Substantiation of an Economically Feasible Option for Ordering Unmanned Aerial Vehicles for Joint Aviation Groups

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Abstract. This study offers a solution to one of the problems that arise in the routine practice of the Head managers of the Ukrainian Armed Forces and Ministry of Defence – budgetary units when making management decisions. Namely, the search for the most economical (cost saving) option for placing an order between several potential contractors to save budgetary funds, minimise possible risks of exceeding the customer's costs, and organisation of rational spending of financial resources. The purpose of the study is to determine the mechanisms for rapid replenishment of losses of defence products due to the early distribution of defence orders among manufacturers with savings in budgetary funds. To solve the stated problem, an approach was proposed using a statistical method of quantitative risk analysis based on two indicators: the probability of savings and the risk of not receiving the expected savings. An example of using the proposed approach is given for two alternative options for placing an order for unmanned aerial vehicles to create joint aviation groups between three potential contractors. The proposed mechanism for summarising calculations in the final table, acceptable for analysis and allows making the final decision in the management link. In contrast to the approaches used in developed economies, the proposed approach takes into account the capabilities of the manufacturer in terms of production volumes and short deadlines for the production of defence products. Notably, the approach in question can be applied if there are more than two alternative options for the distribution of orders and for more than three potential contractors

Keywords: expected value of savings, probability of savings, risk of not saving, fluctuations of possible savings, variation coefficient of savings

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Introduction

In recent times, in the context of a significant increase in funding of the Armed Forces of Ukraine [1-4], of particular relevance is the issue of reasonable distribution of budgetary funds between contractors and the leadership of the Armed Forces (AF) – budgetary units. The tasks of the department for the organisation of rational spending of financial resources by the relevant authorities have been repeatedly mentioned in state and departmental regulatory and execution documents [5-12]. There is a certain practice in the headquarters of multi-stage executive decision-making to justify the cost indicators when contracting orders. However, this practice is mainly based on many years of empirical experience of data preparers and final decision makers and therefore depends largely on the human factor. Therefore, the issue of improving the data origination for decision-making to rationally use the limited budgetary resources is relevant and has not only departmental but also state importance.

Issues of state importance of reasonable and rational spending of limited budgetary financial resources for the Armed Forces of Ukraine are stated not only in the above Ukrainian regulations and policy documents [13-15]. These issues are also considered in scientific and professional environment in recent years in the works of Ukrainian scientists. V.P. Horbulin [16], I.M. Ivanova [17], I.V. Pavlovsky, I.B. Chep-ko, V.K. Borokhvostov, I.V. Borokhvostov, O.M. Ryabets [18], B.O. Demidova, O.P. Korosteleva [19]. The foreign experts [20-22] also considered the issue of pricing and cost savings at the stage ordering products, but the authors do not always take into account the volume and timeliness of production. Current views on the importance of the price factor in world and Ukrainian arms trade and changes in approaches to pricing of defence products are systematically considered at the political, expert and scientific levels. In particular, in the materials of the "Defence enterprises League of Ukraine", which unites more than 120 privately owned enterprises and is the vast majority of the defence-industrial complex of Ukraine [23-26]. In addition, as of the end of 2020, the League's enterprises fulfilled two thirds of the state defence order (SDO).

The military administration understands the importance of the problem of economical use of financial resources when placing orders to meet the needs of the Armed Forces. The solution to the problem mainly represents the constant improvement of practical experience based on the analysis and overcoming of the identified shortcomings, at the stage of individual scientific developments. This requires the development of simple, not cumbersome scientific approaches for use in the daily practice of troops.

The *purpose of the study* is to develop a practical approach to the choice of options for ordering UAVs for combat use in joint aviation groups, while saving the financial resources of the customer and minimising the risks of its cost overruns when making management decisions.

Methodological Framework

When making management decisions on the placement of SDO there is a need to assess the most economically feasible options for placing orders between several potential contractors to save budgetary funds and prevent (minimise) possible risks of exceeding costs. For the public contracting authority, savings are a certain analogue of increasing profits for a commercial customer. That is, there is a need to assess (forecast) the consequences of successful or unsuccessful selection of possible options for placing an order. This, in turn, leads to savings or to an excess of expenditures of the state customer – budgetary funds. One approach to solving such a management problem may be to use a statistical method of quantitative risk analysis. This method involves analysis of the statistics of savings (profit) in management decisions to determine two indicators:

- 1) the probability of obtaining the result, i.e. – savings (profit);
- 2) the risk of not obtaining the result, i.e. – the expected (projected) savings.

For its part, the magnitude of the risk of not receiving the expected savings is measured by two indicators:

- 1) the average expected savings;
- 2) fluctuations (variability) of the possible result, i.e. – possible savings.

The average (arithmetic mean) expected value of the savings is related to the uncertainty of the result – the possible savings. It is defined as the weighted average of all possible savings $E(x)$, where the probability P of each individual result (individual component of savings) is used as the frequency or weight (weighting factor) of the corresponding value x of the individual result. In general, this can be written as follows (Eq.1):

$$E(x) = P_1 x_1 + P_2 x_2 + \dots + P_i x_i + \dots + P_n x_n \quad (1)$$

where: x_i – the size of a separate component of savings during the implementation of a measure i ($i = 1, \dots, n$) from the group of measures n , UAH.; P_i – the probability of the measure i .

Results and Discussion

Assume that SDO requires 200 unmanned aerial vehicles (UAVs). Due to a number of factors, such as limited production capacity of potential contractors, short deadlines due to the immediate need of the UAV, problems with order payment and other factors, it is not possible to place an order to the one contractor. However, there is an option to distribute the order between the three potential contractors. Preliminary agreements have been reached with each of the possible contractors, which will assist the customer in the emergence of certain savings of financial resources – budgetary funds. There are two possible options for placing a SDO between three contractors. Each of the options differs in the number of UAVs acceptable for the manufacture and the amount of

possible savings for the customer. It is necessary to choose a more economical and less risky option for the customer to place a SDO.

If the expected levels of savings from each contractor are well known and can be measured in monetary terms when deciding on the choice of contractors and the number of UAVs to be ordered. The final results of the savings can be calculated as a certain sum of expected levels of savings from each contractor. At the time of deciding on the choice of contractors and the number of UAVs to be ordered, the levels of savings can be defined not as accurate but as possible, i.e., as probable. Thus, probabilistic approaches to assessing the situation can be applied to quantitatively substantiate the decision on the order.

Option 1. According to this variant of distribution of SDO between contractors it is supposed that 90 units of UAVs from 200 are ordered to one contractor, with savings of 20 thousand UAH on each UAV (probability of savings – $90 : 200 = 0.45$). The second contractor is ordered 60 units of UAVs out of 200, with savings of 25 thousand UAH on each UAV (probability of savings – $60 : 200 = 0.30$). The third contractor is ordered 50 units of UAVs out of 200, with savings of 30 thousand UAH for each UAV (probability of savings – $50 : 200 = 0.25$). The average expected value of savings per UAV unit for the first option of order distribution between the three contractors is:

$$E(x) = 20.0 \times 0.45 + 25.0 \times 0.30 + 30.0 \times 0.25 = 24 \text{ ths. UAH.}$$

Option 2. According to this variant of SDO distribution, 95 UAVs out of 200 are ordered to one contractor, with savings of 19 thousand UAH on each UAV (probability of savings – $95 : 200 = 0.475$). The second contractor is ordered 55 units out of 200, with savings of 22 thousand UAH on each UAV (probability of savings – $55 : 200 = 0.275$). The third contractor is ordered 50 units out of 200, with savings of 32 thousand UAH on each UAV (probability of savings – $50 : 200 = 0.25$). The average expected value of savings per unit of UAVs in the second option of the order distribution between the three contractors is:

$$E(x) = 19.0 \times 0.475 + 22.0 \times 0.275 + 32.0 \times 0.25 = 23.075 \text{ ths. UAH.}$$

The average value represents a generalised quantitative characteristic and does not allow making a final decision in favour of one of the considered options for the distribution of orders. For the final decision it is necessary to estimate fluctuations (range of deviations, variability) of indicators, i.e., to define a measure of fluctuations of possible result, i.e., – savings. The fluctuation of the possible result is the degree of deviation of the expected value of the result from its average value. To determine it, usually the variance or standard deviation is calculated. The variance is the weighted average of the squares of the deviations of actual values of the results from their average expectations (Eq. 2):

$$\sigma^2 = \frac{\sum (x - \bar{x})^2 A}{\sum A} \quad (2)$$

where: σ^2 – variance; x – expected value for each case of observations; $\bar{x}$ – expected average (arithmetic mean) value; A – frequency of cases or the number of observations.

For the case under consideration, x – expected value, and $\bar{x}$ – average expected value of savings for each UAV from the selected order placement option; A – the number of UAVs selected for the order of each of the performers for a particular order. The standard deviation is determined by the equation (3):

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2 A}{\sum A}} \quad (3)$$

The variance σ^2 and the standard deviation σ are measures of absolute oscillation. They are measured in the same units as the changeable subject. For the given example the changeable subject – savings (profit) of the contractor in UAH for the UAV unit. To analyse the degree of deviation of the expected value from the average value, the variation coefficient (the ratio of standard deviation to the expected average value) (Eq. 4):

$$v = \frac{\sigma}{\bar{x}} \cdot 100 \quad (4)$$

where: v – variation coefficient, %.

In general, the coefficient of variation allows comparing features that fluctuate and have different units of measurement. The larger the variation coefficient, the stronger the fluctuation; in the second example – savings, that is, the greater the risk in obtaining the expected savings. Using the statistical method of quantitative risk analysis, the following estimates of the variation coefficients have been established:

- up to 10% – weak fluctuation;
- 10...25% – moderate fluctuation;
- over 25% – strong fluctuation.

For this instance, the standard deviation (SD) of the savings is equal to:

• for the 1st option of distribution of the order between three contractors:

$$\sigma_1^2 = \frac{(20-24)^2 \cdot 90 + (25-24)^2 \cdot 60 + (30-24)^2 \cdot 50}{200} = 16.5 \text{ ths. UAH.},$$

$$\sigma_1 = \sqrt{16.5} = 4.06 \text{ ths. UAH.};$$

• for the 2nd option of distribution of the order between three contractors:

$$\sigma_2^2 = \frac{(19-23.075)^2 \cdot 95 + (22-23.075)^2 \cdot 55 + (32-23.075)^2 \cdot 50}{200} = 28.12 \text{ ths. UAH}$$

$$\sigma_2 = \sqrt{28.12} \approx 5.3 \text{ ths. UAH.}$$

Coefficient of variation (risk factor):

- for the option 1: $v_1 = (4.06 \div 24) \times 100 = 16.9\%$;
- for the option 2: $v_2 = (5.3 \div 23.075) \times 100 = 22.9\%$

That is, for the initial conditions of both possible options for placing an order, the variation coefficients are in the range of values of moderate fluctuation. However, the variation coefficient of the savings, during the distribution of SDO between three contractors, in option 1 is less than in option 2. Therefore the 1st option of distribution of orders is less risky and more expedient. In general, for option 1, two factors are more positive: a higher average value of expected savings and a lower risk of obtaining savings compared to option 2. Using the variation coefficient to determine the lower and upper limits of deviation of the

expected savings from its average value for comparable options for SDO distribution, the following figures are obtained in thousands of UAH for one UAV unit (Table 1).

Absolute average and threshold values of expected savings for possible options for placement of SDO indicate the priority of *option 1* over *option 2*. For clarity, the final results of the calculations can be summarised in a comparative

table of possible options for SDO placement to substantiate the economically priority option. This approach can be used in the presence of more than two alternative options for the distribution of orders (Table 2) and for more than three potential contractors. For orders of more expensive objects and for bigger budget allocations the units of measurement can be not thousands, but millions of UAH.

Table 1. Determination of the lower and upper limits of deviation of the expected savings from its average value for the options for SDO distribution

Option of order distribution	The lower limit of expected savings	The average value of the expected savings	The upper limit of expected savings
1	19.94	24	28.06
2	17.8	23.07	28.35

Table 2. Comparative table of possible options for placement of SDO and substantiation of the priority option

Option for SDO distribution between potential contractors	Potential contractors for SDO						Indicators of quantitative analysis of savings for different options for SDO placement (per order unit)						
	I		II		III		Average value of savings, ths. UAH	Variance of savings σ^2 , ths. UAH	Standard deviation of savings σ , ths. UAH	Variation coefficient of savings v , %	Lower limit of possible savings, ths. UAH	Upper limit of possible savings, ths. UAH	Priority of possible options for SDO placement
	Number of order units	Savings per order unit, ths. UAH	Number of order units	Savings per order unit, ths. UAH	Number of order units	Savings per order unit, ths. UAH							
1.	90	20	60	25	50	30	24	16.5	4.06	16.9	19.95	28.06	1
2.	95	19	55	22	50	32	23.07	28.12	5.3	22.9	17.8	28.35	2
...	...	...	...	...	...	...	...	...	...	...	...	...	...

Conclusions

An approach to the estimation of possible options for the placement of SDO for the products of industrial enterprises has been considered. It can be viewed as an additional technique for substantiation of a choice for the Customer of the most economic and least risky variant. Furthermore, the proposed approach does not cancel or replace the existing rules of preparation for contracting orders. At the same time, it does not contradict sustainable approaches and can be used as an additional mechanism of preliminary study by the Customer of the conditions on the market of production offers. If necessary, it can be used as one of the final measures in preparation for the final decision on the distribution of the order. In addition, the proposed method

is quite appropriate in terms of short deadlines and low production capacity of the necessary defence products, it allows avoiding non-supply during the active phase of the armed confrontation to replenish the forces and means of the Armed Forces.

Further development of the proposed approach may be associated with the formalisation of it as an algorithm and development of software for the generation of a final comparative table of possible order options. Thus, a source of initial reference information (databank) on production programmes and production capacities of contracting enterprises with a certain nomenclature and range of products that the customer needs can be created.

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Обґрунтування економічно доцільного варіанту замовлення безпілотних літальних апаратів для спільних авіаційних груп

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Анотація. У статті пропонується рішення однієї з проблем, що виникає у повсякденній практиці керівного складу Збройних Сил та Міністерства оборони України – розпорядників коштів під час прийняття управлінських рішень. Актуальність дослідження полягає у визначенні механізмів швидкого поповнення втрат оборонної продукції завдяки завчасному розподіленню оборонного замовлення серед виробників із заощадженням бюджетних коштів. Мета статті полягала у розробленні найбільш економічного (заощадливого) варіанту розміщення замовлення між декількома потенційними виконавцями із завданням економії бюджетних коштів, мінімізації можливих ризиків із перевищення витрат замовника та організації раціонального витрачання фінансового ресурсу. Для розв’язання проблеми запропоновано підхід із використанням статистичного методу кількісного аналізу ризиків на підставі визначення двох показників: імовірності отримання економії та ризику неотримання очікуваної економії. Наведено приклад використання запропонованого підходу для двох альтернативних варіантів розміщення замовлення безпілотних літальних апаратів для створення спільних авіаційних груп між трьома потенційними виконавцями. Запропонований механізм зведення розрахунків у підсумкову таблицю, прийнятну для аналізу та прийняття остаточного рішення у ланці управління щодо замовлень продукції. На відміну від підходів, що використовуються у країнах із розвинутою економікою, у запропонованому підході враховуються можливості виробника щодо обсягів виробництва продукції та стислості термінів виготовлення продукції оборонного характеру. Зазначено, що розглянутий підхід може бути використаний і за наявності більш ніж двох альтернативних варіантів розподілу замовлень та для більш ніж трьох потенційних виконавців замовлення

Ключові слова: очікуване значення економії, імовірність економії, ризик неотримання економії, коливання можливої економії, коефіцієнт варіації економії