FUNCTIONAL ANALYSIS OF A SELECTED AIRPORT'S SYSTEM

ANALIZA FUNKCJONALNA WYBRANEGO SYSTEMU PORTU LOTNICZEGO

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Abstract: *In this paper two selected airport's systems (Flight Information System and Public Address Voice Annunciation) are defined and described. Then they are used to create an integrated unit, with the presentation of its way of functioning and a schematic picture. The author names main purposes of the integration process, serving to counteract negative consequences arising from implementation of the increasing number of systems on transport objects. In the following part of the article functional analysis of the integrated unit is carried out, defining system's possible states of work and relations between them. Utilization of mathematical apparatus allows to calculate probabilities of system staying in the respective states, as well as system's time indexes. Presented results are a fundament for the further analysis of this matter.*

Keywords: *functional analysis, integration, airport*

Streszczenie: *W artykule zdefiniowano i opisano dwa wybrane systemy portu lotniczego (System Informacji Lotniczej oraz Dźwiękowy System Ostrzegawczy), a następnie stworzono z nich jednostkę zintegrowaną, przedstawiając jej sposób funkcjonowania oraz rysunek poglądowy. Ponadto zaprezentowano główne cele procesu integracji, służącego przeciwdziałaniu negatywnym konsekwencjom instalowania coraz większej liczby systemów w obiektach transportowych. W dalszej części artykułu przeprowadzono analizę funkcjonalną systemu zintegrowanego, nazywając stany w jakich może on przebywać oraz zachodzące między nimi relacje. Wykorzystanie aparatu matematycznego pozwoliło określić prawdopodobieństwa pozostawania systemu w zdefiniowanych stanach oraz wyznaczyć wybrane wskaźniki czasowe. Przeprowadzone rozważania stanowią podstawę do dalszej analizy tego problemu.*

Słowa kluczowe: *analiza funkcjonalna, integracja, port lotniczy*

1. Introduction

Transport systems belong to our country's critical structure according to [7]. This undoubtedly proves their great importance, as properly functioning transportation (ie, the movement of people and goods in space using the appropriate means of transport) is the foundation of today's economy. We can notice an increase in population movement both for professional and private reasons. Unfortunately, an increase in transport objects threats (both mobile and stationary), resulting from acts of nature and even more frequently man (terrorist attacks) can also be noticed. The natural way to solve this problem is thus implementation of systems ensuring safety of people and objects. Increasing the number of operating subsystems, and what follows the number of physical elements and algorithms working, can cause problems with their service and maintenance of proper functionality and reliability. As renouncement of safety systems implementation is not taken into account, it is necessary to increase probability of systems' staying in the state of full functionality even in highly complex and large-scale structures, while trying to limit the unnecessary repetitions of the same information and the same algorithms (working out of the same output) in a number of subsystems as well as unifying data definitions.

In transport infrastructure element that is used in this article – at the airport, it is possible to identify a number of low-voltage systems, assuring the appropriate level of security to people, cargoes and aviation infrastructure. Basing on an unit consisting of two such subsystems, functional analysis will be presented, allowing calculation of number of indexes and determination of probability of system staying in the full functionality state.

2. Selected airport's systems

The main objective of airport's operation is to handle aircrafts' and passengers' traffic flows. Let's focus on passengers' services in airport's passengers' terminal. A number of electronic systems such as: Fire Alarm System (FAS), Intrusion Alert System (IAS), Close Circuit Television (CCTV), Flight Information System (FIS) or Public Address Voice Annunciation (PAVA), is to be installed there. In our considerations let's focus on the last two systems.

Flight Information System – FIS (pol. System Informacji Lotniczej) is a central data base based system that allows collection, maintenance and presentation of flights' data.

The main tasks of the Flight Information System's are already defined in its definition - the collection, maintenance and presentation of flights' data. A more detailed definition of its tasks is outlined below:

- collection of data, concerning flights, such as arrivals and departures timetables (including: flight number, time of arrival/departure, airport of destination, type of aircraft, airlines, the number of passengers + crew), delays of flights according to the timetable,

- collection of data related to the airport's architecture and the organization of elementary operations of travellers' services at the airport's passenger terminal,
- gathering information on unpredictable and random situations, or events threatening people and environment safety,
- processing of current and historical collected data,
- presentation of the collected information regarding flights (such as: arrivals and departures according to the timetable, real arrivals and departures, delays) through various types of media such as displays, monitors, information boards, websites, telephone centres, voice information systems,
- presentation of data, improving passengers' movement in the airport's passengers' terminal, such as: the current list of check-in desks, the current list of boarding gates, the current list of luggage collection belts,
- presentation to travellers of additional information from security services,
- sharing of the collected data with the operational units, present at the airport: Customs, Boarder Security Service, Airport Security Service, or other,
- forward of the information displayed on airport's monitors and information boards to its website,
- carrying on of the analysis and flight statistics, including, inter alia, number of flights in a time period, number of a selected airline's or selected type of aircraft flights, number of delays with their reasons and duration, etc. in order to support future operation tasks at the airport.

Public Address Voice Annunciation - PAVA (pol. Dźwiękowy System Ostrzegawczy) is a distributed system that allows spreading abroad warnings and sound announcements for safety needs of people present in transport object's space. At the same time it fulfils communication tasks, giving opportunity to broadcast information, create music background and call on people.

The main task of the PAVA System is to broadcast voice statements: of evacuation, fire or warnings received from the Fire Alarm System or induced by an operator. However, it can fulfil other tasks as well. Thus, the detailed list of its tasks is presented below:

- broadcast of warning signals and voice statements for safety needs of people present in transport object's space,
- broadcast of evacuation statements for its efficient execution in case of fire or other dangerous situations,
- presentation to travellers of additional information from security services or organizational information regarding transport object,
- broadcast of data, improving passengers' movement in the airport's passengers' terminal, such as: opening of new check-in desks, boarding gates or luggage collection belts,
- broadcast of statements regarding flight delays according to the timetable,
- recall of passengers to the check-in desks or boarding gates,
- creation of music background, improving object's ambience.

3. Description of integrated system's functioning

Presented FIS and PAVA systems can work independently. In such configuration each of them has its own inputs, outputs [3] and software. From hardware's point of view - each has an independent wiring, central processing unit, maintenance stations and a number of devices (such as monitors, speakers) that serve only to him. However, in order to limit the number of physical elements and operating algorithms, to simplify maintenance structure, without having to repeat the same algorithm (working out of the same outputs) in several subsystems, to unify data definitions or to shorten the response time of individual system's components as a result of having access to additional information, it is worth considering FIS and PAVA subsystems jointly [11].

The very process of integration will be the subject of a separate article, but even, basing on presented systems' definitions, the analysis of the integrated unit (FIS + PAVA) can be taken on.

In such a system the goals and tasks performed by each of the subsystems remain unchanged. Also operating algorithms, particular inputs and outputs (specific to the subsystems) stay unmodified. However in such a configuration the second subsystem has an open access to those data and even if it does not directly use them, it is free to verify them at any time.

On the other hand for both systems it is possible to distinguish a number of common data input and output elements such as: departures/arrivals timetables, delays of the departing/arriving aircrafts, sets of safety statements, etc. In addition, it is possible to point out data worked out by one of the subsystems and subsequently used in the other one (for example actual list of operating luggage collection belts worked out by Flight Information System can be then used in Public Address Voice Annunciation statements). Systems' connection facilitates also work of airport's maintenance crew that oversees operation of both systems from one operator's station with a common interface. The idea of the integrated system's work is shown in Figure 1.

To sum up, relations between both presented systems are wide, so the analysis of the integrated unit seems purposeful. Moreover, it assures achievement of the main systems' integration purposes, presented as follows:

- creation of a new structure with improved characteristics (assuring improved quality),
- limitation of the total number of systems' inputs and outputs, thereby reduction of unnecessary repetitions of the same information,
- creation of a platform for information exchange (in order to increase operation safety),
- synergy obtainment,
- obtainment of an improved operating susceptibility,
- reduction of individual subsystems' response time as a result of the access to additional information,
- standardization of data definitions used in the subsystems.

Fig. 1 Integrated system (FIS + PAVA) – idea of work

4. Integrated system's functional analysis

For a given integrated unit, let us consider the states [1], [4], [10], in which it can stay, and relations between them [5], [6], [8], [9]:

S_{PF} – state of full functionality, intentional state of the system for fulfilling the exploitation tasks; probability of occurrence = $R(t)$,

S_{ZF} – state of functional unreliability; probability of occurrence = $Q_{ZF}(t)$,

S_{NF} – state of partial functionality; probability of occurrence = $Q_{NF}(t)$,

S_{BF} – state of lack of functionality; probability of occurrence = $Q_{BF}(t)$.

Therefore, we discuss a system that as a result of an incorrect response to any of the algorithms contained or the incorrect response of whichever of its inputs or outputs may pass from the state of full functionality S_{PF} to the state of functional unreliability S_{ZF} (with failure rate λ_s). Removal of incorrect response's cause results in system's return to the full functionality state (with failure rate μ_s).

In the case of failure, loss or loss of access to any of the input or output elements as well as failure of any of the implemented algorithms the system passes to the state of partial functionality S_{NF} (with the failure rate λ_{NF}). When the failure is eliminated the system goes back to the full functionality state S_{PF} (with the failure rate μ_{NF}). However, if failure elimination or access restoration are not possible in the expected time, the system may pass from the state of partial functionality S_{NF} to the state of lack of functionality S_{BF} (with the failure rate λ_{BF}). Model of the discussed system is shown in Figure 2.

Fig. 2 Relations in the airport's integrated system (PAVA + FIS)

In figure 2 the dashed line marks passage from the state of lack of functionality S_{BF} to the full functionality state S_{PF} , as such transition is possible and will take place when elimination of (algorithms' or input/output) failure or access restoration will take place, but the repair time will be longer than expected (accepted for S_{NF} state). In this article and its subsequent mathematic analysis, however, the presence of this passage is not considered. This matter will be taken into account in future articles. The probabilities of system's staying in the respective states may be determined by solving the following set of differential Kolmogorov equations:

$$\left. \begin{aligned} R'(t) &= -(\lambda_S + \lambda_{NF})R(t) + \mu_S Q_{ZF}(t) + \mu_{NF} Q_{NF}(t) \\ Q'_{ZF}(t) &= -\mu_S Q_{ZF}(t) + \lambda_S R(t) \\ Q'_{NF}(t) &= -(\lambda_{BF} + \mu_{NF})Q_{NF}(t) + \lambda_{NF} R(t) \\ Q'_{BF}(t) &= \lambda_{BF} Q_{NF}(t) \end{aligned} \right\} \quad (1)$$

Assuming the initial conditions:

$$\begin{aligned} R(0) &= 1 \\ Q_{ZF}(0) &= Q_{NF}(0) = Q_{BF}(0) = 0 \end{aligned} \quad (2)$$

And using the Laplace transformation to the set of equations (1), the following expressions are obtained:

$$\left. \begin{aligned}
 \tilde{R}(s) &= \frac{s^2 + s(\mu_S + \lambda_{BF} + \mu_{NF}) + \mu_S(\lambda_{BF} + \mu_{NF})}{s^3 + s^2(\lambda_S + \lambda_{BF} + \lambda_{NF} + \mu_S + \mu_{NF}) +} \\
 &\quad + s(\lambda_S \lambda_{BF} + \mu_S \lambda_{BF} + \lambda_S \mu_{NF} + \mu_S \lambda_{NF} + \mu_S \mu_{NF} + \lambda_{BF} \lambda_{NF}) + \\
 &\quad + \mu_S \lambda_{BF} \lambda_{NF} \\
 \tilde{Q}_{ZF}(s) &= \frac{s \lambda_S + \lambda_S(\lambda_{BF} + \mu_{NF})}{s^3 + s^2(\lambda_S + \lambda_{BF} + \lambda_{NF} + \mu_S + \mu_{NF}) +} \\
 &\quad + s(\lambda_S \lambda_{BF} + \mu_S \lambda_{BF} + \lambda_S \mu_{NF} + \mu_S \lambda_{NF} + \mu_S \mu_{NF} + \lambda_{BF} \lambda_{NF}) + \\
 &\quad + \mu_S \lambda_{BF} \lambda_{NF} \\
 \tilde{Q}_{NF}(s) &= \frac{\lambda_{NF}(s + \mu_S)}{s^3 + s^2(\lambda_S + \lambda_{BF} + \lambda_{NF} + \mu_S + \mu_{NF}) +} \\
 &\quad + s(\lambda_S \lambda_{BF} + \mu_S \lambda_{BF} + \lambda_S \mu_{NF} + \mu_S \lambda_{NF} + \mu_S \mu_{NF} + \lambda_{BF} \lambda_{NF}) + \\
 &\quad + \mu_S \lambda_{BF} \lambda_{NF} \\
 \tilde{Q}_{BF}(s) &= \frac{\lambda_{BF} \lambda_{NF}(s + \mu_S)}{s^4 + s^3(\lambda_S + \mu_S + \lambda_{BF} + \lambda_{NF} + \mu_{NF}) +} \\
 &\quad + s^2(\lambda_S \lambda_{BF} + \mu_S \lambda_{BF} + \lambda_S \mu_{NF} + \mu_S \lambda_{NF} + \mu_S \mu_{NF} + \lambda_{BF} \lambda_{NF}) + \\
 &\quad + s \mu_S \lambda_{BF} \lambda_{NF}
 \end{aligned} \right\} \quad (3)$$

Assuming also $\lambda_S = \text{const}$, $\lambda_{NF} = \text{const}$, $\lambda_{BF} = \text{const}$, $\mu_S = \text{const}$ and $\mu_{NF} = \text{const}$, it is possible to determine the value of expected time of system's work till the occurrence of lack of functionality state S_{BF} .

$$T_{BF} = \frac{\lambda_S(\lambda_{BF} + \mu_{NF}) + \mu_S(\lambda_{BF} + \lambda_{NF} + \mu_{NF})}{\mu_S \lambda_{BF} \lambda_{NF}} \quad (4)$$

Further mathematical analysis allows determination of other indexes that characterize this system. These are among others: the values of expected time of system's work till the occurrence of respective states, as well as the probabilities of system's staying in the respective states. The calculated values of probabilities and expected time of work for specific physical systems, which means specific airports, enable adjustment of the best solution to the requirements, presented by investor or system's operating personnel.

5. Conclusions

With the growing importance of transport systems in our country, transport objects' safety issues become increasingly important. In order to improve safety of people and goods a variety of electronical systems are installed. In this article two selected systems implemented at airports – Flight Information System (FIS) and Public Address Voice Annunciation (PAVA) are presented and then the purposefulness of

their integration in one unit is briefly justified. For the integrated system (PAVA + FIS) the way of functioning was presented, functional analysis carried out and states in which the system can stay, and relations between them were defined. Use of mathematical apparatus allowed determination of the expected time of system's work till the occurrence of lack of functionality state. At the same time it opens the way to determination of other time and probability indexes that characterize this system (for discussed model). This article is the beginning point for further studies in the field of systems integration and analysis of integrated units compared with the analysis of component subsystems.

6. References

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