	42					Total	175	136
The average statistic assessment of loss R_c:								4,167
The average statistic assessment of loss R_t:								3,238

Table A3.5.4 The expert assessment of loss "The usage of methods and techniques of work which are not relevant to the project".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	2	2	4	4	8	8
2	2	2	2	2	4	4	8	8
3	2	2	2	2	4	4	8	8
4	2	1	1	1	1	1	2	2
5	2	4	2	1	8	4	16	8
6	2	2	2	2	4	4	8	8
7	3	2	2	1	4	2	12	6
8	3	1	2	2	2	2	6	6
9	3	1	1	1	1	1	3	3
10	3	4	2	2	8	8	24	24
11	3	3	1	2	3	6	9	18
12	3	2	2	2	4	4	12	12
13	3	2	3	2	6	4	18	12
14	3	2	2	2	4	4	12	12
15	3	1	2	2	2	2	6	6
16	3	4	2	2	8	8	24	24
Total	42					Total	176	165
The average statistic assessment of loss R_c:								4,190
The average statistic assessment of loss R_t:								3,929

3.6 Assessment of losses due to unnecessary movements

Table A3.6.1 The expert assessment of loss "The lack of discipline in the workplace (in context of materials and units transportation within the building site)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	2	2	4	4	8	8
2	2	1	1	1	1	1	2	2
3	2	2	2	3	4	6	8	12
4	2	2	2	2	4	4	8	8
5	2	3	1	3	3	9	6	18
6	2	2	2	2	4	4	8	8
7	3	3	1	2	3	6	9	18
8	3	2	2	2	4	4	12	12
9	3	1	1	2	1	2	3	6
10	3	2	2	2	4	4	12	12
11	3	5	3	5	15	25	45	75
12	3	3	1	3	3	9	9	27
13	3	2	2	3	4	6	12	18
14	3	4	4	4	16	16	48	48
15	3	1	2	2	2	2	6	6
16	3	3	2	2	6	6	18	18
Total	42					Total	214	296
The average statistic assessment of loss R_c:								5,095
The average statistic assessment of loss R_t:								7,048

Table A3.6.2 The expert assessment of loss "The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	1	1	2	2	4	4
2	2	3	3	3	9	9	18	18
3	2	2	1	2	2	4	4	8
4	2	2	2	2	4	4	8	8
5	2	2	2	2	4	4	8	8

6	2	2	2	2	4	4	8	8
7	3	2	1	1	2	2	6	6
8	3	2	2	2	4	4	12	12
9	3	2	1	2	2	4	6	12
10	3	2	2	2	4	4	12	12
11	3	4	3	4	12	16	36	48
12	3	3	3	3	9	9	27	27
13	3	2	2	3	4	6	12	18
14	3	5	4	5	20	25	60	75
15	3	1	2	2	2	2	6	6
16	3	3	2	3	6	9	18	27
Total	42					Total	245	297
The average statistic assessment of loss R_c:								5,833
The average statistic assessment of loss R_t:								7,071

Table A3.6.3 The expert assessment of loss "Additional (unnecessary) handling of materials, structures and products on the construction site".

Эксперт	Уровень компетентности эксперта (балл)	Вероятность возникновения P (балл)	Величина потерь I_c (балл)	Величина потерь I_t (балл)	Индекс потери R_c(баллы)	Индекс потери R_t(баллы)	Индекс потери R_c с учетом компетентности эксперта	Индекс потери R_t с учетом компетентности эксперта
1	2	3	3	3	9	9	18	18
2	2	2	2	2	4	4	8	8
3	2	1	1	1	1	1	2	2
4	2	2	2	2	4	4	8	8
5	2	2	1	2	2	4	4	8
6	2	2	2	2	4	4	8	8
7	3	1	1	1	1	1	3	3
8	3	2	1	1	2	2	6	6
9	3	2	1	3	2	6	6	18
10	3	2	2	2	4	4	12	12
11	3	4	2	3	8	12	24	36
12	3	3	1	1	3	3	9	9
13	3	3	1	2	3	6	9	18
14	3	3	2	3	6	9	18	27
15	3	1	1	1	1	1	3	3
16	3	3	1	3	3	9	9	27
Total	42					Total	147	211
The average statistic assessment of loss R_c:								3,500
The average statistic assessment of loss R_t:								5,024

3.7 Assessment of losses due to release of defective products

Table A3.7.1 The expert assessment of loss "The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	2	2	4	4	8	8
2	2	2	2	2	4	4	8	8
3	2	1	1	1	1	1	2	2
4	2	1	1	1	1	1	2	2
5	2	2	1	2	2	4	4	8
6	2	2	1	1	2	2	4	4
7	3	1	5	3	5	3	15	9
8	3	1	3	3	3	3	9	9
9	3	4	3	4	12	16	36	48
10	3	4	3	3	12	12	36	36
11	3	5	5	5	25	25	75	75
12	3	2	4	4	8	8	24	24
13	3	3	4	3	12	9	36	27
14	3	4	4	5	16	20	48	60
15	3	1	2	2	2	2	6	6
16	3	4	4	4	16	16	48	48
Total	42					Total	361	374
The average statistic assessment of loss R_c:								8,595
The average statistic assessment of loss R_t:								8,905

Table A3.7.2 The expert assessment of loss "The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	2	2	4	4	8	8
2	2	2	2	2	4	4	8	8
3	2	3	2	2	6	6	12	12
4	2	1	1	1	1	1	2	2
5	2	2	2	1	4	2	8	4
6	2	1	1	1	1	1	2	2
7	3	1	5	3	5	3	15	9
8	3	1	3	3	3	3	9	9
9	3	3	1	4	3	12	9	36
10	3	4	3	3	12	12	36	36
11	3	4	4	3	16	12	48	36
12	3	2	4	4	8	8	24	24
13	3	2	4	3	8	6	24	18
14	3	3	3	3	9	9	27	27
15	3	1	2	1	2	1	6	3
16	3	2	2	3	4	6	12	18
Total	42					Total	250	252
The average statistic assessment of loss R_c:								5,952
The average statistic assessment of loss R_t:								6,000

Table A3.7.3 The expert assessment of loss " The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	2	2	2	4	4	8	8
2	2	3	3	3	9	9	18	18
3	2	3	3	3	9	9	18	18
4	2	1	1	1	1	1	2	2

5	2	3	2	2	6	6	12	12
6	2	2	2	2	4	4	8	8
7	3	1	5	2	5	2	15	6
8	3	1	3	3	3	3	9	9
9	3	4	3	3	12	12	36	36
10	3	4	2	3	8	12	24	36
11	3	2	3	2	6	4	18	12
12	3	2	4	4	8	8	24	24
13	3	2	2	2	4	4	12	12
14	3	3	3	3	9	9	27	27
15	3	1	2	2	2	2	6	6
16	3	2	2	3	4	6	12	18
Total	42					Total	249	252
The average statistic assessment of loss R_c:								5,929
The average statistic assessment of loss R_t:								6,000

Table A3.7.4 The expert assessment of loss "The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	Index of loss R_c (points)	Index of loss R_t (баллы)	Index of loss R_c taking into account of experts' competence	Index of loss R_t taking into account of experts' competence
1	2	3	3	3	9	9	18	18
2	2	5	5	5	25	25	50	50
3	2	1	1	1	1	1	2	2
4	2	1	1	1	1	1	2	2
5	2	3	1	1	3	3	6	6
6	2	2	1	1	2	2	4	4
7	3	2	1	1	2	2	6	6
8	3	1	2	2	2	2	6	6
9	3	4	2	5	8	20	24	60
10	3	4	3	4	12	16	36	48
11	3	5	1	1	5	5	15	15
12	3	3	2	2	6	6	18	18
13	3	2	3	3	6	6	18	18
14	3	3	2	3	6	9	18	27
15	3	1	2	2	2	2	6	6
16	3	3	1	1	3	3	9	9
Total	42					Total	238	295
The average statistic assessment of loss R_c:								5,667
The average statistic assessment of loss R_t:								7,024

3.8 Summary tables for losses assessment

Table A3.8 Summary table of the losses due to overproduction which influence on construction cost.

Expert	Index of loss R_c taking into account of experts' competence				
	1.1	1.2	1.3	1.4	1.5
1	2	2	8	2	24
2	8	8	24	2	8
3	2	2	8	2	18
4	2	2	2	2	2
5	2	2	16	12	12
6	2	2	2	2	8
7	24	30	30	30	18
8	9	9	9	6	9
9	6	6	9	18	6
10	3	3	3	12	36
11	18	6	6	9	9
12	45	12	12	45	27
13	24	12	6	24	9
14	3	6	3	6	9
15	6	3	3	3	3
16	9	6	6	18	24
The weighted average rating	3,929	2,643	3,500	4,595	5,286
Weight	0,197	0,132	0,175	0,230	0,265
Variation coefficient	1,000	0,879	0,901	0,879	0,661

Note:

1.1 Filling of columns formwork before the end of their complete installation and inspection of the correct execution.

1.2 Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation.

1.3 Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns.

1.4 Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements.

1.5 Production of large quantities of waste (rebar off-cuts, wires, boards, etc.).

Table A3.9. Summary table of the losses due to overproduction which influence on construction time.

Expert	Index of loss R_t taking into account of experts' competence				
	1.1	1.2	1.3	1.4	1.5
1	2	2	8	2	24
2	8	8	24	2	8
3	2	2	32	2	18
4	2	2	2	2	2
5	2	4	24	12	6
6	2	2	2	2	4
7	12	12	12	12	9
8	9	9	12	6	9
9	3	12	27	18	3
10	3	3	3	6	24
11	6	6	6	9	9
12	36	18	12	45	18
13	18	12	6	6	18
14	3	12	3	12	3
15	3	3	3	6	3
16	9	18	18	9	12
The weighted average rating	2,857	2,976	4,619	3,595	4,048
Weight	0,158	0,164	0,255	0,199	0,224
Variation coefficient	1,034	0,591	0,922	0,981	0,732

Note:

1.1 Filling of columns formwork before the end of their complete installation and inspection of the correct execution.

1.2 Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation.

1.3 Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns.

1.4 Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements.

1.5 Production of large quantities of waste (rebar off-cuts, wires, boards, etc.).

Table A3.10 Summary table of the losses due to waiting which influence on construction cost.

Expert	Index of loss R_c taking into account of experts' competence					
	2.1	2.2	2.3	2.4	2.5	2.6
1	32	50	32	2	8	2
2	2	2	18	50	32	2
3	18	18	24	24	8	2
4	2	2	4	2	2	2
5	8	4	6	18	8	4
6	4	4	2	4	2	2
7	18	15	9	9	3	12
8	9	12	9	24	6	6
9	3	3	3	3	12	12
10	18	12	12	12	12	12
11	9	12	9	30	30	6
12	27	12	18	27	9	6
13	24	30	15	15	24	9
14	3	3	3	3	12	6
15	3	6	3	3	6	6
16	18	9	9	24	18	18
The weighted average rating	4,714	4,619	4,190	5,952	4,571	2,548
Weight	0,177	0,174	0,158	0,224	0,172	0,096
Variation coefficient	0,806	1,133	0,907	0,940	0,779	0,561

Note:

2.1 Waiting on delivery of materials and products for construction of structures (concrete, reinforcement, fixings).

2.2 Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example.

2.3 Waiting for the supply of means of production on the work front.

2.4 The breaks of workers in the work process.

2.5 The idles of workers while waiting for work front.

2.6 Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.).

Table A3.11 Summary table of the losses due to waiting which influence on construction time.

Expert	Index of loss R_t taking into account of experts' competence					
	2.1	2.2	2.3	2.4	2.5	2.6
1	32	50	32	2	8	2
2	2	2	18	50	32	2
3	12	18	24	24	8	2
4	2	2	8	2	2	2
5	8	6	12	18	8	4
6	8	8	4	8	4	2
7	18	15	18	9	3	36
8	9	12	9	24	12	6
9	9	3	6	3	24	18
10	18	24	12	12	12	12
11	18	24	27	60	60	12
12	18	18	27	18	9	12
13	36	45	30	30	24	9
14	3	3	3	3	12	12
15	6	6	3	3	6	6
16	18	18	18	36	27	18
The weighted average rating	5,167	6,048	5,976	7,190	5,976	3,690
Weight	0,152	0,178	0,176	0,211	0,176	0,108
Variation coefficient	0,714	0,936	0,669	0,931	0,868	0,772

Note:

2.1 Waiting on delivery of materials and products for construction of structures (concrete, reinforcement, fixings).

2.2 Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example.

2.3 Waiting for the supply of means of production on the work front.

2.4 The breaks of workers in the work process.

2.5 The idles of workers while waiting for work front.

2.6 Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.).

Table A3.12 Summary table of the losses due to unnecessary transportation (moving of structures or materials) which influence on construction cost.

Expert	Index of loss R_c taking into account of experts' competence				
	3.1	3.2	3.3	3.4	3.5
1	2	2	2	8	12
2	50	8	2	8	2
3	24	4	2	4	2
4	8	2	2	2	2
5	4	8	8	12	4
6	2	2	2	8	2
7	3	3	3	6	3
8	12	12	6	18	6
9	6	3	6	6	3
10	18	3	3	3	3
11	9	9	12	12	12
12	18	9	9	9	9
13	27	3	6	18	24
14	6	3	3	6	3
15	3	6	3	6	3
16	3	6	6	18	3
The weighted average rating	4,643	1,976	1,786	3,429	2,214
Weight	0,331	0,141	0,127	0,244	0,158
Variation coefficient	1,175	0,579	0,567	0,522	0,933

Note:

3.1 Large distances between on-site warehouse and the construction object.

3.2 Damage to structures of formwork when taping of the already built structures.

3.3 Damage to reinforcement units and fixings when applying by the crane.

3.4 Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers).

3.5 Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work).

Table A3.13. Summary table of the losses due to unnecessary transportation (moving of structures or materials) which influence on construction time.

Expert	Index of loss R_t taking into account of experts' competence				
	3.1	3.2	3.3	3.4	3.5
1	2	2	2	8	18
2	50	8	2	8	2
3	24	2	2	8	2
4	8	2	2	2	2
5	8	4	8	18	8
6	2	2	2	8	4
7	3	3	3	3	3
8	6	12	12	27	12
9	6	9	9	6	6
10	18	3	3	3	3
11	9	6	9	12	18
12	18	6	6	18	18
13	27	6	3	18	24
14	12	3	3	3	3
15	3	6	3	6	3
16	3	3	12	18	3
The weighted average rating	4,738	1,833	1,929	3,952	3,071
Weight	0,305	0,118	0,124	0,255	0,198
Variation coefficient	1,145	0,544	0,635	0,658	0,863

Note:

3.1 Large distances between on-site warehouse and the construction object.

3.2 Damage to structures of formwork when taping of the already built structures.

3.3 Damage to reinforcement units and fixings when applying by the crane.

3.4 Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers).

3.5 Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work).

Table A3.14 Summary table of the losses due to excess inventory which influence on construction cost.

Expert	Index of loss R_t taking into account of experts' competence			
	4.1	4.2	4.3	4.4
1	2	2	8	2
2	2	8	32	2
3	2	8	18	2
4	2	2	2	2
5	4	8	12	6
6	4	2	2	4
7	9	6	6	3
8	12	24	6	18
9	6	12	12	9
10	18	18	18	3
11	30	12	12	9
12	6	9	9	9
13	3	3	9	24
14	12	3	12	3
15	3	3	3	3
16	3	12	27	6
The weighted average rating	2,810	3,143	4,476	2,500
Weight	0,217	0,243	0,346	0,193
Variation coefficient	0,882	0,658	0,785	0,822

Note:

4.1 The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse.

4.2 The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products.

4.3 The mismatch of the terms of materials, structures and products storage to requirements of normative documents.

4.4 Storage of wastes at the construction site, without exporting them to a landfill.

Table A3.15 Summary table of the losses due to excess inventory which influence on construction time.

Expert	Index of loss R_t taking into account of experts' competence			
	4.1	4.2	4.3	4.4
1	2	2	8	2
2	2	8	32	2
3	2	8	18	2
4	2	2	2	2
5	2	4	12	12
6	2	2	2	4
7	9	12	6	3
8	24	24	6	6
9	18	12	60	15
10	9	18	18	3
11	15	24	12	9
12	6	18	18	9
13	3	3	3	36
14	3	3	3	3
15	3	3	3	3
16	3	12	27	6
The weighted average rating	2,500	3,690	5,476	2,786
Weight	0,173	0,255	0,379	0,193
Variation coefficient	0,882	0,675	1,075	1,050

Note:

4.1 The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse.

4.2 The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products.

4.3 The mismatch of the terms of materials, structures and products storage to requirements of normative documents.

4.4 Storage of wastes at the construction site, without exporting them to a landfill.

Table A3.16 Summary table of the losses due to unnecessary processing steps which influence on construction cost.

Expert	Index of loss R_c taking into account of experts' competence			
	5.1	5.2	5.3	5.4
1	18	2	8	8
2	18	8	8	8
3	18	18	8	8
4	8	8	2	2
5	24	8	6	16
6	4	2	2	8
7	3	12	6	12
8	12	12	30	6
9	27	18	6	3
10	24	24	24	24
11	9	12	9	9
12	18	12	18	12
13	24	12	9	18
14	48	3	18	12
15	3	3	3	6
16	6	12	18	24
The weighted average rating	6,286	3,952	4,167	4,190
Weight	0,338	0,213	0,224	0,225
Variation coefficient	0,673	0,552	0,627	0,534

Note:

5.1 The production of defective construction products.

5.2 Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc.

5.3 The usage of materials, structures, products and etc. which are not of appropriate by design while work execution.

5.4 The usage of methods and techniques of work which are not relevant to the project.

Table A3.17 Summary table of the losses due to unnecessary processing steps which influence on construction time.

Expert	Index of loss R_t taking into account of experts' competence			
	5.1	5.2	5.3	5.4
1	18	2	8	8
2	18	8	8	8
3	18	18	8	8
4	8	8	2	2
5	16	12	6	8
6	4	2	2	8
7	3	12	6	6
8	12	9	12	6
9	18	36	3	3
10	24	24	24	24
11	9	9	9	18
12	18	12	18	12
13	18	6	3	12
14	48	3	12	12
15	3	3	6	6
16	6	18	9	24
The weighted average rating	5,738	4,333	3,238	3,929
Weight	0,333	0,251	0,188	0,228
Variation coefficient	0,685	0,724	0,598	0,540

Note:

5.1 The production of defective construction products.

5.2 Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc.

5.3 The usage of materials, structures, products and etc. which are not of appropriate by design while work execution.

5.4 The usage of methods and techniques of work which are not relevant to the project.

Table A3.18 Summary table of the losses due to unnecessary movements which influence on construction cost.

Expert	Index of loss R_c taking into account of experts' competence		
	6.1	6.2	6.3
1	8	4	18
2	2	18	8
3	8	4	2
4	8	8	8
5	6	8	4
6	8	8	8
7	9	6	3
8	12	12	6
9	3	6	6
10	12	12	12
11	45	36	24
12	9	27	9
13	12	12	9
14	48	60	18
15	6	6	3
16	18	18	9
The weighted average rating	5,095	5,833	3,500
Weight	0,353	0,404	0,243
Variation coefficient	0,869	0,841	0,643

Note:

6.1 The lack of discipline in the workplace (in context of materials and units transportation within the building site).

6.2 The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan).

6.3 Additional (unnecessary) handling of materials, structures and products on the construction site.

Table A3.19 Summary table of the losses due to unnecessary movements which influence on construction time.

Expert	Index of loss R_t taking into account of experts' competence		
	6.1	6.2	6.3
1	8	4	18
2	2	18	8
3	12	8	2
4	8	8	8
5	18	8	8
6	8	8	8
7	18	6	3
8	12	12	6
9	6	12	18
10	12	12	12
11	75	48	36
12	27	27	9
13	18	18	18
14	48	75	27
15	6	6	3
16	18	27	27
The weighted average rating	7,048	7,071	5,024
Weight	0,368	0,369	0,262
Variation coefficient	0,870	0,875	0,658

Note:

6.1 The lack of discipline in the workplace (in context of materials and units transportation within the building site).

6.2 The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan).

6.3 Additional (unnecessary) handling of materials, structures and products on the construction site.

Table A3.20 Summary table of the losses due to release of defective products which influence on construction cost.

Expert	Index of loss R_c taking into account of experts' competence			
	7.1	7.2	7.3	7.4
1	8	8	8	18
2	8	8	18	50
3	2	12	18	2
4	2	2	2	2
5	4	8	12	6
6	4	2	8	4
7	15	15	15	6
8	9	9	9	6
9	36	9	36	24
10	36	36	24	36
11	75	48	18	15
12	24	24	24	18
13	36	24	12	18
14	48	27	27	18
15	6	6	6	6
16	48	12	12	9
The weighted average rating	8,595	5,952	5,929	5,667
Weight	0,329	0,228	0,227	0,217
Variation coefficient	0,807	0,688	0,496	0,935

Note:

7.1 The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required).

7.2 The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project).

7.3 The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.).

7.4 The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.).

Table A3.21 Summary table of the losses due to release of defective products which influence on construction cost.

Expert	Index of loss R_t taking into account of experts' competence			
	7.1	7.2	7.3	7.4
1	8	8	8	18
2	8	8	18	50
3	2	12	18	2
4	2	2	2	2
5	8	4	12	6
6	4	2	8	4
7	9	9	6	6
8	9	9	9	6
9	48	36	36	60
10	36	36	36	48
11	75	36	12	15
12	24	24	24	18
13	27	18	12	18
14	60	27	27	27
15	6	3	6	6
16	48	18	18	9
The weighted average rating	8,905	6,000	6,000	7,024
Weight	0,319	0,215	0,215	0,251
Variation coefficient	0,840	0,654	0,577	0,966

Note:

7.1 The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required).

7.2 The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project).

7.3 The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.).

7.4 The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.).

Annex 4

Calculation of integrated indicator of losses impact.

Annex 4.1 A. The calculation of the integrated indicator of losses impact that affect the cost of construction.

Table A4.1 The assessment values given by experts.

Experts	Losses																															The total score $\sum_{k=1}^{m} h_{ik}$
	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	2.6	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	5.1	5.2	5.3	5.4	6.1	6.2	6.3	7.1	7.2	7.3	7.4	
1	2	2	8	2	24	32	50	32	2	8	2	2	2	2	8	12	2	2	8	2	18	2	8	8	8	4	18	8	8	8	18	312
2	8	8	24	2	8	2	2	18	50	32	2	50	8	2	8	2	2	8	32	2	18	8	8	8	2	18	8	8	8	18	50	424
3	2	2	8	2	18	18	18	24	24	8	2	24	4	2	4	2	2	8	18	2	18	18	8	8	8	4	2	2	12	18	2	292
4	2	2	2	2	2	2	2	4	2	2	2	8	2	2	2	2	2	2	2	2	8	8	2	2	8	8	8	2	2	2	2	100
5	2	2	16	12	12	8	4	6	18	8	4	4	8	8	12	4	4	8	12	6	24	8	6	16	6	8	4	4	8	12	6	260
6	2	2	2	2	8	4	4	2	4	2	2	2	2	2	8	2	4	2	2	4	4	2	2	8	8	8	8	4	2	8	4	120
7	24	30	30	30	18	18	15	9	9	3	12	3	3	3	6	3	9	6	6	3	3	12	6	12	9	6	3	15	15	15	6	342
8	9	9	9	6	9	9	12	9	24	6	6	12	12	6	18	6	12	24	6	18	12	12	30	6	12	12	6	9	9	9	6	345
9	6	6	9	18	6	3	3	3	3	12	12	6	3	6	6	3	6	12	12	9	27	18	6	3	3	6	6	36	9	36	24	318
10	3	3	3	12	36	18	12	12	12	12	12	18	3	3	3	3	18	18	18	3	24	24	24	24	12	12	12	36	36	24	36	486
11	18	6	6	9	9	9	12	9	30	30	6	9	9	12	12	12	30	12	12	9	9	12	9	9	45	36	24	75	48	18	15	561
12	45	12	12	45	27	27	12	18	27	9	6	18	9	9	9	9	6	9	9	9	18	12	18	12	9	27	9	24	24	24	18	522
13	24	12	6	24	9	24	30	15	15	24	9	27	3	6	18	24	3	3	9	24	24	12	9	18	12	12	9	36	24	12	18	495
14	3	6	3	6	9	3	3	3	3	12	6	6	3	3	6	3	12	3	12	3	48	3	18	12	48	60	18	48	27	27	18	435
15	6	3	3	3	3	3	6	3	3	6	6	3	6	3	6	3	3	3	3	3	3	3	3	6	6	6	3	6	6	6	6	132
16	9	6	6	18	24	18	9	9	24	18	18	3	6	6	18	3	3	12	27	6	6	12	18	24	18	18	9	48	12	12	9	429

Table A4.2 The matrix of weight coefficients.

Experts	Weight estimates for each loss																															The total score $\sum_{k=1}^{m} h_{ik}$
	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	2.6	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	5.1	5.2	5.3	5.4	6.1	6.2	6.3	7.1	7.2	7.3	7.4	
1	0,006	0,006	0,026	0,006	0,077	0,103	0,160	0,103	0,006	0,026	0,006	0,006	0,006	0,006	0,026	0,038	0,006	0,006	0,026	0,006	0,058	0,006	0,026	0,026	0,026	0,013	0,058	0,026	0,026	0,026	0,058	312
2	0,019	0,019	0,057	0,005	0,019	0,005	0,005	0,042	0,118	0,075	0,005	0,118	0,019	0,005	0,019	0,005	0,005	0,019	0,075	0,005	0,042	0,019	0,019	0,019	0,005	0,042	0,019	0,019	0,019	0,042	0,118	424
3	0,007	0,007	0,027	0,007	0,062	0,062	0,062	0,082	0,082	0,027	0,007	0,082	0,014	0,007	0,014	0,007	0,007	0,027	0,062	0,007	0,062	0,062	0,027	0,027	0,027	0,014	0,007	0,007	0,041	0,062	0,007	292
4	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,040	0,020	0,020	0,020	0,080	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,080	0,080	0,020	0,020	0,080	0,080	0,080	0,020	0,020	0,020	0,020	100
5	0,008	0,008	0,062	0,046	0,046	0,031	0,015	0,023	0,069	0,031	0,015	0,015	0,031	0,031	0,046	0,015	0,015	0,031	0,046	0,023	0,092	0,031	0,023	0,062	0,023	0,031	0,015	0,015	0,031	0,046	0,023	260
6	0,017	0,017	0,017	0,017	0,067	0,033	0,033	0,017	0,033	0,017	0,017	0,017	0,017	0,017	0,067	0,017	0,033	0,017	0,017	0,033	0,033	0,017	0,017	0,067	0,067	0,067	0,067	0,033	0,017	0,067	0,033	120
7	0,070	0,088	0,088	0,088	0,053	0,053	0,044	0,026	0,026	0,009	0,035	0,009	0,009	0,009	0,018	0,009	0,026	0,018	0,018	0,009	0,009	0,035	0,018	0,035	0,026	0,018	0,009	0,044	0,044	0,044	0,018	342
8	0,026	0,026	0,026	0,017	0,026	0,026	0,035	0,026	0,070	0,017	0,017	0,035	0,035	0,017	0,052	0,017	0,035	0,070	0,017	0,052	0,035	0,035	0,087	0,017	0,035	0,035	0,017	0,026	0,026	0,026	0,017	345
9	0,019	0,019	0,028	0,057	0,019	0,009	0,009	0,009	0,009	0,038	0,038	0,019	0,009	0,019	0,019	0,009	0,019	0,038	0,038	0,028	0,085	0,057	0,019	0,009	0,009	0,019	0,019	0,113	0,028	0,113	0,075	318
10	0,006	0,006	0,006	0,025	0,074	0,037	0,025	0,025	0,025	0,025	0,025	0,037	0,006	0,006	0,006	0,006	0,037	0,037	0,037	0,006	0,049	0,049	0,049	0,049	0,025	0,025	0,025	0,074	0,074	0,049	0,074	486
11	0,032	0,011	0,011	0,016	0,016	0,016	0,021	0,016	0,053	0,053	0,011	0,016	0,016	0,021	0,021	0,021	0,053	0,021	0,021	0,016	0,016	0,021	0,016	0,016	0,080	0,064	0,043	0,134	0,086	0,032	0,027	561
12	0,086	0,023	0,023	0,086	0,052	0,052	0,023	0,034	0,052	0,017	0,011	0,034	0,017	0,017	0,017	0,017	0,011	0,017	0,017	0,017	0,034	0,023	0,034	0,023	0,017	0,052	0,017	0,046	0,046	0,046	0,034	522
13	0,048	0,024	0,012	0,048	0,018	0,048	0,061	0,030	0,030	0,048	0,018	0,055	0,006	0,012	0,036	0,048	0,006	0,006	0,018	0,048	0,048	0,024	0,018	0,036	0,024	0,024	0,018	0,073	0,048	0,024	0,036	495
14	0,007	0,014	0,007	0,014	0,021	0,007	0,007	0,007	0,007	0,028	0,014	0,014	0,007	0,007	0,014	0,007	0,028	0,007	0,028	0,007	0,110	0,007	0,041	0,028	0,110	0,138	0,041	0,110	0,062	0,062	0,041	435
15	0,045	0,023	0,023	0,023	0,023	0,023	0,045	0,023	0,023	0,045	0,045	0,023	0,045	0,023	0,045	0,023	0,023	0,023	0,023	0,023	0,023	0,023	0,023	0,045	0,045	0,045	0,023	0,045	0,045	0,045	0,045	132
16	0,021	0,014	0,014	0,042	0,056	0,042	0,021	0,021	0,056	0,042	0,042	0,007	0,014	0,014	0,042	0,007	0,007	0,028	0,063	0,014	0,014	0,028	0,042	0,056	0,042	0,042	0,021	0,112	0,028	0,028	0,021	429
The total score r_i	0,438	0,324	0,446	0,516	0,647	0,566	0,586	0,525	0,680	0,519	0,327	0,567	0,271	0,231	0,462	0,268	0,332	0,384	0,525	0,315	0,791	0,516	0,479	0,536	0,642	0,708	0,478	0,897	0,641	0,733	0,649	$\sum_{i=1}^{n} r_i$=16
σ	0,027	0,020	0,028	0,032	0,040	0,035	0,037	0,033	0,043	0,032	0,020	0,035	0,017	0,014	0,029	0,017	0,021	0,024	0,033	0,020	0,049	0,032	0,030	0,033	0,040	0,044	0,030	0,056	0,040	0,046	0,041	1
The index value	3,929	2,643	3,500	4,595	5,286	4,714	4,619	4,190	5,952	4,571	2,548	4,643	1,976	1,786	3,429	2,214	2,810	3,143	4,476	2,500	6,286	3,952	4,167	4,190	5,095	5,833	3,500	8,595	5,952	5,929	5,667	K_{cum} = 4,730
The indicator calculation	0,108	0,053	0,097	0,148	0,214	0,167	0,169	0,137	0,253	0,148	0,052	0,164	0,034	0,026	0,099	0,037	0,058	0,075	0,147	0,049	0,311	0,128	0,125	0,140	0,205	0,258	0,105	0,482	0,238	0,272	0,230	K_{loss}=0,189

Annex 4.2 A. The calculation of the integrated indicator of losses impact that affect the time of construction.

Table A4.2 The assessment values given by experts.

Experts	Losses																															The total score $\sum_{k=1}^{m} h_{ik}$
	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	2.6	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	5.1	5.2	5.3	5.4	6.1	6.2	6.3	7.1	7.2	7.3	7.4	
1	2	2	8	2	24	32	50	32	2	8	2	2	2	2	8	18	2	2	8	2	18	2	8	8	8	4	18	8	8	8	18	318
2	8	8	24	2	8	2	2	18	50	32	2	50	8	2	8	2	2	8	32	2	18	8	8	8	2	18	8	8	8	18	50	424
3	2	2	32	2	18	12	18	24	24	8	2	24	2	2	8	2	2	8	18	2	18	18	8	8	12	8	2	2	12	18	2	320
4	2	2	2	2	2	2	2	8	2	2	2	8	2	2	2	2	2	2	2	2	8	8	2	2	8	8	8	2	2	2	2	104
5	2	4	24	12	6	8	6	12	18	8	4	8	4	8	18	8	2	4	12	12	16	12	6	8	18	8	8	8	4	12	6	286
6	2	2	2	2	4	8	8	4	8	4	2	2	2	2	8	4	2	2	2	4	4	2	2	8	8	8	8	4	2	8	4	132
7	12	12	12	12	9	18	15	18	9	3	36	3	3	3	3	3	9	12	6	3	3	12	6	6	18	6	3	9	9	6	6	285
8	9	9	12	6	9	9	12	9	24	12	6	6	12	12	27	12	24	24	6	6	12	9	12	6	12	12	6	9	9	9	6	348
9	3	12	27	18	3	9	3	6	3	24	18	6	9	9	6	6	18	12	60	15	18	36	3	3	6	12	18	48	36	36	60	543
10	3	3	3	6	24	18	24	12	12	12	12	18	3	3	3	3	9	18	18	3	24	24	24	24	12	12	12	36	36	36	48	495
11	6	6	6	9	9	18	24	27	60	60	12	9	6	9	12	18	15	24	12	9	9	9	9	18	75	48	36	75	36	12	15	693
12	36	18	12	45	18	18	18	27	18	9	12	18	6	6	18	18	6	18	18	9	18	12	18	12	27	27	9	24	24	24	18	561
13	18	12	6	6	18	36	45	30	30	24	9	27	6	3	18	24	3	3	3	36	18	6	3	12	18	18	18	27	18	12	18	525
14	3	12	3	12	3	3	3	3	3	12	12	12	3	3	3	3	3	3	3	3	48	3	12	12	48	75	27	60	27	27	27	471
15	3	3	3	6	3	6	6	3	3	6	6	3	6	3	6	3	3	3	3	3	3	3	6	6	6	6	3	6	3	6	6	135
16	9	18	18	9	12	18	18	18	36	27	18	3	3	12	18	3	3	12	27	6	6	18	9	24	18	27	27	48	18	18	9	510

Table A4.4 The matrix of weight coefficients.

Experts	Weight estimates for each loss																															The total score $\sum_{k=1}^{m} h_{ik}$
	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	2.6	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	5.1	5.2	5.3	5.4	6.1	6.2	6.3	7.1	7.2	7.3	7.4	
1	0,006	0,006	0,025	0,006	0,075	0,101	0,157	0,101	0,006	0,025	0,006	0,006	0,006	0,006	0,025	0,057	0,006	0,006	0,025	0,006	0,057	0,006	0,025	0,025	0,025	0,013	0,057	0,025	0,025	0,025	0,057	318
2	0,019	0,019	0,057	0,005	0,019	0,005	0,005	0,042	0,118	0,075	0,005	0,118	0,019	0,005	0,019	0,005	0,005	0,019	0,075	0,005	0,042	0,019	0,019	0,019	0,005	0,042	0,019	0,019	0,019	0,042	0,118	424
3	0,006	0,006	0,100	0,006	0,056	0,038	0,056	0,075	0,075	0,025	0,006	0,075	0,006	0,006	0,025	0,006	0,006	0,025	0,056	0,006	0,056	0,056	0,025	0,025	0,038	0,025	0,006	0,006	0,038	0,056	0,006	320
4	0,019	0,019	0,019	0,019	0,019	0,019	0,019	0,077	0,019	0,019	0,019	0,077	0,019	0,019	0,019	0,019	0,019	0,019	0,019	0,019	0,077	0,077	0,019	0,019	0,077	0,077	0,077	0,019	0,019	0,019	0,019	104
5	0,007	0,014	0,084	0,042	0,021	0,028	0,021	0,042	0,063	0,028	0,014	0,028	0,014	0,028	0,063	0,028	0,007	0,014	0,042	0,042	0,056	0,042	0,021	0,028	0,063	0,028	0,028	0,028	0,014	0,042	0,021	286
6	0,015	0,015	0,015	0,015	0,030	0,061	0,061	0,030	0,061	0,030	0,015	0,015	0,015	0,015	0,061	0,030	0,015	0,015	0,015	0,030	0,030	0,015	0,015	0,061	0,061	0,061	0,061	0,030	0,015	0,061	0,030	132
7	0,042	0,042	0,042	0,042	0,032	0,063	0,053	0,063	0,032	0,011	0,126	0,011	0,011	0,011	0,011	0,011	0,032	0,042	0,021	0,011	0,011	0,042	0,021	0,021	0,063	0,021	0,011	0,032	0,032	0,021	0,021	285
8	0,026	0,026	0,034	0,017	0,026	0,026	0,034	0,026	0,069	0,034	0,017	0,017	0,034	0,034	0,078	0,034	0,069	0,069	0,017	0,017	0,034	0,026	0,034	0,017	0,034	0,034	0,017	0,026	0,026	0,026	0,017	348
9	0,006	0,022	0,050	0,033	0,006	0,017	0,006	0,011	0,006	0,044	0,033	0,011	0,017	0,017	0,011	0,011	0,033	0,022	0,110	0,028	0,033	0,066	0,006	0,006	0,011	0,022	0,033	0,088	0,066	0,066	0,110	543
10	0,006	0,006	0,006	0,012	0,048	0,036	0,048	0,024	0,024	0,024	0,024	0,036	0,006	0,006	0,006	0,006	0,018	0,036	0,036	0,006	0,048	0,048	0,048	0,048	0,024	0,024	0,024	0,073	0,073	0,073	0,097	495
11	0,009	0,009	0,009	0,013	0,013	0,026	0,035	0,039	0,087	0,087	0,017	0,013	0,009	0,013	0,017	0,026	0,022	0,035	0,017	0,013	0,013	0,013	0,013	0,026	0,108	0,069	0,052	0,108	0,052	0,017	0,022	693
12	0,064	0,032	0,021	0,080	0,032	0,032	0,032	0,048	0,032	0,016	0,021	0,032	0,011	0,011	0,032	0,032	0,011	0,032	0,032	0,016	0,032	0,021	0,032	0,021	0,048	0,048	0,016	0,043	0,043	0,043	0,032	561
13	0,034	0,023	0,011	0,011	0,034	0,069	0,086	0,057	0,057	0,046	0,017	0,051	0,011	0,006	0,034	0,046	0,006	0,006	0,006	0,069	0,034	0,011	0,006	0,023	0,034	0,034	0,034	0,051	0,034	0,023	0,034	525
14	0,006	0,025	0,006	0,025	0,006	0,006	0,006	0,006	0,006	0,025	0,025	0,025	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,102	0,006	0,025	0,025	0,102	0,159	0,057	0,127	0,057	0,057	0,057	471
15	0,022	0,022	0,022	0,044	0,022	0,044	0,044	0,022	0,022	0,044	0,044	0,022	0,044	0,022	0,044	0,022	0,022	0,022	0,022	0,022	0,022	0,022	0,044	0,044	0,044	0,044	0,022	0,044	0,022	0,044	0,044	135
16	0,018	0,035	0,035	0,018	0,024	0,035	0,035	0,035	0,071	0,053	0,035	0,006	0,006	0,024	0,035	0,006	0,006	0,024	0,053	0,012	0,012	0,035	0,018	0,047	0,035	0,053	0,053	0,094	0,035	0,035	0,018	510
The total score r_i	0,306	0,322	0,538	0,390	0,464	0,605	0,699	0,700	0,747	0,588	0,428	0,545	0,235	0,229	0,487	0,345	0,283	0,393	0,555	0,308	0,660	0,508	0,372	0,456	0,773	0,756	0,567	0,815	0,570	0,652	0,704	$\sum_{i=1}^{n} r_i$=16
σ	0,019	0,020	0,034	0,024	0,029	0,038	0,044	0,044	0,047	0,037	0,027	0,034	0,015	0,014	0,030	0,022	0,018	0,025	0,035	0,019	0,041	0,032	0,023	0,029	0,048	0,047	0,035	0,051	0,036	0,041	0,044	1
The index value	2,857	2,976	4,619	3,595	4,048	5,167	6,048	5,976	7,190	5,976	3,690	4,738	1,833	1,929	3,952	3,071	2,500	3,690	5,476	2,786	5,738	4,333	3,238	3,929	7,048	7,071	5,024	8,905	6,000	6,000	7,024	$K_{сов}$ = 5,266
The indicator calculation	0,055	0,060	0,155	0,088	0,117	0,195	0,264	0,261	0,336	0,220	0,099	0,161	0,027	0,028	0,120	0,066	0,044	0,091	0,190	0,054	0,237	0,138	0,075	0,112	0,341	0,334	0,178	0,453	0,214	0,244	0,309	K_{loss}=0,211

Annex 5

Additional verification of completed assessment and creation of losses maps.

5.1 Assessment of losses due to overproduction.

Table A5.1.1 The expert assessment of loss "Filling of columns formwork before the end of their complete installation and inspection of the correct execution".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	2	2	2	4	4	4
3	2	1	1	1	2	2	2
4	2	1	1	1	2	2	2
5	2	1	1	1	2	2	2
6	2	1	1	1	2	2	2
7	3	2	4	2	6	12	6
8	3	1	3	3	3	9	9
9	3	1	2	1	3	6	3
10	3	1	1	1	3	3	3
11	3	2	3	1	6	9	3
12	3	3	5	4	9	15	12
13	3	2	4	3	6	12	9
14	3	1	1	1	3	3	3
15	3	1	2	1	3	6	3
16	3	1	3	3	3	9	9
Total	42			Total	59	98	74
The average statistic value					1,405	2,333	1,762

Table A5.1.2. The expert assessment of loss "Assembly of the formwork of walls and columns before the completing of rebar and reinforcement cages installation".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	2	2	2	4	4	4
3	2	1	1	1	2	2	2
4	2	1	1	1	2	2	2
5	2	1	1	2	2	2	4
6	2	1	1	1	2	2	2
7	3	2	5	2	6	15	6
8	3	1	3	3	3	9	9
9	3	2	1	2	6	3	6
10	3	1	1	1	3	3	3
11	3	1	2	2	3	6	6
12	3	2	2	3	6	6	9

13	3	2	2	2	6	6	6
14	3	2	1	2	6	3	6
15	3	1	1	1	3	3	3
16	3	2	1	3	6	3	9
Total	42			Total	62	71	79
The average statistic value					1,476	1,690	1,881

Table A5.1.3 The expert assessment of loss "Installation of mullions and panels of the formwork prior to disassembly of the formwork of walls and columns".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	2	2	4	4	4
2	2	3	4	4	6	8	8
3	2	4	1	4	8	2	8
4	2	1	1	1	2	2	2
5	2	4	2	3	8	4	6
6	2	1	1	1	2	2	2
7	3	2	5	2	6	15	6
8	3	1	3	4	3	9	12
9	3	3	1	3	9	3	9
10	3	1	1	1	3	3	3
11	3	2	1	1	6	3	3
12	3	2	2	2	6	6	6
13	3	1	2	2	3	6	6
14	3	1	1	1	3	3	3
15	3	1	1	1	3	3	3
16	3	2	1	3	6	3	9
Total	42			Total	78	76	90
The average statistic value					1,857	1,810	2,143

Table A5.1.4 The expert assessment of loss "Over reinforcement modification of structures by increasing the diameters or the applicable classes of reinforcement, the number of rods in the construction elements".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	1	1	1	2	2	2
3	2	1	1	1	2	2	2
4	2	1	1	1	2	2	2
5	2	3	2	2	6	4	4
6	2	1	1	1	2	2	2
7	3	2	5	2	6	15	6
8	3	1	2	2	3	6	6

9	3	2	3	3	6	9	9
10	3	2	2	1	6	6	3
11	3	1	3	3	3	9	9
12	3	3	5	5	9	15	15
13	3	2	4	1	6	12	3
14	3	2	1	2	6	3	6
15	3	1	1	2	3	3	6
16	3	3	2	1	9	6	3
Total	42			Total	73	98	80
The average statistic value					1,738	2,333	1,905

Table A5.1.5 The expert assessment of loss "Production of large quantities of waste (rebar off-cuts, wires, boards, etc.)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	3	4	4	6	8	8
2	2	2	2	2	4	4	4
3	2	3	3	3	6	6	6
4	2	1	1	1	2	2	2
5	2	3	2	1	6	4	2
6	2	2	2	1	4	4	2
7	3	3	2	1	9	6	3
8	3	3	1	1	9	3	3
9	3	1	2	1	3	6	3
10	3	4	3	2	12	9	6
11	3	3	1	1	9	3	3
12	3	3	3	2	9	9	6
13	3	3	1	2	9	3	6
14	3	1	3	1	3	9	3
15	3	1	1	1	3	3	3
16	3	4	2	1	12	6	3
Total	42			Total	106	85	63
The average statistic value					2,524	2,024	1,500

5.2 The assessment of losses due to waiting.

Table A5.2.1 The expert assessment of loss "Waiting on delivery of materials and products for construction of structures (concrete, reinforcement, fixings)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	4	4	4	8	8	8
2	2	1	1	1	2	2	2
3	2	3	3	2	6	6	4
4	2	1	1	1	2	2	2
5	2	2	2	2	4	4	4
6	2	2	1	2	4	2	4
7	3	3	2	2	9	6	6
8	3	3	1	1	9	3	3
9	3	1	1	3	3	3	9
10	3	3	2	2	9	6	6
11	3	3	1	2	9	3	6
12	3	3	3	2	9	9	6
13	3	4	2	3	12	6	9
14	3	1	1	1	3	3	3
15	3	1	1	2	3	3	6
16	3	3	2	2	9	6	6
Total	42			Total	101	72	84
The average statistic value					2,405	1,714	2,000

Table A5.2.2 The expert assessment of loss "Execution of related processes by the crane (while using the crane(s) for the production of monolithic and masonry works at the same time, for example)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	5	5	5	10	10	10
2	2	1	1	1	2	2	2
3	2	3	3	3	6	6	6
4	2	1	1	1	2	2	2
5	2	1	2	3	2	4	6
6	2	2	1	2	4	2	4
7	3	5	1	1	15	3	3
8	3	4	1	1	12	3	3
9	3	1	1	1	3	3	3
10	3	4	1	2	12	3	6
11	3	4	1	2	12	3	6
12	3	2	2	3	6	6	9

13	3	5	2	3	15	6	9
14	3	1	1	1	3	3	3
15	3	1	2	2	3	6	6
16	3	3	1	2	9	3	6
Total	42			Total	116	65	84
The average statistic value					2,762	1,548	2,000

Table A5.2.3 The expert assessment of loss "Waiting for the supply of means of production on the work front".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	4	4	4	8	8	8
2	2	3	3	3	6	6	6
3	2	4	3	3	8	6	6
4	2	2	1	2	4	2	4
5	2	3	1	2	6	2	4
6	2	1	1	2	2	2	4
7	3	3	1	2	9	3	6
8	3	3	1	1	9	3	3
9	3	1	1	2	3	3	6
10	3	2	2	2	6	6	6
11	3	3	1	3	9	3	9
12	3	3	2	3	9	6	9
13	3	5	1	2	15	3	6
14	3	1	1	1	3	3	3
15	3	1	1	1	3	3	3
16	3	3	1	2	9	3	6
Total	42			Total	109	62	89
The average statistic value					2,595	1,476	2,119

Table A5.2.4 The expert assessment of loss "The breaks of workers in the work process".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	5	5	5	10	10	10
3	2	4	3	3	8	6	6
4	2	1	1	1	2	2	2
5	2	3	3	3	6	6	6
6	2	2	1	2	4	2	4
7	3	3	1	1	9	3	3
8	3	4	2	2	12	6	6
9	3	1	1	1	3	3	3
10	3	2	2	2	6	6	6

11	3	5	2	4	15	6	12
12	3	3	3	2	9	9	6
13	3	5	1	2	15	3	6
14	3	1	1	1	3	3	3
15	3	1	1	1	3	3	3
16	3	4	2	3	12	6	9
Total	42			Total	119	76	87
The average statistic value					2,833	1,810	2,071

Table A5.2.5 The expert assessment of loss " The idles of workers while waiting for work front".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	2	2	4	4	4
2	2	4	4	4	8	8	8
3	2	2	2	2	4	4	4
4	2	1	1	1	2	2	2
5	2	2	2	2	4	4	4
6	2	1	1	2	2	2	4
7	3	1	1	1	3	3	3
8	3	2	1	2	6	3	6
9	3	2	2	4	6	6	12
10	3	2	2	2	6	6	6
11	3	5	2	4	15	6	12
12	3	3	1	1	9	3	3
13	3	4	2	2	12	6	6
14	3	2	2	2	6	6	6
15	3	1	2	2	3	6	6
16	3	3	2	3	9	6	9
Total	42			Total	99	75	95
The average statistic value					2,357	1,786	2,262

Table A5.2.6 The expert assessment of loss "Downtimes while the documentation preparation (documentation for supplying and preparation of work permissions, issuing of assignments, plans, etc.)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	1	1	1	2	2	2
3	2	1	1	1	2	2	2
4	2	1	1	1	2	2	2
5	2	2	1	1	4	2	2
6	2	1	1	1	2	2	2
7	3	4	1	3	12	3	9

8	3	2	1	1	6	3	3
9	3	2	2	3	6	6	9
10	3	2	2	2	6	6	6
11	3	2	1	2	6	3	6
12	3	2	1	2	6	3	6
13	3	3	1	1	9	3	3
14	3	2	1	2	6	3	6
15	3	1	2	2	3	6	6
16	3	3	2	2	9	6	6
Total	42			Total	83	54	72
The average statistic value					1,976	1,286	1,714

5.3 Assessment of losses due to unnecessary transportation (moving of structures or materials).

Table A5.3.1 The expert assessment of loss "Large distances between on-site warehouse and the construction object".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	5	5	5	10	10	10
3	2	3	4	4	6	8	8
4	2	2	2	2	4	4	4
5	2	2	1	2	4	2	4
6	2	1	1	1	2	2	2
7	3	1	1	1	3	3	3
8	3	2	2	1	6	6	3
9	3	1	2	2	3	6	6
10	3	3	2	2	9	6	6
11	3	1	3	3	3	9	9
12	3	3	2	2	9	6	6
13	3	3	3	3	9	9	9
14	3	2	1	2	6	3	6
15	3	1	1	1	3	3	3
16	3	1	1	1	3	3	3
Total	42			Total	82	82	84
The average statistic value					1,952	1,952	2,000

Table A5.3.2 The expert assessment of loss "Damage to structures of formwork when taping of the already built structures".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	2	2	2	4	4	4
3	2	1	2	1	2	4	2
4	2	1	1	1	2	2	2
5	2	2	2	1	4	4	2
6	2	1	1	1	2	2	2
7	3	1	1	1	3	3	3
8	3	2	2	2	6	6	6
9	3	1	1	3	3	3	9
10	3	1	1	1	3	3	3
11	3	1	3	2	3	9	6
12	3	1	3	2	3	9	6

13	3	1	1	2	3	3	6
14	3	1	1	1	3	3	3
15	3	1	2	2	3	6	6
16	3	1	2	1	3	6	3
Total	42			Total	49	69	65
The average statistic value					1,167	1,643	1,548

Table A5.3.3 The expert assessment of loss "Damage to reinforcement units and fixings when applying by the crane".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	1	1	1	2	2	2
3	2	1	1	1	2	2	2
4	2	1	1	1	2	2	2
5	2	2	2	2	4	4	4
6	2	1	1	1	2	2	2
7	3	1	1	1	3	3	3
8	3	2	1	2	6	3	6
9	3	1	2	3	3	6	9
10	3	1	1	1	3	3	3
11	3	1	4	3	3	12	9
12	3	1	3	2	3	9	6
13	3	1	2	1	3	6	3
14	3	1	1	1	3	3	3
15	3	1	1	1	3	3	3
16	3	2	1	2	6	3	6
Total	42			Total	50	65	65
The average statistic value					1,190	1,548	1,548

Table A5.3.4 The expert assessment of loss " Delivery of materials without the organized transport scheme and logistic planning (long distance delivery of concrete, structures and products from suppliers)"

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	2	2	4	4	4
2	2	2	2	2	4	4	4
3	2	2	1	2	4	2	4
4	2	1	1	1	2	2	2
5	2	3	2	3	6	4	6
6	2	2	2	2	4	4	4
7	3	1	2	1	3	6	3
8	3	3	2	3	9	6	9

9	3	1	2	2	3	6	6
10	3	1	1	1	3	3	3
11	3	1	4	4	3	12	12
12	3	3	1	2	9	3	6
13	3	3	2	2	9	6	6
14	3	1	2	1	3	6	3
15	3	1	2	2	3	6	6
16	3	3	2	2	9	6	6
Total	42			Total	78	80	84
The average statistic value					1,857	1,905	2,000

Table A5.3.5 The expert assessment of loss "Improper placement of unloading zones for building materials and products on the construction site (placing them away from places of storage, places feed on the front of the work)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	3	2	3	6	4	6
2	2	1	1	1	2	2	2
3	2	1	1	1	2	2	2
4	2	1	1	1	2	2	2
5	2	2	1	2	4	2	4
6	2	1	1	2	2	2	4
7	3	1	1	1	3	3	3
8	3	2	1	2	6	3	6
9	3	1	1	2	3	3	6
10	3	1	1	1	3	3	3
11	3	2	2	3	6	6	9
12	3	3	1	2	9	3	6
13	3	4	2	2	12	6	6
14	3	1	1	1	3	3	3
15	3	1	1	1	3	3	3
16	3	1	1	1	3	3	3
Total	42			Total	69	50	68
The average statistic value					1,643	1,190	1,619

5.4 Assessment of losses due to unnecessary processing steps

Table A5.4.1 The expert assessment of loss "The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	1	1	1	2	2	2
3	2	1	1	1	2	2	2
4	2	1	1	1	2	2	2
5	2	1	2	1	2	4	2
6	2	1	2	1	2	4	2
7	3	3	1	1	9	3	3
8	3	4	1	2	12	3	6
9	3	2	1	3	6	3	9
10	3	3	2	1	9	6	3
11	3	5	2	1	15	6	3
12	3	2	1	1	6	3	3
13	3	1	1	1	3	3	3
14	3	1	4	1	3	12	3
15	3	1	1	1	3	3	3
16	3	1	1	1	3	3	3
Total	42			Total	81	61	51
The average statistic value					1,929	1,452	1,214

Table A5.4.2 The expert assessment of loss "The absence of a system of recording and planning on the on-site stock, difficulties in finding the necessary materials and products".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	2	2	2	4	4	4
3	2	2	2	2	4	4	4
4	2	1	1	1	2	2	2
5	2	2	2	1	4	4	2
6	2	1	1	1	2	2	2
7	3	2	1	2	6	3	6
8	3	4	2	2	12	6	6
9	3	2	2	2	6	6	6
10	3	3	2	2	9	6	6
11	3	4	1	2	12	3	6
12	3	3	1	2	9	3	6

13	3	1	1	1	3	3	3
14	3	1	1	1	3	3	3
15	3	1	1	1	3	3	3
16	3	2	2	2	6	6	6
Total	42			Total	87	60	67
The average statistic value					2,071	1,429	1,595

Table A5.4.3 The expert assessment of loss "The presence of excess quantities of materials, components and structures, support elements at the on-site warehouse".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	2	2	4	4	4
2	2	4	4	4	8	8	8
3	2	3	3	3	6	6	6
4	2	1	1	1	2	2	2
5	2	3	2	2	6	4	4
6	2	1	1	1	2	2	2
7	3	2	1	1	6	3	3
8	3	2	1	1	6	3	3
9	3	4	1	5	12	3	15
10	3	3	2	2	9	6	6
11	3	4	1	1	12	3	3
12	3	3	1	2	9	3	6
13	3	1	3	1	3	9	3
14	3	1	4	1	3	12	3
15	3	1	1	1	3	3	3
16	3	3	3	1	9	9	3
Total	42			Total	100	80	74
The average statistic value					2,381	1,905	1,762

Table A5.4.4 The expert assessment of loss "Storage of wastes at the construction site, without exporting them to a landfill".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	1	1	1	2	2	2
3	2	1	1	1	2	2	2
4	2	1	1	1	2	2	2
5	2	3	1	2	6	2	4
6	2	1	2	2	2	4	4
7	3	1	1	1	3	3	3
8	3	2	3	1	6	9	3

9	3	1	3	5	3	9	15
10	3	1	1	1	3	3	3
11	3	3	1	1	9	3	3
12	3	3	1	1	9	3	3
13	3	4	2	3	12	6	9
14	3	1	1	1	3	3	3
15	3	1	1	1	3	3	3
16	3	2	1	1	6	3	3
Total	42			Total	73	59	64
The average statistic value					1,738	1,405	1,524

5.5 Assessment of losses due to to unnecessary processing steps

Table A5.5.1 The expert assessment of loss "The production of defective construction products".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	3	3	3	6	6	6
2	2	3	3	3	6	6	6
3	2	3	3	3	6	6	6
4	2	2	2	2	4	4	4
5	2	4	3	2	8	6	4
6	2	1	2	2	2	4	4
7	3	1	1	1	3	3	3
8	3	1	4	4	3	12	12
9	3	3	3	2	9	9	6
10	3	4	2	2	12	6	6
11	3	1	3	3	3	9	9
12	3	2	3	3	6	9	9
13	3	2	4	3	6	12	9
14	3	4	4	4	12	12	12
15	3	1	1	1	3	3	3
16	3	1	2	2	3	6	6
Total	42			Total	92	113	105
The average statistic value					2,190	2,690	2,500

Table A5.5.2 The expert assessment of loss "Fixing of damaged formwork structures, reinforcing products, ready-made structures (foozle) and etc."

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	1	1	1	2	2	2
2	2	2	2	2	4	4	4
3	2	3	3	3	6	6	6
4	2	2	2	2	4	4	4
5	2	2	2	3	4	4	6
6	2	1	1	1	2	2	2
7	3	2	2	2	6	6	6
8	3	1	4	3	3	12	9
9	3	3	2	4	9	6	12
10	3	4	2	2	12	6	6
11	3	1	4	3	3	12	9
12	3	2	2	2	6	6	6
13	3	1	4	2	3	12	6
14	3	1	1	1	3	3	3

15	3	1	1	1	3	3	3
16	3	2	2	3	6	6	9
Total	42			Total	76	94	93
The average statistic value					1,810	2,238	2,214

Table A5.5.3 The expert assessment of loss "The usage of materials, structures, products and etc. which are not of appropriate by design while work execution".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	2	2	4	4	4
2	2	2	2	2	4	4	4
3	2	2	2	2	4	4	4
4	2	1	1	1	2	2	2
5	2	3	1	1	6	2	2
6	2	1	1	1	2	2	2
7	3	2	1	1	6	3	3
8	3	2	5	2	6	15	6
9	3	1	2	1	3	6	3
10	3	4	2	2	12	6	6
11	3	3	1	1	9	3	3
12	3	2	3	3	6	9	9
13	3	1	3	1	3	9	3
14	3	2	3	2	6	9	6
15	3	1	1	2	3	3	6
16	3	3	2	1	9	6	3
Total	42			Total	85	87	66
The average statistic value					2,024	2,071	1,571

Table A5.5.4 The expert assessment of loss "The usage of methods and techniques of work which are not relevant to the project".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	2	2	4	4	4
2	2	2	2	2	4	4	4
3	2	2	2	2	4	4	4
4	2	1	1	1	2	2	2
5	2	4	2	1	8	4	2
6	2	2	2	2	4	4	4
7	3	2	2	1	6	6	3
8	3	1	2	2	3	6	6
9	3	1	1	1	3	3	3
10	3	4	2	2	12	6	6

11	3	3	1	2	9	3	6
12	3	2	2	2	6	6	6
13	3	2	3	2	6	9	6
14	3	2	2	2	6	6	6
15	3	1	2	2	3	6	6
16	3	4	2	2	12	6	6
Total	42			Total	92	79	74
The average statistic value					2,190	1,881	1,762

5.6 Assessment of losses due to unnecessary movements

Table A5.6.1 The expert assessment of loss "The lack of discipline in the workplace (in context of materials and units transportation within the building site)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	2	2	4	4	4
2	2	1	1	1	2	2	2
3	2	2	2	3	4	4	6
4	2	2	2	2	4	4	4
5	2	3	1	3	6	2	6
6	2	2	2	2	4	4	4
7	3	3	1	2	9	3	6
8	3	2	2	2	6	6	6
9	3	1	1	2	3	3	6
10	3	2	2	2	6	6	6
11	3	5	3	5	15	9	15
12	3	3	1	3	9	3	9
13	3	2	2	3	6	6	9
14	3	4	4	4	12	12	12
15	3	1	2	2	3	6	6
16	3	3	2	2	9	6	6
Total	42			Total	102	80	107
The average statistic value					2,429	1,905	2,548

Table A5.6.2 The expert assessment of loss "The lack of a clear sequence of processes (vanity) in the production of installation, concrete, shuttering works and etc. (the lack of implementation of requirements, instructions, WPP (work performance project) and CMP (construction management plan)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	1	1	4	2	2
2	2	3	3	3	6	6	6
3	2	2	1	2	4	2	4
4	2	2	2	2	4	4	4
5	2	2	2	2	4	4	4
6	2	2	2	2	4	4	4
7	3	2	1	1	6	3	3
8	3	2	2	2	6	6	6
9	3	2	1	2	6	3	6
10	3	2	2	2	6	6	6

11	3	4	3	4	12	9	12
12	3	3	3	3	9	9	9
13	3	2	2	3	6	6	9
14	3	5	4	5	15	12	15
15	3	1	2	2	3	6	6
16	3	3	2	3	9	6	9
Total	42			Total	104	88	105
The average statistic value					2,476	2,095	2,500

Table A5.6.3 The expert assessment of loss "Additional (unnecessary) handling of materials, structures and products on the construction site".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	3	3	3	6	6	6
2	2	2	2	2	4	4	4
3	2	1	1	1	2	2	2
4	2	2	2	2	4	4	4
5	2	2	1	2	4	2	4
6	2	2	2	2	4	4	4
7	3	1	1	1	3	3	3
8	3	2	1	1	6	3	3
9	3	2	1	3	6	3	9
10	3	2	2	2	6	6	6
11	3	4	2	3	12	6	9
12	3	3	1	1	9	3	3
13	3	3	1	2	9	3	6
14	3	3	2	3	9	6	9
15	3	1	1	1	3	3	3
16	3	3	1	3	9	3	9
Total	42			Total	96	61	84
The average statistic value					2,286	1,452	2,000

5.7 Assessment of losses due to release of defective products

Table A5.7.1 The expert assessment of loss "The violation of the concreting technology (insufficient compaction; the exposure of the regulatory period of maturing, the temperature of the concrete, adequate concrete cover; the usage of concrete with water-cement ratio below or above the designed; improper warm-up of concrete (in winter), the usage of concrete with characteristics that do not match the required)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	2	2	4	4	4
2	2	2	2	2	4	4	4
3	2	1	1	1	2	2	2
4	2	1	1	1	2	2	2
5	2	2	1	2	4	2	4
6	2	2	1	1	4	2	2
7	3	1	5	3	3	15	9
8	3	1	3	3	3	9	9
9	3	4	3	4	12	9	12
10	3	4	3	3	12	9	9
11	3	5	5	5	15	15	15
12	3	2	4	4	6	12	12
13	3	3	4	3	9	12	9
14	3	4	4	5	12	12	15
15	3	1	2	2	3	6	6
16	3	4	4	4	12	12	12
Total	42			Total	107	127	126
The average statistic value					2,548	3,024	3,000

Table A5.7.2 The expert assessment of loss "The violation of the technology for reinforcement works (the usage of defective reinforcing units and fixings; the presence of deviations during installation; the violation of integrity of the reinforcing mesh when pouring of concrete and vibrating; the usage of reinforcement with characteristics not relevant to the project)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	2	2	4	4	4
2	2	2	2	2	4	4	4
3	2	3	2	2	6	4	4
4	2	1	1	1	2	2	2

5	2	2	2	1	4	4	2
6	2	1	1	1	2	2	2
7	3	1	5	3	3	15	9
8	3	1	3	3	3	9	9
9	3	3	1	4	9	3	12
10	3	4	3	3	12	9	9
11	3	4	4	3	12	12	9
12	3	2	4	4	6	12	12
13	3	2	4	3	6	12	9
14	3	3	3	3	9	9	9
15	3	1	2	1	3	6	3
16	3	2	2	3	6	6	9
Total	42			Total	91	113	108
The average statistic value					2,167	2,690	2,571

Table A5.7.3 The expert assessment of loss "The violation of technology of installation works (incorrect horizontal and vertical installation of the formwork of columns, deflection of the formwork during the installation, usage of accessories, which exhaust their life span, defective formwork and damage to the formwork, pillars, shields etc.)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points)taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	2	2	2	4	4	4
2	2	3	3	3	6	6	6
3	2	3	3	3	6	6	6
4	2	1	1	1	2	2	2
5	2	3	2	2	6	4	4
6	2	2	2	2	4	4	4
7	3	1	5	2	3	15	6
8	3	1	3	3	3	9	9
9	3	4	3	3	12	9	9
10	3	4	2	3	12	6	9
11	3	2	3	2	6	9	6
12	3	2	4	4	6	12	12
13	3	2	2	2	6	6	6
14	3	3	3	3	9	9	9
15	3	1	2	2	3	6	6
16	3	2	2	3	6	6	9
Total	42			Total	94	113	107
The average statistic value					2,238	2,690	2,548

Table A5.7.4 The expert assessment of loss "The violations in the field of HSE (working without scaffolding, installation of fencing and the use of PPE with not good quality or spent of standard service life, working without work permits, etc.)".

Expert	The level of experts' competence (points)	The probability of occurrence P_q (points)	The value of loss I_c (points)	The value of loss I_t (points)	The probability of occurrence P_q (points) taking into account of experts' competence	The value of loss I_c (points) taking into account of experts' competence	The value of loss I_t (points) taking into account of experts' competence
1	2	3	3	3	6	6	6
2	2	5	5	5	10	10	10
3	2	1	1	1	2	2	2
4	2	1	1	1	2	2	2
5	2	3	1	1	6	2	2
6	2	2	1	1	4	2	2
7	3	2	1	1	6	3	3
8	3	1	2	2	3	6	6
9	3	4	2	5	12	6	15
10	3	4	3	4	12	9	12
11	3	5	1	1	15	3	3
12	3	3	2	2	9	6	6
13	3	2	3	3	6	9	9
14	3	3	2	3	9	6	9
15	3	1	2	2	3	6	6
16	3	3	1	1	9	3	3
Total	42			Total	114	81	96
The average statistic value					2,714	1,929	2,286

5.8 Summary tables for development of losses map

Table A5.8 The calculation of the index of losses R_c for development of losses map.

Basic data of losses for the losses map:			**Calculation:**
Loss No.	**The probability of occurrence P_q (points) taking into account of experts' competence**	**The value of loss I_c (points) taking into account of experts' competence**	**Loss index R_c (points) taking into account of experts' competence**
1.1	1,405	2,333	3,278
1.2	1,476	1,690	2,495
1.3	1,857	1,810	3,361
1.4	1,738	2,333	4,056
1.5	2,524	2,024	5,108
2.1	2,405	1,714	4,122
2.2	2,762	1,548	4,274
2.3	2,595	1,476	3,831
2.4	2,833	1,810	5,127
2.5	2,357	1,786	4,209
2.6	1,976	1,286	2,541
3.1	1,952	1,952	3,812
3.2	1,167	1,643	1,917
3.3	1,190	1,548	1,842
3.4	1,857	1,905	3,537
3.5	1,643	1,190	1,956
4.1	1,929	1,452	2,801
4.2	2,071	1,429	2,959
4.3	2,381	1,905	4,535
4.4	1,738	1,405	2,442
5.1	2,190	2,690	5,893
5.2	1,810	2,238	4,050
5.3	2,024	2,071	4,192
5.4	2,190	1,881	4,120
6.1	2,429	1,905	4,626
6.2	2,476	2,095	5,188
6.3	2,286	1,452	3,320
7.1	2,548	3,024	7,704
7.2	2,167	2,690	5,829
7.3	2,238	2,690	6,022
7.4	2,714	1,929	5,235

Table A5.9 The calculation of the index of losses R_t for development of losses map.

Basic data of losses for the losses map:			Calculation:
Loss No.	**The probability of occurrence P_q (points) taking into account of experts' competence**	**The value of loss I_t (points) taking into account of experts' competence**	**Loss index R_t (points) taking into account of experts' competence**
1.1	1,405	1,762	2,475
1.2	1,476	1,881	2,777
1.3	1,857	2,143	3,980
1.4	1,738	1,905	3,311
1.5	2,524	1,500	3,786
2.1	2,405	2,000	4,810
2.2	2,762	2,000	5,524
2.3	2,595	2,119	5,499
2.4	2,833	2,071	5,869
2.5	2,357	2,262	5,332
2.6	1,976	1,714	3,388
3.1	1,952	2,000	3,905
3.2	1,167	1,548	1,806
3.3	1,190	1,548	1,842
3.4	1,857	2,000	3,714
3.5	1,643	1,619	2,660
4.1	1,929	1,214	2,342
4.2	2,071	1,595	3,304
4.3	2,381	1,762	4,195
4.4	1,738	1,524	2,649
5.1	2,190	2,500	5,476
5.2	1,810	2,214	4,007
5.3	2,024	1,571	3,180
5.4	2,190	1,762	3,859
6.1	2,429	2,548	6,187
6.2	2,476	2,500	6,190
6.3	2,286	2,000	4,571
7.1	2,548	3,000	7,643
7.2	2,167	2,571	5,571
7.3	2,238	2,548	5,702
7.4	2,714	2,286	6,204

Table A5.10 The high tolerance level for the value of the losses impact.

The high tolerance level for the value of loss index R_c	5,0
The high tolerance level for the value of loss index R_t	5,0

Table A5.11 The low tolerance level for the value of the losses impact.

The low tolerance level for the value of loss index R_c	3,0
The low tolerance level for the value of loss index R_t	3,0