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Evaluation of Management System Effectiveness in the Preparation of the Aircraft for Flight in Faulty Conditions

Ruta Bogdane[1,3], Andris Vaivads[2,3], Dejan Dencic[3]
[1,2]*Institute of Aeronautics, Faculty of Transport and Mechanical Engineering,*
Riga Technical University, Latvia
[3]*SmartLynx Airlines, Serbia*

***Abstract* – Most flight delays in aviation enterprises are related to air traffic management and technical centers. This can happen for various reasons: untimely removal of defects, lack of spare parts, deficiencies in maintenance scheduling, etc. Another reason may be inefficient management in the system of preparing the aircraft for departure. The article suggests a possible option of such an assessment as well as the results obtained from the use of this methodology applied to a specific airline.**

***Keywords* – Aircraft, aviation specialists, faulty condition, flight delay, management efficiency, management system.**

I. Introduction

Faulty situations in air transport enterprises happen randomly, which causes the delay of regular flights. A significant part of flight delays and faulty aircraft conditions in airlines occur due to deficiencies in maintenance services [1]–[5]. This is related to the fact that in most airlines in engineering practice the techniques of eliminating failures and faults, which provide high dispatch reliability, have not been fully established.

One of the reasons of the faulty condition is a failure of the airline maintenance services contributing to a group of factors related to the efficient organization of maintenance process management and the support of aircraft's continuing airworthiness.

Ineffective solutions in the developing work conditions along with the existing technologies inevitably lead to the breach of organizational and technological regulations of work and decrease in quality.

Therefore, to ensure the high quality of the airline performance and increase its competitiveness it is required to form the organizational structures in an appropriate way including the structure of process management in aircraft maintenance service.

One of the main directions in finding the solution is the development of the structure and mathematical models that concern the organizational tasks of the aircraft maintenance operation. The process of managing the aircraft maintenance service is related to the solution of a range of specific tasks. In addition, each level of the system deals with solving its own range of tasks. Management problems are connected with the distribution of authority between structures and persons who make decisions, division of resources, etc. These questions are very complex and multidimensional.

II. Mathematical Interpretation of Optimal Function Distribution Between the Levels of Aircraft Preparation for Flights

We introduce the coefficient concept [6]–[7], i.e. a subordination link for the manager with the lower level of management. We will mark this subordination link as K_{cj}. The current coefficient depends on:

- the nature of the guidelines and their regularity;
- the link between the manager and the functional units;
- the completeness of the management unit accounting regardless the calendar time, etc.

Taking into account the above mentioned aspects the expression can be presented as follows (1):

$$K_{cj} = \sum_{i=1}^{n_j} K_{pi} \tag{1}$$

where K_p – management coefficient;
n_j – number of links of manager i (2):

$$i = \overline{1, n_j} \tag{2}$$

We will evaluate these conditions using a 9-point scale (Table I).

TABLE I

SCALE OF MANAGEMENT COEFFICIENTS

Characteristics of quality management	Regularity		
	Daily	Weekly	1–2 times a month
Detailed, specific instructions	9	8	7
Coordination of means and ways of implementation and some methodological advices	6	5	4
Common directions in work	3	2	1

Let us compare two simplified options of the management structure with management coefficient $K_p = 9$:

A) A three-level management system. The manager has one subordinate, so $n_1 = 1$ and $K_{cj} = 9$;
B) The manager has two subordinates, 2 and 3, so $n_1 = 2$ and $K_{cj} = 18$ (Fig. 1).

It is obvious that the best structure will be at maximum n_1. In this case, this is a two-level management system. However, with a larger number of links this system will be complicated and inefficient, while a multi-stage management system would be more effective.

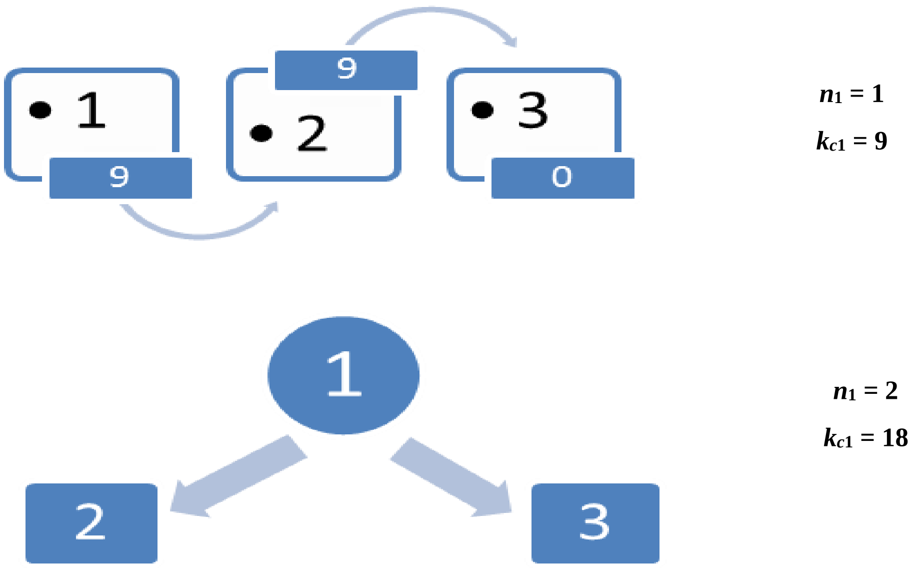

Fig. 1. Comparison of management structures.

Practice shows that the aircraft maintenance organization uses the 3-level system with a certain number of specialists involved in the preparation of the aircraft for flight:

1) Shift.
2) Section.
3) Technical center.

Let us mark the number of specialists participating in the preparation of the aircraft for flight with κ_0 and their quantity on each level with κ_1, κ_2, κ_3. Then the total number of specialists who participate in the preparation of the aircraft for flight will be equal to (3):

$$\kappa_0 = \kappa_1+\kappa_2+\kappa_3 \tag{3}$$

where 1..3 represents the management levels.

We denote the totality of tasks to be solved in aviation-maintenance service by M_0 (4). This coefficient includes all types of tasks on all 3 levels with the maintenance of the aircraft.

$$M_0 = \sum_{i=}^{1} M_i = \sum_{i=1}^{1} \sum_{j=1}^{J_i} M_{ij} \tag{4}$$

where M_i – quantity of tasks occurring during the *i* shift;
M_{ij} – quantity of tasks occurring in section *j* during maintenance shift *i*;
i – quantity of shifts;
J_i – quantity of sections during shift *i*.

The solution of these tasks requires resources which are under control and at the disposal of the 1st, 2nd and 3rd levels of maintenance management. Thus, M_j is (5):

$$M_j = M_{1j}+M_{2j}+M_{3j} \tag{5}$$

where M_{1j} – quantity of tasks occurring in section *j* of the system of aircraft preparation and requiring the resources of the 1st management level for their solution.
M_{2j}, M_{3j} – number of problems occurring in section *j* and to be fixed using the resources of the 2nd and 3rd management levels.

Let us mark by ς_1, ς_2, ς_3 the part of tasks to be solved on the 1st, 2nd, 3rd management levels against the total number of tasks occurring at the Technical Service Center during a certain calendar period (6):

$$\varsigma_1 = \frac{M_1}{M_0}$$

$$\varsigma_2 = \frac{M_2}{M_0} \tag{6}$$

$$\varsigma_3 = \frac{M_3}{M_0}$$

The amount of tasks implemented using the resources of the 1st, 2nd, 3rd management levels can be expressed as (7):

$$M_1 = \sum_{j=1}^{J} M_{1j}$$

$$M_2 = \sum_{j=1}^{J} M_{2j} \tag{7}$$

$$M_3 = \sum_{j=1}^{J} M_{3j}$$

where ς_1, ς_2 and ς_3 represent (8):

$$\varsigma_1 + \varsigma_2 + \varsigma_3 = 1 \tag{8}$$

III. Mathematical Model of the Effectiveness System Evaluation for the Aircraft Preparation for Flight in Faulty Situations

Let us introduce the efficiency index of the aircraft preparation for flight [7]–[11] (9):

$$C(t) = C_s * \sigma(t) \tag{9}$$

where C_s – economic damage from faulty situations per unit of time or the specific index of economic damage caused by faults (10):

$$C_s = C_p + C_t + C_{st} + C_g \tag{10}$$

where C_p – wages paid to the aircraft crew per unit of time in their actual downtime;

C_t – wages paid to the team of specialists performing flight ground support per unit of time for their inactivity in case of flight delay;

C_{st} – cost of aircraft flight hour;

C_g – airline expenses related to the passengers' waiting per unit of time for their inactivity in case of faulty situation.

The second multiplier $\sigma(t)$ in the expression (9) represents the average total time for the enterprise in case of faulty situation per unit of time. In accordance with the accepted control scheme above, faults are being fixed during the aircraft preparation for flight on the 3 management levels (11):

$$\sigma(t) = \varsigma_1 \tau_1(t) + \varsigma_2 \tau_2(t) + \varsigma_3 \tau_3(t) \tag{11}$$

where $\tau_1(t)$, $\tau_2(t)$, $\tau_3(t)$ – total time duration of flight delay elimination on different management levels.

Let us accept the assumption that for time t on one level of aircraft preparation for flight there cannot be more than one fault. Mathematical expectations $\tau_1(t)$, $\tau_2(t)$, $\tau_3(t)$ can be calculated as follows (12):

$$\begin{aligned} \tau_1(t) &= \int_0^1 f_1(\tau)\tau d\tau \\ \tau_2(t) &= \int_0^1 f_2(\tau)\tau d\tau \\ \tau_3(t) &= \int_0^1 f_3(\tau)\tau d\tau \end{aligned} \tag{12}$$

After some transformations the model of efficiency evaluation for the system of the aircraft preparation for flight in faulty situations can be obtained (13):

$$C(t) = C_s \cdot \sum_{j=1}^{3} \varsigma_j \left[\tau_j - (t + \tau_j) \cdot e^{-\frac{t}{t_j}} \right] \tag{13}$$

IV. Evaluation of Efficiency of the System of the Aircraft Preparation for Flight in Faulty Situations in the Airline Enterprise "Airline"

For the calculation we use a database of flight delays [6], [12], [13] due to technical reasons in "Airline" for a period of three years ($T = 3$), the number of which is $M_o(T) = 152$. The quantity of tasks to eliminate faults on the 1st, 2nd and 3rd levels of the system are respectively equal: $M_1(T) = 110$, $M_2(T) = 25$ and $M_3(T) = 15$. An evaluation per one night was carried out, $t = 24$ H; and the average duration of failure elimination on different levels is as follows (14):

$$\tau_1 = 0.78 \text{ H}$$
$$\tau_2 = 1.12 \text{ H} \qquad (14)$$
$$\tau_3 = 1.36 \text{ H}$$

A specific index of economic damage failures is equal to $C_s = 2552$ *Euro/Hour*.

The tasks of "Airline" aviation-maintenance service are distributed among the levels (15):

$$\varsigma_1 = \frac{M_1(T)}{M_0(T)} = \frac{110}{152} \approx 0.72$$
$$\varsigma_2 = \frac{M_2(T)}{M_0(T)} = \frac{25}{152} \approx 0.19 \qquad (15)$$
$$\varsigma_3 = \frac{M_3(T)}{M_0(T)} = \frac{15}{152} \approx 0.10$$

Economic damage $C(t)$ caused to the company by flight delays during one night is equal to 61 288 Euro.

V. Conclusion

As the current airline work analysis shows, most flight delays are related to the technical defects of the aircraft, classical causes such as lack of spare parts, engines, technical means of control, etc. Another reason can be a sub-optimal distribution of specialists among the levels and distribution among the levels of tasks within the system of aircraft preparation for flight in a faulty situation.

A substantial reduction of economic losses in business can be achieved by optimizing the management system and eliminating flight delays in the aviation maintenance center.

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Ruta Bogdane has been a Doctoral student at the Institute of Aeronautics, Riga Technical University, since 2014. In 2013 she obtained a degree of Master in Aviation Transport, Riga Technical University. In 2005 she obtained a degree of Master at Turiba University.
Work experience: 2003–2004 – Service Engineer at SIA Danlats. 2004–2008 – Quality Manager at the Civil Aviation Agency of Latvia. Since 2008 – Compliance Monitoring Manager (AIR OPS, Part M, Part FCL) at SIA SmartLynx Airlines.
Her fields of research: airworthiness, commercial aviation, management efficiency, quality management.
Address: Institute of Aeronautics, Faculty of Transport and Mechanical Engineering, Riga Technical University, Lomonosova 1A, k-1, Riga, LV-1019, Latvia.
Phone: (+371) 28377793
E-mail: Ruta.Bogdane@rtu.lv, Ruta.Bogdane@gmail.com

Andris Vaivads has been a Doctoral student at the Institute of Aeronautics, Riga Technical University, since 2014. In 1995 he obtained a degree of Master at Riga Civil Aviation University, Mechanical Engineering Faculty, Maintenance of Aircraft and Engines.
Work experience: 2007–2012 – VP Production at SIA airBaltic. 2012–2013 – VP Engineering at SIA airBaltic. Since 2013 – VP Technical Operations at SIA airBaltic.
His fields of research: aircraft technical operation, airworthiness, safety.
Address: Institute of Aeronautics, Faculty of Transport and Mechanical Engineering, Riga Technical University, Lomonosova 1A, k-1, Riga, LV-1019, Latvia.
Phone: (+371) 29106155
E-mail: Andris.Vaivads@rtu.lv, dtrixts@inbox.lv

Dejan Dencic in 1998 obtained a degree of Master in Mechanical Aerospace Engineering at the University of Belgrade, Faculty of Mechanical Engineering, Aerospace Department.
Work experience: 1999–2001 – Test Equipment Engineer in MCC Engineering Bureau, Component Maintenance Department. 2001–2005 – Planning Engineer in MCC Base Maintenance Bureau, Aircraft Maintenance Department. 2005–2008 – Production Engineer / Project Manager in MCC Production Bureau, Base Maintenance Department. 2008-2012 – Senior Engineer in MCC Troubleshooting Bureau, Line Maintenance Department. Since 2012 – Manager in MCC Bureau, Line Maintenance Department. Since 2014 – Manager of Technical Control Centre, SmartLynx Airlines.
His fields of research: aircraft maintenance, airworthiness, safety, troubleshooting.
Phone: (+381) 112154038
Email: dencicdejan@gmail.com