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Risk-oriented approach to life cycle contract implementation of weapons and military equipment

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Abstract. Aim. *Today, the development and operation of weapons and military equipment is characterized by fast-growing customer requirements, which, in turn, leads to their increased technical complexity and cost. It is obvious that maintaining the required physical and operational characteristics of high-technology weapons and military equipment by the users is not always possible due to a number of reasons, including insufficient capabilities of the service units that do not have the required personnel, assets and competences. In turn, the manufacturers involved in the delivery of the government defence order are also interested in shaping long-term relations with the customer allowing to build a platform for sound progress. One of the possible solutions for such interaction between the customer and the contractor used worldwide and in Russia is public-private partnership in the form of life cycle contracts. Despite the obvious advantages, its introduction into the practice of weapons and military equipment life cycle is hampered by a number of adverse factors (insufficiencies in the regulatory framework and technical standards, poor level of information technology deployment in LC management) that need to be overcome in terms of both scientific and practical considerations. It is perfectly clear that developing a tool that would allow mitigating a full spectrum of problems as part of this study would be an extremely challenging task. Given the above, the paper aims to examine risks as one of the aspects of this complex problem that implies the development of a new approach to the interaction of the parties involved in a life cycle contract for weapons and military equipment, taking into account the current conditions, interests, goals and objectives. It involves comprehensive analysis of uncertainty and the whole spectrum of possible risks associated with the weapons and military equipment life cycle processes.* **Methods.** *The managerial decision-making is based on the decision tree method that allows dividing the complex decision-making problem into component tasks and obtaining quantitative risk estimates, thus developing an adequate system of measures for the prevention of event risks and reduction of their negative consequences.* **Results.** *Based on the proposed methodological framework, a risk management algorithm has been developed, a matrix has been defined for assessing risks and their impact on the temporal and technical characteristics, as well as the costs of a project.* **Conclusion.** *The suggested approach is universally applicable and can be used by both the officials of military authorities in the process of scientific support of LCC implementation, and by the management of defense contractors as they develop their interaction with the military authorities responsible for the creation and operation of weapons and military equipment.*

Keywords: *public-private partnership, risk management, decision tree.*

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1. Introduction

The widespread economic integration of public organizations and business entities inevitably involved the military agencies of the Russian Federation. Outsourcing has become the most widely used process [1] implying the transfer of a number of non-core functions from units of the Ministry of Defence of the Russian Federation (MOD RF) to private companies. It normally involves activities associated with catering, supply of uniforms and gear, etc. In turn, the involvement of weapons and military equipment (WaME) manufacturers into the after-sales service is defined in accordance with service contracts that set forth a limited scope of WaME maintenance operations. Additionally, the operator remains responsible for the technical condition and operational capability of the WaME. Such situation is unacceptable, since the legal aspect contradicts the technical one and requires an alternative solution that would take into account the interests of all involved stakeholders.

Back in February 2013, at a meeting with defence contractors, the Minister of Defence of the Russian Federation made a case for life cycle contracts (LCC). A Decree of the President of the Russian Federation followed. Among other things, it defined the objective of developing a system for managing a complete industrial cycle of weapons, military and special equipment.

It should be noted that the matter of LCC application in various industries is not new. As of today, there is a fair number of Russian [2-7] and foreign publications [21-24] dealing with the subject matter that are usually either general in their nature or address the solution of risk management problems in individual industries [8-10] and local issues of engineering products LCC management [11-15]. In practical terms, the most interesting is [16] that makes an overview of the experience of LCC application in developed countries as part of public procurement and the analysis of the prospects of LCC development in Russia [17], where the author examines a set of problems in the context of WaME-related matters.

Despite the highest relevance of the issue and the large number of studies dedicated to finding the solution, it must be stated that there is no adequate theoretical foundation for an efficient application of WaME LCC.

A certain optimism is associated with the fact that all WaME LC stakeholders are interested in finding a solution. Each of them pursues their own pragmatic interest. Thus, the procurement agency of the MOD RF receives a specifications-compliant item that is able to fulfil the tasks assigned to the Armed Forces of the Russian Federation; the contractor, on the basis of long-term obligations involving guaranteed contractual funding, is able to invest in business development, while the operating agency is able to obtain WaME with required physical and operational characteristics with the assistance of third parties.

Such organization of interaction involves reassigning the responsibilities among the WaME LC stakeholders. That means that the technical availability of WaME is the responsibility of not only the operator, but the contracted company. In this case, the manufacturer will be interested in creating more dependable WaME, which would later allow minimizing the cost of maintenance and repair. For its part, the customer, the MOD RF, undertakes to comply with the terms of the contract, including the financial ones. That will obviously entail a paradigm shift in the way the MOD RF interacts with the military industrial complex (MIC), whose effectiveness will largely define the quality of the weapons systems.

Conceptually, such method of interaction is good for each of the WaME LC stakeholders, yet in practice the situation is not as trouble-free, since there are a number of serious organizational and legal barriers that prevent the process. They were examined in sufficient detail in [5, 17].

LC contracts proved to be efficient in many industries, including defense procurement in a number of foreign countries [18, 19]. But the specificity of the current internal processes of MOD RF defines a number of factors that cause differences between the public customer and the defence contractors.

Let us consider one of them. The existing system of interaction is designed mainly for the peacetime conditions and normal operation of WaME, which allows observing the scheduled dates of creation, delivery, maintenance, reasonably planning the delivery of required spare parts and accessories, frequency of maintenance personnel arrival, etc.

Implementing the WaME LC processes under special conditions will be affected by significant uncertainty, whose sources will consist in the following: stochastic demand for the required quantities of WaME; impossibility to accurately predict the locations of intended use; existence of a large number of factors that cannot be foreseen and predicted even in the probabilistic setting; violation of service schedules, premature life depletion, as well as a high probability of permanent loss of WaME. A separate issue is the operation beyond the normal operation period and subsequent disposal.

Thus, LCC will be implemented in an environment of uncertainty and risk. These two categories are interconnected.

Let us define *uncertainty* as incomplete and inaccurate information on the conditions of LC processes implementation, including the associated costs and results. Uncertainty involves the presence of factors that make the outcomes of actions non-deterministic, while the degree of such factors' effect on the outcomes is difficult to predict. Its sources include the lack of knowledge, many external and internal environment factors and their possible combinations affecting the WaME LC processes.

Risk is a potential, measurable probability of an adverse situation and associated severity of consequences in the form of non-compliance with customer requirements, failures and faults, contractor's losses, unfavourable circumstances, including act of God.

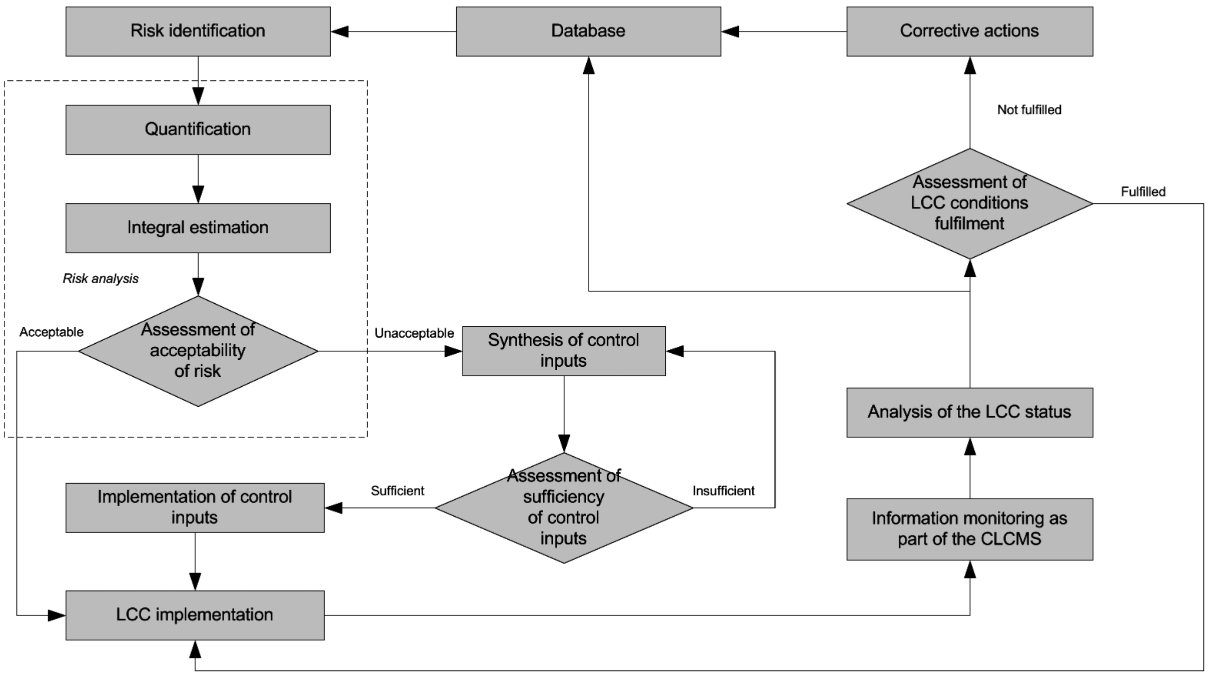

Fig. 1. A generalized risk management algorithm as part of WaME LCC implementation

The existence of a large number of risks arising from LCC implementation is currently one of the main outstanding issues. In this context, it appears relevant to develop a mechanism for the LCC implementation based on procedures enabling the identification, analysis of possible risks and development of appropriate managerial decisions for their minimization.

2. Methods

Following this reasoning, it is required to identify the primary risks associated with LCC implementation. That will later allow decomposing them, performing their qualitative and quantitative analysis. Figure 1 shows a generalized risk identification and management algorithm that illustrates a conceptual approach to their mitigation.

It is quite obvious that identifying a complete list of risks associated with the WaME LC process is extremely difficult, therefore the groups of the most likely risks were classified and then detailed to a level, at which they could be quantified and described as a particular event (set of events) with specific consequences.

In accordance with the established indicator of LC management efficiency, we will assume that the ultimate goal of LCC will be to ensure the required availability value within the budgetary limitations. As the efficiency criterion we will use the minimization of the integral risk indicator of LCC implementation, including the following types of risks [8]:

technical risk that characterizes the discrepancy between the performance characteristics and the performance specifications, which leads to deteriorating combat and operational performance;

economic risk that characterizes actual expenditures overrunning the planned values and leading to increasing LC cost indicators;

temporal risk that characterizes the discrepancies between the actual periods of activities and the scheduled dates causing failure to comply with the customer's requirements.

Factors of the above risks are identified and analysed according to the key LC characteristics, including: customer's requirements, logistics, cost and time parameters.

In this context, let us note that the uncertainty drives the risk and should be regarded as its main source. Therefore, analysing and subsequently managing risks is to be the focus of attention for preventive actions by the LC participants, as the elimination of the consequences of past events, including risk events, is more about situational management. That means that researching uncertainty would allow creating an empirical basis for subsequent identification and risk management in the course of LCC implementation.

An LCC is essentially a complex, long-term project, therefore a major part of managerial decisions requires thorough substantiation. The decision tree method is a convenient tool for such situations. It allows visualising and structuring complex decision-making problems amidst uncertainty and risk (see Fig. 2).

The method is based on decision points and consequence points of such decisions. Their number is not limited, therefore, so is the number of branches on the tree. Each decision point can produce a branch that represents a candidate decision in the given situation. For convenience, a brief description of the possible action is given. Let us denote the possible actions in the decision tree as a_1 and a_2, the execution of each of which can result in consequences from the set b_i, $i = 1, 2, 3, \ldots, n$. In turn, each of

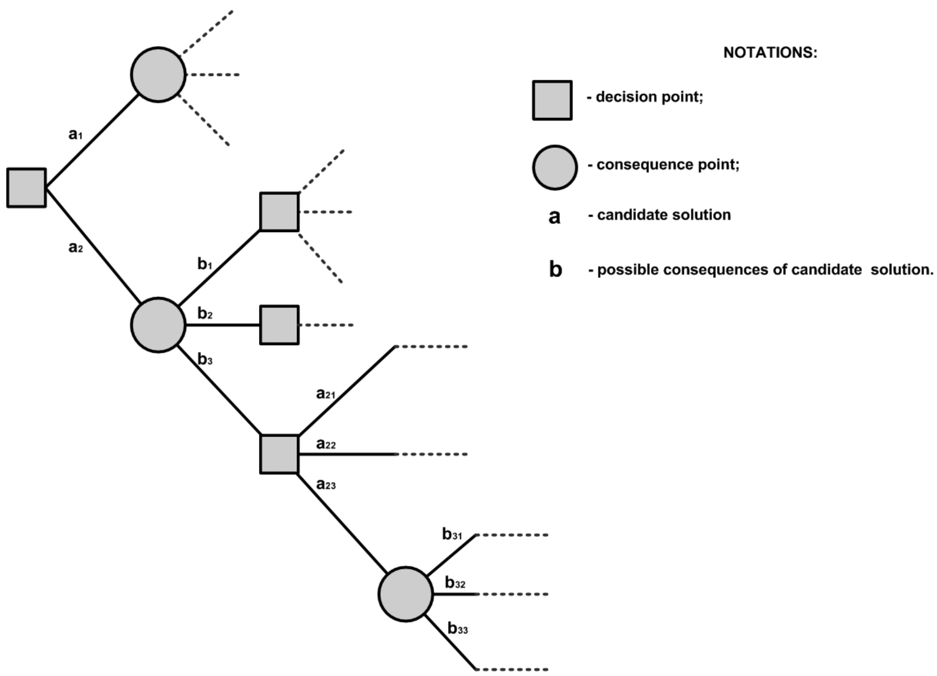

Fig. 2. General view of the decision tree

the possible consequences leads to the next decision point. That shows the convenience of this approach that allows segmenting the complex decision-making problem to the required level of detail, thereby ensuring total coverage of the subject area.

The next step involves quantifying the risk of events. A quantitative estimation of the risks of LCC implementation is required for substantiated planning of activities allowing to prevent or eliminate the negative consequences of the risk events. If their probability is high, adequate activities should be organized, which may require large amounts of resources.

Expert and statistical methods are now the most widely used, but the reliability of the application of the former depends largely on the competence of the experts, and the latter requires the availability of sufficient statistical data, which is not always possible in the case of LC contracts. Of some interest are the methods of sensitivity analysis, scenarios and stability testing that have some advantages and disadvantages.

In this context, it is proposed to quantify risks as the product of the frequency of the risk event P by the magnitude of damage S when realized and to represent them as expression

$$R = P \cdot S.$$

Given its obvious simplicity, this approach is quite justified. The fact is that WaME LC is a rather complex and lasting project, therefore it does not appear to be pos-

Table 1. Risk matrix

Frequency (points)	Degree of damage (points)				
	Insignificant **(0.05)**	Small **(0.1)**	Medium **(0.2)**	Significant **(0.4)**	High **(0.8)**
A. Frequent **(1)**	**1a** Low **0.05**	**2a** Moderate **0.1**	**3a** Moderate **0.2**	**4a** High **0.4**	**5a** Unacceptable **0.8**
B. Remote **(0.8)**	**1в** Low **0.04**	**2в** Low **0.08**	**3в** Moderate **0.16**	**4в** Moderate **0.32**	**5в** Unacceptable **0.64**
C. Probable **(0.6)**	**1c** Low **0.03**	**2c** Low **0.06**	**3c** Moderate **0.12**	**4c** Moderate **0.24**	**5c** High **0.48**
D. Improbable **(0.4)**	**1d** Negligible **0.02**	**2d** Low **0.04**	**3d** Low **0.08**	**4d** Moderate **0.16**	**5d** High **0.32**
E. Practically incredible **(0.2)**	**1e** Negligible **0.01**	**2e** Negligible **0.02**	**3e** Low **0.04**	**4e** Low **0.08**	**5e** Moderate **0.16**

sible to take into account the full range of possible risks. But at the same time, each stakeholder involved in these processes should understand the extent of the possible damage from the realization of a particular risk event throughout the project.

3. Results and discussion.

Risk estimates are normally represented quantitatively with the dimensionality of the consequence measurements taken relative to the observation period, but in some cases the obtained estimates may be represented qualitatively, e.g., as "low" or "high" (Table 1). When assigning probability estimates, especially if quantitative values cannot be obtained, they can be accompanied by more detailed comments.

For the purpose of visualizing the risk estimates and further substantiating the LCC solutions, a matrix is built that consists of five columns (corresponding to the scale of event occurrence) and five lines (corresponding to the degrees of possible damage), at the intersection of which the corresponding integral estimates are formed.

In dark grey are shown high and unacceptable risk values that indicate that the project has no further positive outlook, in light grey are shown negligible and low risk values that do not require any action on the part of the responsible officials. In turn, the estimates in grey boxes require appropriate risk reduction activities. In respect to the complete life cycle, their set is quite large and will differ depending on the specific conditions and LC stage. In the fundamental publication [8], the authors quite aptly note that the existing approaches to risk management are strictly specific in their nature, i.e., take into consideration either the financial and economic aspects of the manufacturing processes, or the research and development or engineering and manufacturing potential of the defence contractors. Following on that conclusion, it could be justifiably noted that the specificity of LCC adds a number of factors to the assessment of the risks caused by the divergence of the goals of the LC stakeholders. Therefore, given the requirements of the WaME customer, risks should be assessed subject to their impact on the execution periods, technical characteristics and financial costs of the parties (Table 2) that define the selection of one or another project execution option.

Such situations are discussed in sufficient detail in system engineering studies and normally come down to rethinking the resource allocation, synchronization of parallel activities and optimization of logistics. In general, the possible options are: project termination in case of high and unacceptable risks; risk reduction in case of moderate risks; project continuation in case of low and minor risks.

4. Conclusions

Summing up the conducted study, the following conclusions should be made:

1. The introduction of the LC contracts in the practice of WaME development and operation, first, is one of the most common forms of private-public partnerships that has been successfully proven in many sectors of the economy, and,

Table 2. Definition of the risk's impact on the project

Degree of damage	Impact on delivery dates	Impact on technical characteristics	Impact on financial costs
Insignificant	minimal or none	minimal or none	minimal or none
Small	minimal deviations in intermediate points of the graph. Shift of secondary reference points of the graph	insignificant performance degradation; effect on the program is minimal or none	increase of program budget or production cost by more than 1% of the allocated funds
Medium	shift of the intermediate points of the graph, deviations unable to affect the progress of the program in general	moderate performance degradation that has an insignificant effect on the progress of the program	increase of program budget or production cost by 1 to 5% of the allocated funds
Significant	critical non-compliance with program execution schedule. Key reference points shifting over 2 months away and/or intermediate reference points shifting over 6 months away	significant degradation of performance undermining program implementation	increase in program budget or production cost 5 to 10% of the allocated funds
High	impossibility to clear the established reference points within the established time limits	critical degradation of performance; impossibility to achieve key parameters or minimal allowed performance values; risk of program failure	more than 10% program cost overrun

second, is an objective necessity of the military organization of the nation due to the growing technical complexity of the WaME.

2. In the current economic conditions, developing an LCC system for the entire range of WaME is probably one of the few ways allowing to ensure the preparedness of the Armed Forces of the Russian Federation to fulfil their intended mission. Given the global experience, it can be stated that, today, there is no other way to achieve that.

3. The establishment of a long-term system of LCC-based interaction between the defence contractors and the departments of the MOD RF is to be preceded by a thorough analysis of all possible conditions for their implementation, which would allow identifying a significant part of possible risks and create the required conditions for their minimization.

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The authors’ contribution

Dubovsky V.A. defined the basic idea of the research, developed a generalized risk management algorithm.

Dubovskaya N.I. analysed subject-matter literature, drawn up the paper’s conclusions.

Nikolaev A.S. contributed to the discussion of the research methods and the obtained results.

Conflict of interests

The authors declare the absence of a conflict of interests.