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OPTIMIZATION ASPECTS OF TECHNICAL MAINTENANCE SYSTEM FOR AIRCRAFT GROUND SUPPORT EQUIPMENT

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Abstract

Keeping the aircraft Ground Support Equipment (GSE) at airfields of Armed Forces of the Republic of Poland in state of operational readiness determines possession of adequate means and resources by the entity, which provides its maintenance and repair. The article presents the characteristic features of the maintenance model used for GSE items used for aircraft ground handling. Basic assumptions have been presented, and mathematical notation of the system input data has been identified and presented. Selected elements of the optimization task, its decision-making variables and limitations have been formulated. A preliminary quality evaluation of the proposed maintenance GSE system model has been made. The authors have emphasized the importance of the system optimization, which involves minimizing the criterion function of system evaluation. Components of this function are mainly costs per unit of time resulting from the necessity to use a given GSE and from the necessity to keep a given GSE type in the technical maintenance system. In addition, an example of such approach in the table format has been given, and selected parameters of airfields and GSE items have bene presented. There is a short summary section, which stresses the importance of such optimization of GSE maintenance system.

Keywords: *GSE, technical maintenance system, system optimization*

1. Introduction

Rational use of available resources is one of the determinants of operation of the entity, which provides the maintenance of aircraft ground support equipment (GSE) located at military airfields. Resources are understood as both means of production (adequate technological, documentation and staffing level) and the overall organizational system. Combining those resources into a system determines its correct functioning. Therefore, such system should be adequately managed. In this article, it is assumed that the maintenance system management is an effective realization of functions, which involve quantitative and qualitative selection of resources according to their intended use and maintaining the resources in a continuous state of readiness. The term "technical maintenance" is understood as a set of intentional organizational, technical and economic actions of people and equipment with the aim to keep or restore the capability of further operation.

The technical equipment maintenance system has two subsystems:

– executive, responsible for realization of maintenance,
– planning, responsible for correct planning of all maintenance tasks performed (by the contractor).

The maintenance subsystem and the use subsystem make up the system of technical operation, which comprises the set of GSE items, technical personnel and control of the technical operation process, which cooperate in order to keep the GSE fit for handling aircraft.

The use subsystem is the set of GSE items, personnel, technical operation means, regulations and standards, which specify the selection, and maintenance of the most appropriate scopes of ground aviation equipment and maintaining and restoring the fitness for use.

The technical maintenance subsystem comprises the GSE, technical personnel, technical operation means, programmes and methods of maintenance, and relations between individual system components. This subsystem ensures mainly aircraft refuelling, supply of power, gases and consumable liquids to aircraft, special equipment, check of technical condition, preventive maintenance, repairs, etc.

The logistics subsystem provides spare parts, fuel, oxygen and other media, and it contains the equipment to feed these media, provide airfield power supply, individual ground equipment, etc.

From the point of view of entities responsible for technical maintenance of GSE located in military airfields, realization of these tasks determines possession of relevant resources in the form of service teams, processing lines, personnel trained in GSE handling, and stock of spare parts. At the same time, the entity must maximize the utilization of resources at minimum involvement of personnel and contractor operating means.

2. Model of maintenance system for aircraft ground support equipment

2.1. Model building assumptions

Due to a huge number of components, the actual maintenance system for aircraft ground support equipment (GSE) is too complicated to be analysed directly, and therefore needs to be modelled. The form of the model depends on the aim of research, and the model should represent the complexity and interdependence of phenomena, which occur during the actual operation of the system.

In model building, it is necessary to represent its basic properties, i.e. system components and their characteristics. The model input data should be identified for formal description of modelling of the technical maintenance system.

The model of maintenance system for aircraft ground support equipment MS_{GSE} can be expressed as an ordered triple:

$$MS_{GSE} = \langle S, F, O \rangle, \tag{1}$$

where:

MS_{GSE} – model of maintenance system for aircraft ground support equipment,

S – structure of model of GSE maintenance system,

F – set of characteristics of the system components,

O – organization of maintenance system for aircraft ground support equipment.

The optimum organization of aircraft technical maintenance is the organization, which ensures the best maintenance (from the point of view of chosen evaluation criteria). Optimization of the considered decision-making situation requires defining of the decision-making variables, limitations, and a criterion function, which will be a measure of how well the problem was, solved (problem solution quality).

2.2. Representation of resources for equipment and aircraft maintenance

For needs of the model of maintenance system for aircraft ground support equipment MS_{GSE}, it was assumed that various GSE types will be numbered, forming set U_N:

$$U_N = \{1, 2, ..., u, ..., U\}, \tag{2}$$

where:
u – number of a GSE,
U – number of all GSEs.

Analogously, individual types of maintenance performed on GSE form set P_N:

$$P_N = \{1, 2, ..., p, ..., P\}, \tag{3}$$

where:
p – number of a GSE maintenance type,
P – number of all types of maintenance performed on GSE.

In addition, it is advisable to account for possible, various methods of GSE maintenance, which can be identified e.g. by defining the set of technologies (methods) R_N:

$$R_N = \{1, 2, ..., r, ..., R\}, \tag{4}$$

where:
r – number of a GSE maintenance,
R – number of all types of maintenance performed on GSE.

According to previous assumptions, the model should represent the GSE maintenance system. For this objective of research, the values, which will affect the operation of the system (apart from previously defined sets), will include, inter alia:

– assigning maintenance types to GSE types $\psi(p, u)$, where $\psi(p, u) \in \{0,1\}$,
– duration of a given maintenance on a given GSE type using a given technology $\tau(p, u, r)$, where $\tau(p, u, r) \in \Re^+$,
– cost of upkeep of technical maintenance system which performs a given maintenance on a given GSE type using a given technology (method) $\chi(p, u, r)$, where $\chi(p, u, r) \in \Re^+$,
– other.

Hence, the characteristics of all types of maintenance performed on a given GSE type can be presented in the form of three matrices:

$\Psi = [\psi(p, u)]$ – matrix of assigning maintenance types to GSE types;
$\Omega = [\tau(p, u, r)]$ – matrix of duration of a given maintenance on a given GSE type using a given technology;
$X = [\chi(p, u, r)]$ – matrix of cost of upkeep of technical maintenance system which performs a given maintenance on a given GSE type using a given technology;

Taking the above into account, we can define the set of maintenance types, which are performed on given GSE types as:

$$\forall u \in U_N \quad P_N(u) = \left\{ p : \begin{matrix} \psi(p, u) = 1 \wedge p \in P_N \\ \psi(p, u) = 0 \wedge p \notin P_N \end{matrix} \right\}. \tag{5}$$

2.3. Representation of entity characteristics

Assuming that the technical maintenance system in an entity (contractor) which provides the GSE maintenance consists of the system components in the form of processing lines (in-house maintenance) or service teams (on-site maintenance, wherever GSE is used), we can defined set I_N of numbers of individual processing lines:

$$I_N = \{1, 2, ..., i, ..., I\}, \tag{6}$$

where:

i – number of a processing line,
I – number of all processing lines,
and set J_N of numbers of individual service teams:

$$J_N = \{1, 2, ..., j, ..., J\}, \quad (7)$$

where:
j – number of a service team,
J – number of all service teams.

Analysis of availability of maintenance system components requires that the time be accounted for in the model. Therefore, the time was divided into fixed intervals (e.g. one-second intervals) which set T_N can be expressed as:

$$T_N = \{t_k : \ k \in \{1, ..., K\}\}, \quad (8)$$

where:
k – time interval,
K – number of all-time intervals.

Airfields where GSE is used are also components of the GSE maintenance system model (MS_{GSE}). The set of individual (serviced) airfields A_N can be expressed as:

$$A_N = \{1, 2, ..., a, ..., A\}, \quad (9)$$

where:
a – number of a serviced airfield,
A – number of all serviced airfields.

The characteristics of serviced airfields include:

- type of place (airfield, contractor) where a given maintenance type is performed on a given GSE type $\alpha(p, u)$, where $\alpha(p, u) \in \{1,2\}$. $\alpha(p, u) = 1$ when a given maintenance on a given GSE type is performed at the airfield, whereas $\alpha(p, u) = 2$ when a given maintenance on a given GSE type is performed at the contractor's,
- service team travel time to the airfield $t(a)$, where $t(a) \in \Re^+$,
- efficiency of service teams which perform a given maintenance on a given GSE type using a given technology $\mu(j, p, u, r)$, where $\mu(j, p, u, r) \in \Re^+$,
- efficiency of processing lines which perform a given maintenance on a given GSE type using a given technology $\eta(i, p, u, r)$, where $\eta(i, p, u, r) \in \Re^+$
- and other.

2.4. Decision-making variables and limitations of optimization task

There are two types of defined binary variables in the optimization task:

- $x(a, j, p, u, r)$, where $x(a, j, p, u, r) \in \{0,1\}$. It is equal to 1 when at a given airfield a given service team has performed a given maintenance on a given GSE type using a given technology; otherwise $x(a, j, p, u, r) = 0$,
- $x(i, p, u, r)$, where $x(i, p, u, r) \in \{0,1\}$. $x(i, p, u, r) = 1$ if a given processing line has been used to perform a given maintenance on a given GSE type using a given technology.

The task of optimization of operation of the GSE maintenance system has many limitations, such as:

- limitations relating to the character of decision-making variables,
- limitations relating to the duration of individual maintenance of equipment,
- limitations relating to the amount of available resources (service teams, process lines),

- limitations relating to the number of employees,
- limitations relating to the costs of maintenance
- and other.

2.5. Preliminary evaluation of solution quality

The evaluation criterion of contractors (entities) which perform aircraft ground maintenance at military airfields should reconcile the interests of both partners in the operation process from one more general point of view, which commonly can be equated to business benefits. Therefore, for an entity which operates aircraft the problem of optimization of GSE maintenance is reduced to minimizing the criterion function F.

Function F, which is the system evaluation criterion, is a sum of the following components:

$$F = \sum_{u \in U_N} \left[KW(u) tw(u) + KS(u) ts(u) \right], \tag{10}$$

where:

KW(u) – cost per unit of time, resulting from the necessity to use a given GSE,
tw(u) – time of use a given GSE,
KS(u) – cost per unit of time, resulting from the necessity to keep a given GSE type in the technical maintenance system,
ts(u) – time of keep a given GSE type in the technical maintenance system.

3. Application example of presented methodology

3.1. Contractor characteristics

The entity under consideration (contractor) which provides GSE maintenance and repairs is located in Warsaw, Poland, and its main (strategic) customer is the Armed Forces of the Republic of Poland. The serviced GSE is located in individual airbases all over the country.

Typical (simplified) organizational chart of the contractor is presented in Fig. 1.

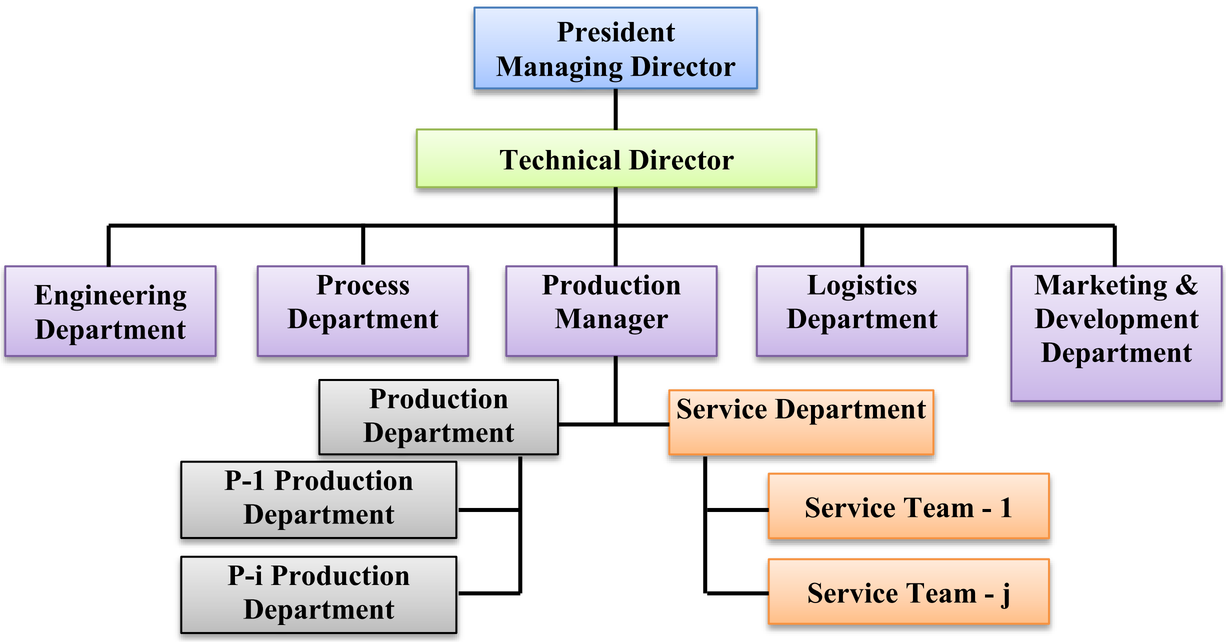

Fig. 1. Simplified organizational chart of GSE maintenance contractor. Source: own study

The entity has five service teams, which are dispatched when it is necessary to perform maintenance at an airbase or military unit where a given GSE is used. In house (Warsaw) the contractor has seven processing lines, which perform individual maintenance.

3.2. Selected parameters of airfields and equipment

The elements of set of GSE types, which undergo a given type of maintenance performed by the entity (contractor), are presented in Tab. 1. Plus sign means that a given GSE type undergoes a given type of maintenance.

Tab. 1. Elements of set UN and set PN

Item	Serviced equipment	Equipment type – set **U**	Types of maintenance performed on equipment		
			Technical maintenance (p=1)	Overhau l (p=2)	Overhaul with extension of service life (p=3)
1	Ground power unit	LUZES V/D (u=1)	+	+	+
2	Ground power unit	LUZES V/N (u=2)	+	+	+
3	Ground power unit	LUZES II/M (u=3)	+	+	+
4	Ground power unit	LUZES III/M (u=4)	+	+	+
5	Ground power unit	LZE 6/M (u=5)	+	+	+
6	Hydraulic power unit	LZH/N (u=6)	+	+	+
7	Oxygen distributor	LDT/N (u=7)	+	+	+
9	Nitrogen distributor	LDA/N (u=9)	+	+	+
11	Air distributor	LDP/N (u=11)	+	+	+
12	Air compressor	LSP/N (u=12)	+	+	
13	Oxygen gasification unit	LGT/N (u=13)	+	+	+
14	Nitrogen gasification unit	LGA/N (u=14)	+	+	+

The set of maintenance types is a three-element set:

$$P_N = \{p: \quad p \in \{1, 2, 3\}\}, \tag{11}$$

where:
p=1 – corresponds to technical maintenance,
p=2 – corresponds to overhaul,
p=3 – corresponds to maintenance which aim is to extend the service life.

Table 2 presents locations of individual serviced GSE and the number of GSE items in a given military unit/ airfield.

Taking into account the GSE locations (airfields) listed in Tab. 2, set of airfield numbers A_N can be mathematically expressed as $A_N = \{1,2,3,4,5,6,7,8,9,10,11,12\}$, whereas – for instance – the set of GSE items present on airfield No. 1 (Minsk Mazowiecki) can be expressed as: $U_N(1) = \{1,2,3,4,5,6,7,8,9,10,11,12\}$.

Such ordered records can be used directly by the GSE maintenance system model, which will enable an effective and rational utilization of GSE items, including performance of necessary technical maintenance.

Tab. 2. List of GSE items at individual airfields

Item	Location of serviced GSE items A	List of GSE items at individual airfields											
		u=1	u=2	u=3	u=4	u=5	u=6	u=7	u=8	u=9	u=10	u=11	u=12
1	Minsk Mazowiecki	3	2	13	1	24	2	2	2	2	2	1	1
2	Malbork	3	1	5	1	7	2	1		1	2		
3	Babie Doły	4	2	1		11	3	1			3		
4	Bydgoszcz	1				1	1						
5	Darłowo - Siemierowice	2	1	3			1				2		
6	Świdwin	2	1	16	1	8	1	1		2	1		1
7	Mirosławiec	1		18	1	14	1						
8	Poznan	12		2		4		1	2		1		1
9	Łask	8				1		2			1		1
10	Powidz	7	1	2		1	3	2	2	2		1	
11	Leźnica Wielka	1	1	2		2	1				1		
12	Pruszcz Gdanski		1			2	1				1		
13	Inowrocław	4		1		4	2	1		1	1		
14	Warszawa	10		6		5	2				1		
15	Krakow	14		1		2	1	1					
16	Deblin	9	3	1		3	2	1		2	1	1	
17	Radom	2	4	2		5		1	1	1			
18	Nowy Glinnik	1	1	1		2				1	1		

4. Conclusions

A dynamic growth of air transport, both civil and military, generates an increased demand for aircraft technical maintenance services. Such maintenance should be performed not only professionally, but also quickly and inexpensively. Consequently, the aircraft ground support equipment (GSE) should be in good working order and have a sufficient reserve of service life.

Therefore, a correct organization of GSE maintenance becomes a crucial issue with two different goals: reduce the GSE operating costs, and prevent unexpected failures. Keeping the GSE at airfields of Armed Forces of the Republic of Poland in good working order and on the outsourcing principles makes it necessary for contractors to have adequate resources in order to fulfil this task.

The proposed formal notation of the optimization task of technical maintenance system for aircraft ground support equipment accounts for actual system parameters. Application of the proposed model allows making correct decisions in terms of choice of parameters, which characterize the GSE maintenance system used by the contractor.

The values obtained from solution of this optimization task can be an element, which supports the decision-making process in terms of expanding the available contractor's resources at specific forecasts of increased demand for contractor's services.

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