ECONTECHMOD. AN INTERNATIONAL QUARTERLY JOURNAL – 2016. Vol. 5. No. 1. 89–96

Economic problems of aircraft equipment recovery

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Received September 02.2015: accepted January 21.2016

Abstract. The formation of effects of different order in the process of aircraft equipment recovery is investigated. Changes of idle time of aviation equipment, depending on the cost of its recovery and maintenance are estimated. Economic problems of reasonable implementation of qualitative aircraft recovery are considered.

Unlimited theoretical limits of costs on assuring the quality of aircraft equipment recovery are shown on the graphs. Suggestions for reasonable limits of the cost on aircraft equipment recovery are grounded.

It was established that the definition of economic efficiency of providing quality of aircraft equipment recovery requires accounting not only the cost but also the obtained effects. The model showing the possible operating modes of aircraft equipment is presented. Its partial review allows to evaluate the difficulties of calculating the economic effect of providing quality of aircraft equipment recovery.

Theoretical aspects of economic effect formation of quality of aircraft equipment recovery are investigated. It is stated that the annual economic effect from assuring quality of recovery and maintenance of aircraft equipment, resulting in operation of aircraft equipment (the effect of the second-order), occurs in the form of savings and avoided losses for two reasons. First, eliminate losses due to non-compliance of technical parameters of aircraft equipment to normative and technical values. Second, due to changes in the operating costs connected with the elimination of aircraft equipment idle time due to technical reasons. Also, certain effect can be created in general within the whole branch of economics where aircraft equipment is used. Calculation of economic effect requires distinguishing between savings and avoided losses. Potential loss can be the cost of the aircraft equipment itself and damages that it may cause in case of falling. Also, losses can occur due to bad providing of technical condition indicators, and therefore efficiency of aircraft equipment causes inadequate change of operating costs and process in which it participates.

Key words: aircraft equipment, recovery, repair, efficiency, economic effect.

INTRODUCTION

Analysis of the problem of providing the aircraft equipment recovery involves detection of the objective nature of this category, peculiarities of quality of aviation technology recovery in specific conditions of exploitation and recovery. The key to a proper understanding of the nature of the concept of "quality aircraft equipment recovery" gives the analysis of relationship between the concepts of "quality of work" and "product quality". An important issue of aviation equipment recovery is an identification of economic appropriate boundaries of improving the quality of recovery. Also the subject of the study is the effects that result from improving the quality of aircraft equipment recovery.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Research of the problem of different order effects formation in the process of aviation equipment recovery involves detection of the objective nature of this category, peculiarities of quality of aviation equipment recovery in specific conditions of exploitation and recovery.

The peculiarity of aircraft equipment repair is a large range of repair facilities. There are thousands of parts, components and units of aviation engineering. They all have their special design features, the size, and shape is made of different materials [18].

The author [20] gives the following definition: repair is the complex of activities for restoring ope-

rability or efficiency of products and their resources. Repair of aircrafts can be planned and unplanned.

The timing of planned repair is defined by normative documents. Unplanned repair is performed without appointment. Scientists [1] determine the following characteristics of aircraft repair:

1. Aircraft repair – the change of the construction aiming at renewing the flying ability of a product after its damage or wear [16].

2. Aircraft repair – main measures to maintain the aircraft flying ability in the process of its exploitation [13,19]. The basic principles of aircraft recovery used in Ukrainian literature were grounded during the Soviet period. Thus, the scientist [4] notes the importance of maintaining the efficiency of aviation equipment.

The best description of the problem of aircraft equipment recovery nowadays among Ukrainian scientists is given in the thesis "Perspective planning of aircraft repair and economic estimation of its efficiency" [16]. The highest number of scientific publications on the investigated subject in Ukraine is at the National Aviation University.

OBJECTIVES

The goal of the research is an economic analysis of the scientific and methodological foundations of service organization and aircraft recovery, disclosure of practical problems of its implementation in real conditions of Ukrainian aviation industry. The aim is to determine the economic appropriate boundaries of ensuring the quality of aircraft recovery taking into account different economic effects.

THE MAIN RESULTS OF THE RESEARCH

Ukraine is one of the few countries which have a full cycle of aviation activities from designing aircraft engines and aircrafts to their operation, service and repair. Educational and scientific activities are also very important as they provide staff training, efficiency and safety of aviation industry [3, 13].

For the development and efficient operation of aircrafts one must constantly carry out measures to ensure its efficiency. So, formation and development of the aircraft repair industry is very important [20].

Generally, a gradual decrease of enterprises in the aircraft industry is observed as well as in machine – building enterprises due to a low innovation development. Such situation is caused by an absence of effective management of enterprises economic behavior [14].

An important economic indicator of aircraft equipment recovery is the quality of performed work, as well as indicators of the quality of the recovered vehicles. The problem of quality of work at this stage is broadly interpreted. In general quality of work characterizes the quality of all management activities, planned activities, quality of industrial organizations, labor groups and scientific institutions. In this sense the quality of work combines the final outcomes of economic activity and as a category applicable to all levels and sides of business. There is also the interpretation of quality of work in the narrower sense, in relation to a particular level. Quality of work is understood as the accordance of performed work to regulations and other specified requirements. An important part of the concept of quality of work is a product quality [10]. As part of the concept of quality of work it is directly connected with the concept of production efficiency and is expressed together with other indicators of productivity (labor input, capital intensity) in increasing technical and economic product characteristics and improving of its consumer properties [6, 7].

Due to its socio-economic nature, product quality is one of the fundamental characteristics in achieving production best outcomes and can't act as an addition to the concept of quality of work. Product quality is the defining characteristic of the quality of work, and therefore part of final national economic results. The resulting characteristic of a problem of quality recovery is a working condition of repaired aircrafts and of such that passed the repair services. That is, improvement or maintenance of quality recovery is aimed at achieving the most important economic result – ensuring the working condition of the aircraft. Such an approach eliminates the possibility of identification the recovery quality with the quality of repaired aircrafts [2].

Researching the quality of repaired aircrafts we mean functional aircrafts which meet the requirements of regulatory documents. Aircrafts, restored in violation with standards and specifications are considered to be unserviceable aircrafts [15, 17]. When in the process of exploitation after the recovery the aircraft is not able to provide a specific need, it shows not only its initial low technical level, but also the violation of technology of exploitation and recovery [8].

Distinction between recovery quality and quality of repaired aircrafts is caused by the need of taking into consideration the possible additional costs and potential effects of these costs while estimating the recovery quality. The methodological approach to assessing the economic efficiency of providing the recovery quality is as follows: various types of economic effects can result while improving the recovery process and ensuring its quality caused by improving the recovery quality, consequently providing an efficient condition of aircraft. The basic principle of this approach is that ensuring of recovery quality affects the costs and effects as their differences relating to the same process of recovery (works to ensure the working condition of aircraft – the effect of 1st order); process of exploitation of repaired aircraft (providing working condition of aircraft, elimination of technique idle time – the effect

of 2nd order); the transport of goods and people running in the renovated aircraft (increase in traffic (for airlift) to increase combat readiness (military vehicles) – the effect of 3rd order). The general scheme of the formation of a different order effects is presented in Fig. 1.

Providing the recovery quality has a number of coherent actions which form different effects caused by a change of quality of aircraft recovery which is shown in the scheme in Fig. 1. Efficiency is defined by comparing the costs of its maintenance to different effects. General block diagram with definition of economic efficiency of aircraft recovery is shown in Fig. 2. The presence of different effects determines their place of occurrence.

The effect can be beneficial for both the repair company and for the organization that operates the aviation equipment. Though repair of aircrafts is not related to production, we can distinguish conventional producer – aircraft repair company. The main reason for this assumption is: a typical organizational structure of the aircraft repair enterprise offers the availability of repair units, responsible for different stages of repair, such as aircraft manufacturing enterprise. The above considerations give opportunity to separate the producer of repair products (aircraft Repair Company) and consumers of repaired products (organization – owner of aircrafts) [12].

The above, determined the primary factors to consider in determining the economic efficiency of aircraft equipment recovery [11].

The important factor of economic efficiency in general and aircraft recovery in particular is labor saving. Quantitative estimation of this efficiency can be given by using the index – the total economic effect. This index can show the effectiveness of all recovery options. It is necessary to define a mathematical condition for economic efficiency.

Despite the variety of different methods, techniques and formulas to determine the economic efficiency of aircraft recovery, most of them are not perfect.

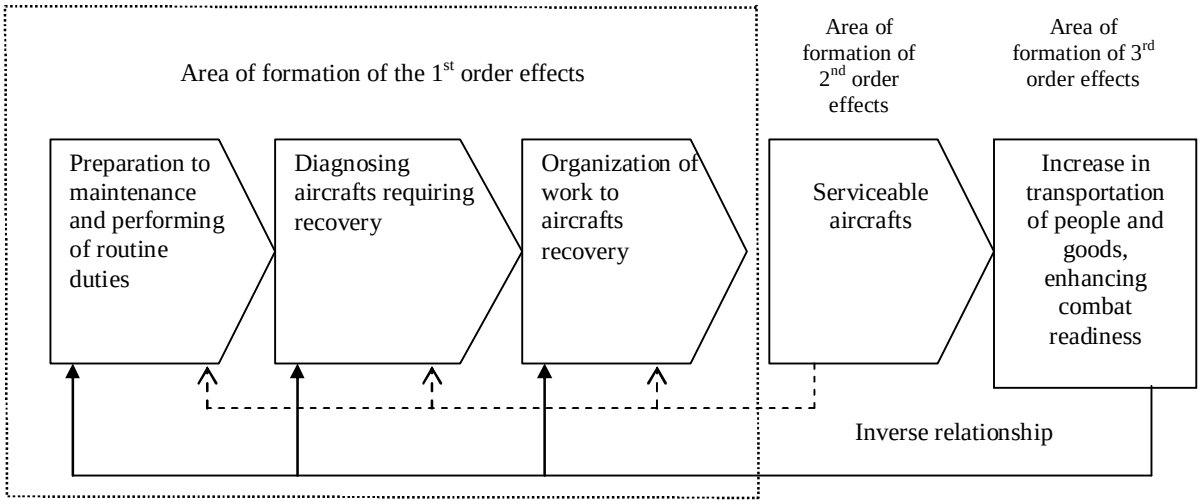

Fig. 1. Areas of formation of economic effects of different orders in the process of aircrafts recovery

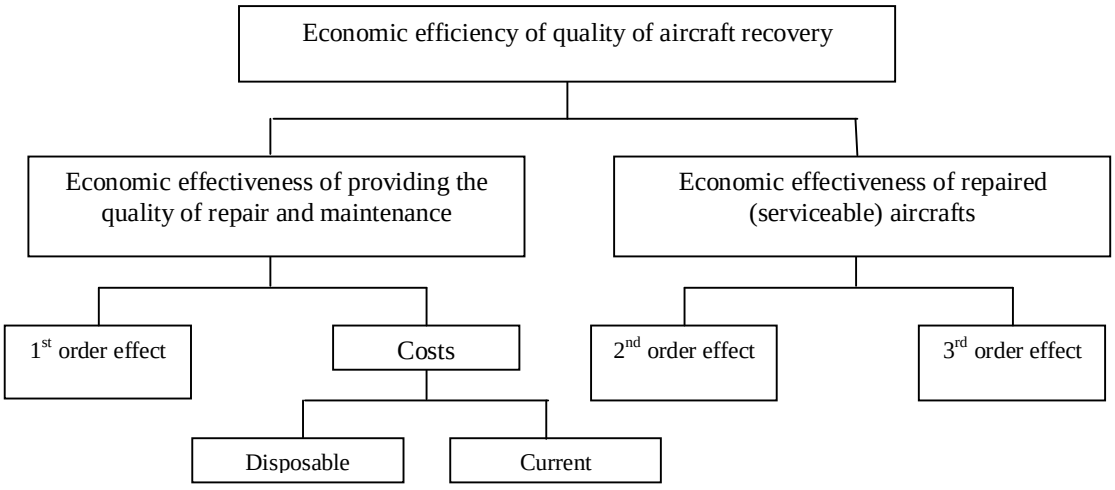

Fig. 2. General structural scheme of determining the economic efficiency of aircraft recovery

Mathematical condition for economic efficiency from providing maintenance and aircraft repair are (in general):

$$E>O. \quad (1)$$

Obviously, the terms in the formula (1) can be either positive (savings) or negative (loss). In general, the rate of economic effectiveness from providing the quality of aircraft recovery is:

$$E = Ep – Bp, \quad (2)$$

where: Ep – positive effect that is prevented damages not arising due to provided level of technique efficiency, hrn., Bp – the cost of providing a given level of aircraft performance, hrn.

The economic nature of quality index of technique service and aircraft repair is caused by the recovery function in the manufacturing process at aircraft Repair Company. This index should consider all possible costs on aircraft recovery works and economic consequences of this work for aircraft repair enterprise as a whole.

Following formula (2), it is possible to achieve a positive result and further increase of economic efficiency from providing maintenance and aircraft repair index due to increase or positive effect in production or by reducing the cost of repairs and maintenance at a constant or increasing positive effect. The choice of a quality parameter as well as a nature of its components change is very important in the construction of economic model for evaluating the quality of aircraft recovery.

Aircraft efficiency factor is a parameter that determines the quality of the aircraft recovery is calculated as follows:

$$Kw = 1 – (Frp / Fp), \quad (3)$$

where: Fp – real fund of working time of an aircraft for the planned period, hours; Frp – time spent on unscheduled repair and idle time of aviation equipment for technical reasons and for the operation that does not meet the technical requirements due to deviations of technical parameters from its normative values.

Reasons for selecting this option for quality assessment of repair and technical condition of aircrafts are as follows. Firstly, the quality of recovery appears to operate through the reliability of aircraft. Secondly, it takes into account the cost of living labor, related with F component which allows maintaining a working state of aircraft. This arouses the interest to investigations related with discovery of the relationship between the cost of repair and maintenance, and efficiency of aircrafts that took place in specific conditions in aircraft repair companies. The presence of a stable feedback between the idle time of aircrafts and the repair costs was experimentally confirmed. According to the methodology used in work [4] we offer to build correlation fields which confirm the existence of a stable feedback between the studied objects. Analysis of the forms of relations for different functions showed that the largest correlation value corresponds to the functional transformation of variable $y = (1 / x)$.

Testing the stability of the connection between variables was carried out on the criterion Z Fisher. Essentiality of relation between the studied factors can be argued with a probability of 99%.

Asymptotic nature of the permanent reduction of values obtained by correlation dependencies Yk = f (Xk) proves that achieving the complete elimination of aircrafts idle time is very difficult. The asymptotic nature of reduction per unit of time needs more funds. There is a decrease in the efficiency of costs for the working condition of aircraft. Foreign researchers also indicate the existence of such form of relation between the repair cost and aircraft idle time [5].

Due to the fact that the cost of providing recovery quality is part of the costs of maintaining the working condition of aviation equipment, we can assume that the form of relation will have curve shape, as shown in Fig. 3 This assumption allows us to conclude that the relatively constant improvement of recovery quality parameter is achieved by costs increasing as we approach the maximum quality parameter. The closer to the maximum is the parameter of aircrafts idle time, the bigger is an increase of costs for quality repair and maintenance**.**

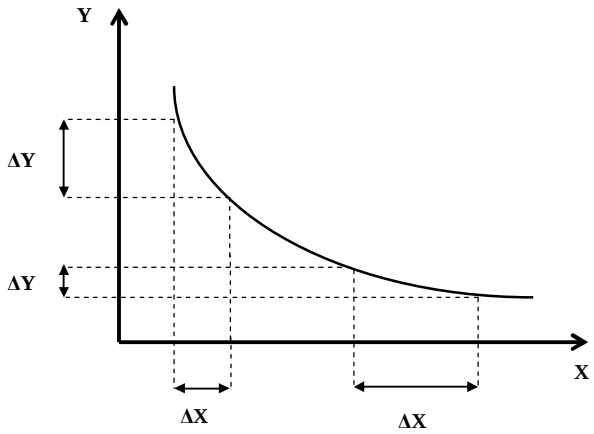

Fig. 3. Graph that describes the change in the aircrafts idle time depending on the cost of repair and maintenance of aviation equipment [9]: Y – total aircrafts idle time for technical reasons; X – costs on repairs and maintenance; ΔY – increase of total aircrafts idle time ; ΔX – increase of costs on repair and maintenance

While improving quality parameter of aircraft recovery the limit value of costs tends to infinity, ie when $Kw \rightarrow 1$ the costs of recovery increases $Zkr \rightarrow \infty$.

The limit value of positive effect Ep along with a change of aircraft recovery quality, which leads to an increase in working condition of aircrafts $Kpd \rightarrow 1$

tends to a finite value. Theoretically, this finite value is the total costs occurred in the process of aircraft exploitation that can be saved by using aviation equipment with "ideal" technical condition. The nature of the functional relationship between the recovery quality parameters in general, is a curve that asymptotically approaches to the boundary of the final value.

If the nature of two curves (the positive effect curve Ep and costs curve Zk) are just the same as that according to the study, it is obvious that the total economic impact E will look like a curve shown in Fig. 4.

Fig. 4 graphically shows the theoretical dependence of economic indicators of quality maintenance and aircraft repair from changing of its quality parameter which characterizes the level of aircraft efficiency. It shows the functions that reflect changes in costs to provide recovery quality Zκ, the positive economic effect from ensuring recovery quality and total economic effect as the algebraic sum of the two curves Ep and Zκ, depending on the parameter of quality recovery. Due to the fact that the quality parameter varies from zero to one, the graph is limited by theoretical limit of the parameter K max, which is possible only if the average recovery time after failure is zero [5].

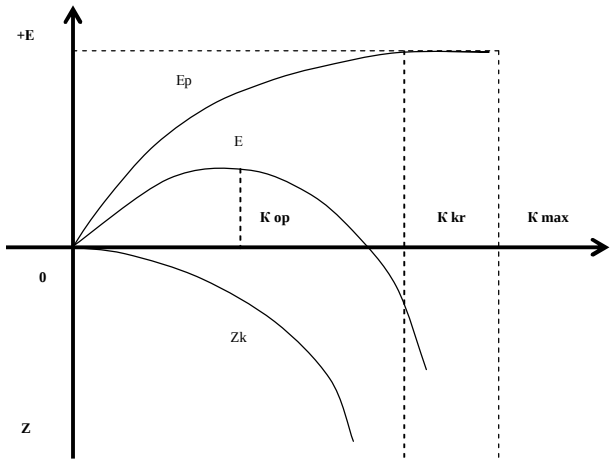

Fig. 4. Graphic representation of total economic effect method to optimize the parameter of aircraft recovery quality

The character of the Ep and Zk dependence from a quality parameter determines the extreme nature of the total economic effect curve E, which allows optimizing the level of aircrafts efficiency. If there are no other restrictions of non-economic nature the level of aircrafts efficiency should be on the limits of economically efficient values of the cost-effectiveness parameter, corresponding value E> 0.

Symbols used in Fig. 4 .: Zk – the costs of providing the aircraft recovery quality, hrn. / hr .; Ep – economic effect of providing aircraft recovery quality, hrn. / hr .; E – the curve of the total economic effect, hrn. / hr .; K op – optimal value of an aircraft recovery quality appropriate to a maximum value of total economic effect; K kr – critical value of an aircraft recovery quality level; K max – the maximum value of an aircraft recovery quality level.

In each certain specific situation, the following options for changing values of relationships are possible. Parameter of recovery quality decreases, and therefore the efficiency by reducing its effect at a cost that survived by his conduct. The value in an extreme point of the positive effect curve Ep in its limit is less than the initial calculation. Accordingly, the total economic impact will change, and the optimum point will shift to the origin. To preserve the optimal level of a quality parameter, it is necessary to reduce the costs of its support with the help of different organizational and technical activities. There is another possible option of changing the optimal value of the quality parameter when its decline is caused by increase of costs for repair and maintenance of aircrafts at the primary level of positive effect.

Determining the economic efficiency of providing quality of aircraft equipment recovery requires not only accounting of the cost but also the obtained effects.

In the process of aircraft equipment use as a result of inspection, overhaul service, supervision, planned repairs some failures and rejections may occur according to which aviation equipment is determined as invalid. If establishing failures and rejections aviation equipment needs to be recovered. Realization of any recovery requires decommissioning of aviation equipment. Due to various reasons the accuracy of control is not full. False establishing of failures (false failures) and rejections (false rejections) together with non detection of real rejections (open rejections) can occur. When false failures occur aviation equipment is removed from service in working condition. When false rejection occur it is removed from service, though in fact is in working condition, but this efficiency will not be used. If latent rejection of aviation equipment – it is not removed from service, but is invalid. Condition of latent failure can be detected in maintenance, planned repairs, main technical parameters control of the aircraft or during operation. Latent rejection is very dangerous for aviation equipment.

After aviation equipment recovery technical parameters are tested and monitored according to Ukrainian State Standard and ISO quality standards and equipment is passed for service. Aviation equipment is in working condition ready for operation.

The above model sufficiently reflects possible operational modes of aircraft equipment, but even its partial review allows evaluating the difficulties of calculating the economic effect of providing the quality of aircraft equipment recovery.

As mentioned above, providing of quality recovery largely affects aircraft equipment efficiency. The volume of these works, the cost should depend on the purpose and conditions of aircraft equipment, operating conditions and economic effects of their conduct.

Purpose of aircraft equipment, its role in modern society influences the nature of its service. Differences in requirements for technical parameters of aircraft equipment cause differences in providing the quality of recovery. But the main principles of costs and economic effect remain common.

The main difference caused by the functions performed by aircraft equipment in the process of its operation, lies in determining of the economic effect of providing aircraft equipment quality recovery.

Aircraft equipment refers to the vehicles, and so the economic effect of providing the quality of recovery can be created by reducing the costs of maintenance and repairs. Also, the effect can be created by reducing transportation costs. Also, certain effect can be created in general within the whole branch of economics where aircraft equipment is used. Thus, providing a fixed level of aircraft efficiency, by providing quality of recovery leads to non increase of operating costs (repair, maintenance), as well as loss from aircraft equipment idle time. Costs on maintaining a large number of reserve spare parts and repair materials don't increase much due to detection of latent failures and false rejection. Ensuring the efficiency of aircraft equipment, and hence its technical parameters allows to provide the quality of recovery. Economic effect of providing stable, timely transportation will be created in addition to an economic effect from operating costs on aircraft equipment. Then it is possible to determine the economic impact of quality of transportation by vehicles, and so the chain of economic effects may be extended.

Depending on the purpose and functions of air transportation one can identify aircrafts for cargo transportation, passenger transportation, military and special aircrafts.

As aircraft equipment has multipurpose use, the economic effect of ensuring the quality of its recovery will have a different composition and will be determined differently. Providing a fixed level of aircraft equipment efficiency due to the quality of recovery, involved in the transportation of raw materials, spare parts and other industrial goods, can promote continuity of implementation of technological processes.

Bad providing of technical condition indicators, and therefore efficiency of aircraft equipment causes inadequate change of operating costs and process in which it participates. That is why the differentiated research of technical indicators impact on determining the economic effect by ensuring the quality of the recovery and maintenance of aircraft equipment is needed. Moreover, character of this impact for different conditions can vary depending on which indicator of technical condition should be provided first. Thus, for the aircraft equipment in difficult weather conditions the accuracy of navigation devices is very important as well as an increased margin of safety of aircraft elements. For commercial cargo aircrafts such indicators as capacity and efficiency are very important. During express transportation speed indicators of aircraft equipment become also important.

Calculation of economic effect requires distinguishing between savings and avoided losses. The aim of our development is to improve the general provisions of economic effect evaluation in case of determining the quality of aircraft recovery.

The economic effect in the form of savings can be reached by reducing the cost of repairs and maintenance of aircraft equipment and the cost of providing the quality of its recovery. The economic effect can also be created by assuring the quality of aircraft equipment recovery, being repaired or maintained. Defect in the construction of aircraft equipment belongs to the avoided loss no matter when it appears: during manufacture or at the stage of its operation and who fixes it (repair company or operating organization).

Due to the difference of objects of economic analysis we should classify the sources of effects. The effects that arise in repair service, call it conditionally manufacturer, effects that arise during the operation of the repaired aircraft equipment (call conditionally consumer). Differentiation of orders of economic effects caused by the difference of their display areas and the need of strict accounting is also needed. For economic analysis we will mention the effects of 1st and 2nd order.

The economic effect of the 1st order in manufacturer - this effect (shows savings of resources) appears when performing work to assure the quality of repair and maintenance of aircraft equipment. This effect may occur due to the improvement of the organization process of repair and maintenance of aircraft equipment, the organization of the recovery process, means of support, increase of employees' level of skills, improvement of recovery process, reducing complexity of work in testing the aircraft equipment, control and reducing costs through occasional defect of renewed details, newly produced components in the repair process of aircraft, reducing the cost for correction of defects and second control of repaired aircraft equipment.

The effect of the second and third orders of consumer is created by changing of the operating costs

of aircraft equipment, as well as by reducing the cost of operation of aircraft equipment.

The proposed economic model for evaluating the quality of repair and maintenance admits determining of the total economic effect. The annual economic effect from assuring quality recovery and maintenance of aircraft equipment, resulting in operation of aircraft equipment (the effect of the second-order), occurs in the form of savings and avoided losses for two reasons. First, eliminate losses due to non-compliance of technical parameters of aircraft equipment to normative and technical values. Second, due to changes in the operating costs connected with the elimination of aircraft equipment idle time due to technical reasons. This allows to get additional income through extra services like people and cargo transportation and consequently to increase total revenue.

CONCLUSIONS

1. In determining the level of aircraft efficiency one should consider not only the technical capabilities of aviation equipment and its service systems, but also economically reasonable limits of providing the parameter of aircraft equipment recovery quality.

2. The research of economic peculiarities of aircrafts reduces to determining costs, economic effects, cost-effectiveness and development of recommendations to improve the quality parameter of aircraft equipment recovery on economic criteria.

3. It was established that in the result of providing optimal level of quality of aircraft equipment recovery appear effects of different order. Effects of the first order include works to assure the working condition of aircraft equipment. Economic effect is achieved by saving directly in the recovery process within aircraft repair plant. Effects of the second order are created by providing working condition of aircraft equipment, elimination of aircrafts idle time and thereby avoiding potential losses, including losses from possible disasters. Third-order effects arise due to the possibility to increase the volume of transportation by increasing of aircraft efficiency.

4. Costs on assuring the quality of recovery and maintenance of aircraft equipment belong to preventive costs on providing working condition of aircraft equipment. They are characterized by the value of work on recovery and maintenance. An important economic effect from assuring the quality of aircraft equipment recovery and maintenance is the effect of avoided loss regardless of the stage at which it appeared: recovery or operation.

5. Application of method of total economic effect for determining the cost-effectiveness of quality assurance of recovery and maintenance of aircraft equipment makes it possible to optimize this process by determining the maximum cumulative economic effect. The annual economic effect from assuring the quality of recovery and maintenance of aircraft equipment, obtained as a result of elimination of reasons of aircrafts idle time caused by their technical state. Revenue generated from the additional services like people and cargo transportation will increase the general profitability of operating organizations.

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