ISSN 1648-4142 TRANSPORT
www.transport.vtu.lt

TRANSPORT – 2005, Vol XX, No 5, 214–217

AIRCRAFT MAINTENANCE ENTERPRISES EXPENDITURES FORMATION ECONOMIC MODEL: SOLUTION PROBLEMS AND DIRECTIONS

Natalia Podolyakina

Transport and Telecommunication Institute, 1, Lomonosova str., LV-1019 Riga, Latvia.
E-mail: npod@tsi.lv

Received 5 March 2005; accepted 25 June 2005

Abstract. Under contemporary economic conditions the businessman is interested in the optimization of expenses. Equipment maintenance is one of the components of the enterprise expenses. That is why it is necessary to develop the model of the formation of the enterprise expenses aimed to the technical equipment maintenance. This model is taken into serious consideration making serious and thorough decisions on the quantity of expenses for providing the appropriate working equipment state and reliability level.

Keywords: the model of the formation of the enterprise expenses, repairing service, probability of unfailed items work**.**

1. Introduction

Transition to the market relations destroyed the usual opinion about the possibilities of financing the state projects connected with the output quality improvement [1–3].

Nowadays civil aviation maintenance enterprises being separate economic units came across a number of problems, the main of which is the decrease of the scope of transport work, unstable financial state, low payment ability and, as a result, the maintenance of the old aviation technique without the perspectives of modernization.

Under these conditions a special role belongs to repairing the equipment with the quality and cost being determined by the ordering maintenance enterprise.

The main task of the aviation maintenance enterprise is to offer its repairing service at a proper time to prove economically its cost and to cause the unfailed functioning of the equipment during the whole quaranteed maintenance period.

We should take into consideration that the industrial production articles of the consumption sphere are of unreserved nature (radio receivers, TV-sets, recorded devices, i.e. all the household gadgets). The reliability of these devices is completely determined by the level of the absence of their constituent parts failures.

As concerns the industrial items not belonging to the consumption sphere-they are quite often reserved. In the first turn it belongs to the unrestored radioelectronic instruments. The reservation of both-repaired (restored) and unrepaired (unrestored) instruments is used on different levels: this is the reservation on the level of units, blocks and apparatus, in general, as well as on the level of elements (deep fractural reservation).

2. The nature of the changes of the probability of the unfailed items work

The analysis of the formation of the economic models of the consumers' common expenditures for the production and maintenance of failed items showed that the models for reserved and unreserved devices substantially differ from each other and should be considered separately.

The market makes the manufacturer of the apparatus be extremely interested in the behaviour of the industrial items in the process of maintenance, the latter pointing to the specification of the transition to the market relations. And not only the expenditures connected with repairing and removing of the failed items, but the readiness of the manufacturer to compete should be taken into account. The enterprise – manufacturer realizes that a definite number of its items could fail in the process of their application. But the manufacturer is striving to define the number of the failed items in comparison with the total quantity of items entering the market because this process causes additional expenditures connected with the items repairing and full removing.

The probability of the unfailed items functioning **P** in time **t**, quantitatively estimated as the ratio of the unfailed items number to their total quantity, can be the important index.

$$P(t) = N - n(t)/N, \quad (1)$$

where N – total number of items; n(t) – number of the items failed for time **t**.

The longer is the period of time of maintenance the greater is the value of **n(t)**, i.e. the number of failed items becomes greater and the value **P(t)** becomes lower. The nature of the change of the probability of the unfailed work of the items **P(t)** is represented in Fig. In the engineering practice value is considered to be changeable according to the exponential law:

$$P(t) = e^{-\lambda t}, \quad (2)$$

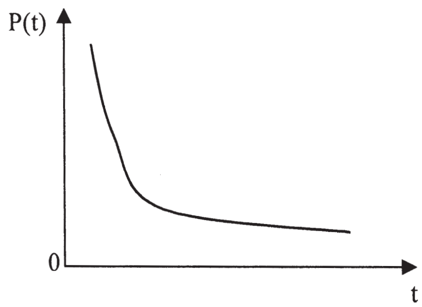
where $\lambda = \frac{1}{T}$ – the intensity of items failures having value I/h; T – the average time of the unfailed work.

The category of reliability is the foundation of the economic models construction. This is explained by the fact that the category of reliability is the temporal function as it has been demonstrated using the example of the probability of the unfailed work of the item p(t).

During maintenance the number of the failed items n(t) is growing. It is quite obvious that the guarantees given by the enterprise – manufacturer should be developed through the prism of probable items failures for this period of time.

If you know the number of possible failures and the value of probability of unfailed work of the enterprise – manufacturer you will solve the problem of its vitality on the market. In this case the category of the reliability of items will become the only category of evaluating the risks of the enterprise-manufacturer in the market conditions when it gives the guarantees for its production.

As a rule, time **t** in the above-mentioned expression (2) will play the role of guarantee term $\mathbf{t_r}$ of the enterprise – manufacturer, because it is the guarantee term during which the enterprise – manufacturer is especially interested in its items. After this term



The nature of the changes of the probability of the unfailed items work

the enterprise – manufacturer does not take a significant interest in the fate of its items, but if it pays some attention to the items, it at the same time provides post guarantee repairing in the case of failures and the customers should pay for all the services.

Let us suppose that the probability of the failure – proof items work – 0,9 for time **t** = 2 years. It means that 10 of 100 items will probably fail for 2 years time, and this fact will enable the enterprise to estimate the additional expenses for items repairing and removing.

Let us suppose that the enterprise – manufacturer decided to make a 3-years guarantee term. Taking into account the correlation (2) we have the equations – system:

$$p(t_{\Gamma 1}) = e^{-\lambda t_{\Gamma 1}}$$
$$p(t_{\Gamma 2}) = e^{-\lambda t_{\Gamma 2}}, \quad (3)$$

from which

$$p(t_{\Gamma 2}) = epx[(t_{\Gamma 2} - t_{\Gamma 1}) \ln p(t_{\Gamma 1}). \quad (4)$$

If $t_r 1$ = 2 years, but $t_r 2$ = 3 years we will get:

$$p(t_{\Gamma 2}) = e^{-\frac{3}{2}\ln 0{,}9} = e^{-0{,}1581} \cong 0{,}85 \quad (5)$$

it means that 15 of 100 items could fail.

It is quite possible that in the case of the cardinal changes with the materials technology and scheme solutions – the new item with the increased reliability will cost less than its predecessor with the lower level of reliability.

But in the majority of cases the increasing reliability of items points to their higher quality, a greater number of tests and they certainly demand considerable expenses.

This important factor determines the amount of possible solutions of the enterprise – manufacturer in its fight for the market.

If the cost of the item with reliability $\boldsymbol{p}$ is **C** then the cost of the similar item with the higher level of reliability $\boldsymbol{p_1} > \boldsymbol{p}$ is $\mathbf{C_1} > \mathbf{C}$. The higher level of items reliability can be achieved in different ways and it is not the same for different items because of maintenance and scheme-technical peculiarities. The value of the probability of the failure – proof work of one and the same item can be achieved by the enterprise - manufacturer in different ways, but even in the case of similar ways of reaching the high level of reliability it can be different at various enterprises, but if $\boldsymbol{p_1} > \boldsymbol{p}$, and $\mathbf{C_1} > \mathbf{C}$, then the increase of items reliability is always connected with the growth of its cost.

This rule does not belong to general expenses for production and maintenance of the items arriving at the market, although the correlation $\mathbf{C_1} > \mathbf{C}$ and $\boldsymbol{p_1} > \boldsymbol{p}$ belongs to each of them. It is not surprising because the expenses connected with increasing item reliability can be lower than the expenses for repairing the failed items and on the contrary.

Any attempt of the enterprise – manufacturer to avoid the expenses for increasing item reliability will lead to the loss of enterprise competitiveness, its status as a supplier of the great amount of items needing the repair.

The price of increasing item reliability is the main indicator of any economic market model.

Looking for the ways of increasing item reliability with the minimal expenses is considered to be the main factor in the programme of creating and selling the items of any economic model.

Looking for the ways of increasing item reliability with the minimal losses is the primary factor of the programme of item manufacturing and selling. There is a lack of the investigations connected with the estimation of economic efficiency of different ways of increasing item reliability and at the same time enterprises do not pay significant attention to the price – formation of item reliability increase.

Taking into consideration the conditions under which the items supplied by the enterprise – manufacturer will fail, the number of the failed items should be known in any case. The enterprise –manufacturer must repair or replace the failed items during the guarantee period. There exists such level of apparatus reliability $p_{\text{ïpt}}$ under which the total losses $\mathbf{C}_{\Sigma}$ for manufacturing, repairing or replacing the failed items are summarized.

When the failed items are served and repaired during the guarantee period then the cost losses could be defined in the following way:

$$C_S = C_{man} + C_{rep}, \tag{6}$$

where $\mathbf{C}_{\Sigma}$ – total cost losses of the enterprise-manufacturer for production and guarantee service of items; $\mathbf{C}_{\mathbf{man}}$ – enterprise-manufacturer losses for items creation and production; $\mathbf{C}_{\mathbf{rep}}$ – enterprise-manufacturer losses for guarantee service of the items failed at the consumer.

The higher is the item reliability, the higher is the item manufacturing cost:

$$C_{man} = a_1 p^{\alpha}, \tag{7}$$

where $\alpha > 0$, and α – const, the expression characterizes the non-linear nature of the apparatus cost growth case of reliability increase. In its turn:

$$C_{rep} = \frac{b}{p^{\beta}}, \tag{8}$$

where $\beta > 0$, where β – const as well as value a in the expression (7) characterizes the non-linear nature of the items guarantee repair cost reduction in case of their reliability growth. Taking into account (7) and (8) the expression (6) is

$$C_{\Sigma} = a_1 p^{\alpha} + \frac{b}{p^{\beta}}. \tag{9}$$

The main feature of this dependence is such level of reliability at which the costs of losses for items manufacturing and repairing are minimal. The provision of reliability of the items differing from the optimal value will lead to the excess losses.

When $\boldsymbol{p < p_{opt}}$ – then the excess losses will take place due to the intensification of the work connected with the items repairing. When $\boldsymbol{p > p_{opt}}$ then the excess losses will take place due to the additional losses for the items reliability growth.

The values of the optimal probability of the items failure – proof work and minimal total losses for items production and maintenance are defined from the condition $\mathbf{dC_{\Sigma} / d\,p = 0}$ with the use of the correlation (9). Differentiating this correlation we will get after elementary transformations:

$$p_{O\Pi T} = \sqrt[\alpha+\beta]{\frac{b\beta}{a_1\alpha}}. \tag{10}$$

With the account of expressions (9) and (10) we will find

$$C_{\Sigma\min} = a_1 \left(\frac{b\beta}{a_1\alpha}\right)^{\frac{\alpha}{\alpha+\beta}} + b\left(\frac{b\beta}{a_1\alpha}\right)^{-\frac{\beta}{\alpha+\beta}}. \tag{11}$$

If the enterprise-manufacturer replaces the failed items and knows the level of their reliability for the fixed guarantee period of time, it is necessary to plan beforehand the production of the additional number of items used for removing the failed ones. It means that for every set of items with amount $\mathbf{N_1}$ – the enterprise-manufacturer produces additionally $\mathbf{(1{-}p)N_1}$ items, where $\mathbf{(1{-}p)}$ – the probability of the items failure during the guarantee service term. As a result – the total number of items in the set $\mathbf{N_{\acute{o}}}$ will compose:

$$N_{\Sigma} = N_1 + (1 - p)\, N_1 = N_1\,(2 - p) \tag{12}$$

and $\mathbf{N_1\,(2{-}p) > N_1}$, as the probability of the items failure – proof work is always $\mathbf{0 < p < 1}$.

If the cost of every item is $\mathbf{C}$, then the total losses – $\mathbf{C}_{\Sigma}$ of the enterprise-manufacturer for the production and maintenance of the common items set will be:

$$C_{\Sigma} = C\,N_{\Sigma} = N_1\,(2 - p)C. \tag{13}$$

Generally the item cost depends on the level of its reliability – $\boldsymbol{p}$.

That is why – similar to expression (9) is

$$C = \alpha p^{\gamma}. \tag{14}$$

The mutual solution of the equations (13) and (14) will give the following expression:

$$C_\Sigma = N_1 (2 - p) \alpha p^\gamma. \quad (15)$$

As before, drawing conclusions from the expression $\mathbf{dC_\Sigma / d\, p = 0}$, we will find:

$$\frac{dC_\Sigma}{dp} = 2N_1 \alpha p^{\gamma-1} - N_1 \alpha(\gamma+1) p^\gamma = 0,$$

from which

$$p_{ОПТ} = \frac{2\gamma}{\gamma+1}. \quad (16)$$

So, in both cases – when the failed items are replaced or repaired, there exists such a level of reliability determined by the correlation (16), where total losses of the enterprise-manufacturer for creating and removing the failed items during the fixed guarantee period of time have the minimal meaning which following the correlations (15) and (16) will be equal to:

$$C_{\Sigma\min} = N_1 (2 - \frac{2\gamma}{\gamma+1}) \alpha (\frac{2\gamma}{\gamma+1})^\gamma = N_1 \alpha \gamma^\gamma (\frac{2}{\gamma+1})^{\gamma+1}. \quad (17)$$

We drew the conclusion that under technical conditions the demands for the reliability of the replaced or repaired maintenance should be determined by the correlations (10) and (16) correspondingly. The total losses for the item production and maintenance in both cases will be minimal and can be determined by the expressions (11) and (17) correspondingly.

Unfortunately in a number of cases the optimal meaning of the probability of the failure – proof work could occur in the area of non-admitted low meanings (in the case of high cost of the chosen way of increasing item reliability, and, as a rule, such situation is taking place), that excludes the use of the considered model. The enterprise-manufacturer should deny the optimal model and transfer to the area of higher meanings of probability of the unfailed work and correspondingly to the higher level of production and maintenance total losses in relation to the optimal model.

3. Conclusions

The advantages of the suggested model can be formulated in the following way:

- in every concrete case – the demands for item reliability are formulated according to the minimal losses for the item production and maintenance.
- these demands should be scientifically proved and determine the choice of the corresponding scientific solution in this item manufacturing.
- such approach excludes using excessive demands for the applied elements base, this fact being especially important as the increase of the electrical radioelements reliability is a prolonged and expensive process.
- the suggested economic model is universal and can be applied to any items.

In cases where this method is not used - the adequate demands for item reliability can cause extra monetary and material losses. The above-mentioned model is very advantageous in the market conditions. Let us suppose that the enterprise-manufacturer constructed the real model of total losses for the concrete item. Let us take into account the fact that minimal losses for the item manufacturing and maintenance correspond to optimal meanings of the probability of item failure-proof work equal to 0,6. Thus, 40 items of every hundred could fail. The only way out is the increase of item reliability, e.g. up to the level 0,9, i.e. it is necessary to achieve the reduction of the intensification of the item failure for 4,85 times.

If the enterprise-manufacturer knows the cost of the ways of increasing item reliability – it will considerably influence the total losses of the enterprise-manufacturer. The adequate economic model can't be built without this valuable knowledge. The nature of the change of the enterprise-manufacturer total losses curve for item developing, producing and maintenance is similar to all the production items which are repaired or replaced during maintenance in the case of their failure. The same factor can be applied to all kinds of consumer goods, electrical appliances and cosmic apparatus.

It is necessary to remember that a successfully chosen scientifically proved economic model will solve all the problems of the enterprise under market conditions. The main way to successful production goes through the modern technologies development. The scientifically tested choice of the corresponding economical model solves the problem of rational financial investment to item production and maintenance and determines its competitiveness. Such approach to item production and maintenance was dictated by the demands of the enterprises transition to the markets conditions where the customer's interests should be of primary significance.

References

1. Donaldson, B. Sales management: theory and practics. London, 1998. 378 p.
2. Innovation in technology, industries, and institutions: Studies in Schumpeterian perspectives. The Univ. of Michigan Press, 1994. 367 p.
3. Хакен, Г. Синергетика иерархии неустойчивостей в самоорганизующихся системах и устройствах. Москва: Мир, 1985.