ARCHIVES OF TRANSPORT
Volume 47, Issue 3, 2018

ISSN (print): *0866-9546*
e-ISSN (online): *2300-8830*
DOI: *10.5604/01.3001.0012.6505*

PASSENGER LEVEL OF SERVICE ESTIMATION MODEL FOR QUEUING SYSTEMS AT THE AIRPORT

Artur KIERZKOWSKI[1], Tomasz KISIEL[2], Maria PAWLAK[3]

[1, 2, 3] *Wroclaw University of Science and Technology, Faculty of Mechanical Engineering, Wroclaw, Poland*

Contact:
2) tomasz.kisiel@pwr.edu.pl (corresponding author)

Abstract:

This paper presents a model for the management of passenger service operations at airports by the estimation of a global index of the level of service. This paper presents a new approach to the scheduling of resources required to perform passenger service operations at airports. The approach takes into account the index of level of service as a quantitative indicator that can be associated with airport revenues. Taking this index into account makes it possible to create an operating schedule of desks, adapted to the intensity of checking-in passengers, and, as such, to apply dynamic process management. This offers positive aspects, particularly the possibility of improvement of service quality that directly translates into profits generated by the non-aeronautical activity of airports. When talking about level of service, there can be distinguish other important indicators that are considered very often (eg maximum queuing time, space in square meters). In this model, however, they are considered as secondary. Of course, space in square meters is important when designing a system. Here this system is already built and functioning. The concept of the model is the use of a hybrid method: computer simulation (Monte Carlo simulation) with multiple regression. This paper focuses on the presentation of a mathematical model used to determine the level of service index that provides new functionality in the current simulation model, as presented in the authors' previous scientific publications. The mathematical model is based on a multiple regression function, taking into account the significance of individual elementary operations of passenger service at an air terminal.

Key words:
level of service, queuing system, airport, passenger service

To cite this article:

Kierzkowski, A., Kisiel, T., Pawlak, M., 2018. Passenger level of service estimation model for queuing systems at the airport. Archives of Transport, 47(3), 29-38. DOI: https://doi.org/10.5604/01.3001.0012.6505

1. Introduction

Airports are now expected to provide a high level of service (LoS) to various customers. From the passenger's perspective, the most important aspect is not only the provision of a service to reach the destination, but also the level of service. With this in mind, improvement of the level of service at the airport has become a priority. However, the multiplicity of airport services is the reason why the attainment of efficiency of measurements and analyses of passenger perception is not easy. There are methods that facilitate optimisation of the level of service. In practice, however, it is difficult to predict precisely passengers' responses. In order to avoid misinterpretation of a passenger's impressions, Bezerra et al. (2016) proposed two solutions. The first one related to the adaptation of the measurement model for the perception of the level of quality based on a typical service provided in air transport. The other solution was supposed to test the equivalence of the model between different passenger groups. In order to verify correctness of the assumptions, example data obtained a survey conducted in real-system circumstances. The results confirm the soundness of the six-factor structure. The presented model is recognised as an alternative to the multidimensional approach in the context of measuring the performance of an airport with reference to the level of service. This is a very significant approach that justifies the analysis of how a passenger terminal functions within the LoS aspect.

For Correia et al. (Correia and Wirasinghe, 2007; Correia et al., 2008), a general level of service concerning passenger terminals is based on the procedure that consists in the observation of passengers and acquisition of information that may affect passengers' evaluation of the airport. This approach is used to obtain quantitative evaluations based on the survey data, whereas an analysis provides a relationship of quantitative evaluations and global indices. Correia et al. (Correia and Wirasinghe, 2007; Correia et al., 2008) also determine the level of service at terminals based on users' opinions. As a ground for this concept, quantitative values are assigned to individual services with reference to tests conducted at airports. An analysis showed that the most noteworthy influence on the level of service is exerted by the following factors: queuing time, service time and space availability. These are the factors that are vital from the process manager's perspective. Creating the right number of stations and counters to be used to perform individual passenger service operations makes it possible to have a considerable influence on passengers' waiting time in queuing systems. The aim of the paper was to develop a concept model that would be suitable for analysing the influence of the operating schedule planning of service desks in queuing systems on LoS index changes. The study involved computer simulations combined with a mathematical model based on a linear regression and multiple regression models and using the least square method. So far, the research has been focused on the evaluation of the current condition of service systems, whereas this paper is oriented towards predicting forthcoming operations in the aspect of decisions to be made in the process of scheduling of resources.

Addressing this subject is essential in the air transport process. The airport service evaluation report (CAPSE, 2016) concerning Asian airports unambiguously shows that the level of passengers' satisfaction has been clearly decreasing for the last five years. At the same time, there are no analogous reports relating to European airports. The significance of passenger satisfaction resulting in profits generated by non-aeronautical activity of an airport was described in DKMA (2014). It was showed that an evaluation increase by 0.1 on a five-point scale results in an increase in the profits generated by non-aviation activity by USD 0.8 per served passenger. The importance of cost management in air transport has already been written (Jafernik and Sklorz, 2015; Jacyna-Gołda, 2015; Żak, 2004, Koucky, 2007; Vintr, 2007)

Subsequent passenger service operations performed in series are dependent processes (Kierzkowski and Kisiel, 2017, 2018). Thus, an appropriate model can be used to develop an operating schedule so that the global index of passenger evaluation at the airport assumes the highest value possible.

2. Queuing systems at the airport

By adapting the notation applied in Malarski (2006), the passenger service operation can be expressed as a graph adjusted for use in computer simulation modelling. The graph consists of elementary subgraphs that take into account an additional variable, on the basis of which it will be possible to determine a passenger's waiting time in the queue. Hence, each elementary graph relates to a subsequent passenger service operation, taking into account these variables:

- ψ: variable describing random conditions of the instant when the passenger appears for a service operation;
- γ: variable describing random conditions of the time between the operation is started and the tasks included in the operation are finished;
- ξ: variable describing the consequent of the operation.

The passenger service operation may be completed at the airport in different configurations. It depends on the arrangement of individual zones in the air terminal. Particular relevance is given to operations of passport control (ID control) and safety control. For instance, safety control may be performed in a centralised system. If this is the case, the safety control zone is located at the transition between the generally-accessible zone and the departure lounge. At some airports, safety control takes place directly at the entrance to the gate or just in front of the gate. At most regional airports, there is a service operation together with a centralised system as well as passport control that takes place in the departure lounge. In such a case, the departure lounge is divided into the Schengen zone and a non-Schengen zone. Independently of the arrangement of individual elements of the passenger service system, the service operations can be expressed in the form of basic elementary graphs. For further discussion, a system of subsequent operations is assumed; they correspond to the passenger service system performed at an international airport with the IATA code: WRO (variable ξ performed according to the arrangement at Wroclaw Air Port).

The airport performs service operations for passengers who arrive (PP) at or depart (PO) from the airport. As far as POs are concerned, there is a certain set of elementary graphs that represent subsequent passenger service operations. By analogy to Malarski (2006), PO service commences when the passenger appears at the passenger terminal. An elementary graph of the operation can be expressed as follows:

$$G^{we}=(\psi^{we},\gamma^{we},\xi^{we}) \quad (1)$$

where:

ψ^{we} – variable describing random conditions of the instant when the passenger appears at the terminal;

γ^{we} – variable describing random conditions of the duration of operation when the passenger enters the terminal – the variable must assume (here deterministically) a value equal to 0 (G^{we} –graph of an artificial operation);

ξ^{we} – variable describing the consequent of the operation, where:

$$\xi^{we}=\begin{cases}0 & \text{- consequent } G^{wiz}\\ 1 & \text{- consequent } G^{c\text{-}in}\\ 2 & \text{- consequent } G^{kb}\end{cases}$$

G^{we} represents the operation of a passenger entering the terminal – this is not a queuing system. However, a comprehensive approach to passenger service operation G^{we} was implemented demonstratively as an artificial passenger service operation.

In the PO check-in process, there are different check-in methods. However, one may generalise by assuming that this is a binary operation. The passenger checks in at the airport (independently of the method: service station or counter, self-service kiosk, etc.) or the passenger has already completed check-in before arriving at the passenger terminal. For passengers checking in, the operation can be expressed as the following elementary graph:

$$G^{c\text{-}in}=\left(\psi^{c\text{-}in},\gamma^{c\text{-}in},\xi^{c\text{-}in}\right) \quad (2)$$

where:

$\psi^{c\text{-}in}$ – variable describing random conditions at the instant when the passenger appears in the check-in queue;

$\gamma^{c\text{-}in}$ – variable describing random conditions of the duration of the check-in operation;

$\xi^{c\text{-}in}$ – variable describing the consequent of the operation, where

$$\xi^{c\text{-}in}=\begin{cases}0 & \text{- consequent } G^{wiz}\\ 1 & \text{- consequent } G^{kb}\end{cases}$$

For passengers required to hold a visa to be allowed to cross borders, if the connection is within the Schengen Area, a visa control operation must be performed:

$$G^{wiz}=\left(\psi^{wiz},\gamma^{wiz},\xi^{wiz}\right) \quad (3)$$

where:

ψ^{wiz} – variable describing random conditions at the instant when the passenger appears in the visas control operation;
γ^{wiz} – variable describing random conditions of the duration of the visa control operation;
ξ^{wiz} – variable describing the consequent of the operation (the value assumes 0 and is the consequent G^{kb})

The safety control operation is performed for every passenger who starts their journey at a given airport. This is a key element in the system because passengers service streams of all flights combine. The safety control operation can be expressed as the following elementary graph:

$$G^{kb}=\left(\psi^{kb},\gamma^{kb},\xi^{kb}\right) \tag{4}$$

where:
ψ^{kb} – variable describing random conditions at the instant when the passenger appears in the safety control operation;
γ^{kb} – variable describing random conditions of the duration of the safety control operation;
ξ^{kb} – variable describing the consequent of the operation, where

$$\xi^{kb}=\begin{cases}0 & \text{- consequent } G^{kp} \\ 1 & \text{- consequent } G^{b}\end{cases}$$

The passengers travelling to countries outside the Schengen Area must pass ID control in order to be allowed to cross borders. The passport control operation can be expressed as the following elementary graph:

$$G^{kp}=\left(\psi^{kp},\gamma^{kp},\xi^{kp}\right) \tag{5}$$

where:
ψ^{kp} – variable describing random conditions at the instant when the passenger appears in the passport control operation;
γ^{kp} – variable describing random conditions of the duration of the passport control operation;
ξ^{kp} – variable describing the consequent of the operation (the value assumes 0 and is the consequent G^{b})

The last operation performed for a PO is boarding; this operation completes the passenger service at the air terminal. At airports, there are three basic boarding methods applied. The main method means that passengers board the plane parked on the apron. Another method involves transporting passengers from the air terminal by transfer bus. In the third method, passengers access the plane directly by walking through a jet bridge. The passenger boarding operation may also be approached as a queuing system due to the fact that the operation begins with checking boarding pass and the passenger waits in the queue until the operation is commenced. The analysis will involve the moment when the passenger appears in the queue and the total boarding time (after commencing the boarding pass control). In such a case, the passenger boarding operation can be expressed as the following elementary graph:

$$G^{b}=\left(\psi^{b},\gamma^{b},\xi^{b}\right) \tag{6}$$

where:
ψ^{b} – variable describing random conditions at the instant when the passenger appears in the operation of boarding pass control;
γ^{b} – variable describing random conditions of the duration of the passenger boarding the plane;
ξ^{b} – variable describing the consequent of the operation (the value assumes 0 and means exit from the system).

It is possible to distinguish an analogous set of elementary graphs for PPs. However, one must bear in mind that the airport can also handle transit passengers (PT) as well as transfer passengers (PTR). The PT and PTR transport includes intermediate landing, which means that the passenger arrives at an airport and departs from the airport while still boarded on the same plane. For PTRs, there is a change of the plane. For PPs, PTs and PTRs, a general elementary graph of process commencement (arrival at the airport) can be expressed. The moment when the plane stops on the apron is used as entrance into the system. The system entrance event can also be recognised as a queuing system. The queuing time can mean the period from the moment when the plane stops on the apron to the moment when the passenger leaves the plane. Next, the passenger system entrance operation means the time the passenger needs to walk to the passenger terminal. In this case, methods analogous to the passenger boarding operation are applied. For POs, PTs and PTRs, the entrance operation can be expressed as the following elementary graph:

$$G^{p}=(\psi^{p},\gamma^{p},\xi^{p}) \tag{7}$$

where:
ψ^{p} – random moment when the plane stops on the apron.
γ^{p} – variable describing random conditions of the duration when the passenger leaves the plane and walks to the passenger terminal;
ξ^{p} – variable describing the consequent of the operation, where

$$\xi^{p}=\begin{cases} 0 & \text{- end of process (PP)} \\ 1 & \text{- consequent } G^{kpp} \text{ (PP, PTR)} \\ 2 & \text{- consequent } G^{ob} \text{ (PP)} \\ 3 & \text{- consequent } G^{kb} \text{ (PTR)} \\ 4 & \text{- consequent } G^{b} \text{ (PT)} \end{cases}$$

Upon entrance to the terminal, PPs travelling within the Schengen Area may leave and finish the passenger service operation. If the passenger travels with hold baggage, the passenger appears the queueing system to reclaim their baggage. On arrival, PPs and PTRs travelling within the non-Schengen Area undergo passport control. The PTRs travelling within the Schengen Area go through safety control. It is assumed that the PTRs who leave the terminal and return to the terminal to continue their journey are sequentially recognised as PP and PO. The PTs stay at the departure lounge, and hence they perform the boarding operation.
The elementary graph of the passport control operation on arrival will be analogous to the operation used for POs, but with a different variable ξ:

$$G^{kpp}=\left(\psi^{kpp},\gamma^{kpp},\xi^{kpp}\right) \tag{8}$$

whereψ^{kpp} – variable describing random conditions at the instant when the passenger appears in the passport control operation;
γ^{kpp} – variable describing random conditions of the duration of the passport control operation;
ξ^{kpp} – variable describing the consequent of the operation, where

$$\xi^{kpp}=\begin{cases} 0 & \text{- end of process (PP)} \\ 1 & \text{- consequent } G^{ob} \text{ (PP)} \\ 2 & \text{- consequent } G^{kb} \text{ (PTR)} \end{cases}$$

It is also assumed that the baggage reclaim operation will be expressed by means of the queuing system, where the passenger approaches the baggage reclaim station to wait for their baggage. The baggage reclaim operation can be described by the following elementary graph:

$$G^{ob}=\left(\psi^{ob},\gamma^{ob},\xi^{ob}\right) \tag{9}$$

whereψ^{kpp} – variable describing random conditions at the instant when the passenger appears the baggage system;
γ^{kpp} – variable describing random conditions of the duration of the baggage reclaim operation;
ξ^{kpp} – variable describing the consequent of the operation (the value assumed 0 and means exit from the system).

By analysing the values assumed by subsequent variables ξ, it is possible to develop a diagram of passenger service at an airport Earlier in the paper, it was mentioned that the passenger service operation was presented for Wroclaw Airport, and thus the diagram of that operation is shown in Fig. 1.
The POs, PPs, PTs and PTRs have different passenger service operation graphs that may be expressed by a superposition of elementary subgraphs (10-14).

$$G_{PO}(\Psi,\Gamma,\Xi)=\begin{pmatrix} G^{we}\left(\psi^{we},\gamma^{we},\xi^{we}\right), \\ G^{c\text{-}in}\left(\psi^{c\text{-}in},\gamma^{c\text{-}in},\xi^{c\text{-}in}\right), \\ G^{wiz}\left(\psi^{wiz},\gamma^{wiz},\xi^{wiz}\right), \\ G^{kb}\left(\psi^{kb},\gamma^{kb},\xi^{kb}\right), \\ G^{kp}\left(\psi^{kp},\gamma^{kp},\xi^{kp}\right), \\ G^{b}\left(\psi^{b},\gamma^{b},\xi^{b}\right) \end{pmatrix} \tag{10}$$

$$G_{PP}(\Psi,\Gamma,\Xi)=\begin{pmatrix} G^{p}\left(\psi^{p},\gamma^{p},\xi^{p}\right), \\ G^{kpp}\left(\psi^{kpp},\gamma^{kpp},\xi^{kpp}\right), \\ G^{ob}\left(\psi^{ob},\gamma^{ob},\xi^{ob}\right) \end{pmatrix} \tag{11}$$

$$G_{PTR}(\Psi,\Gamma,\Xi)=\begin{pmatrix} G^{p}\left(\psi^{p},\gamma^{p},\xi^{p}\right), \\ G^{kpp}\left(\psi^{kpp},\gamma^{kpp},\xi^{kpp}\right), \\ G^{kb}\left(\psi^{kb},\gamma^{kb},\xi^{kb}\right), \\ G^{kp}\left(\psi^{kp},\gamma^{kp},\xi^{kp}\right), \\ G^{b}\left(\psi^{b},\gamma^{b},\xi^{b}\right) \end{pmatrix} \tag{12}$$

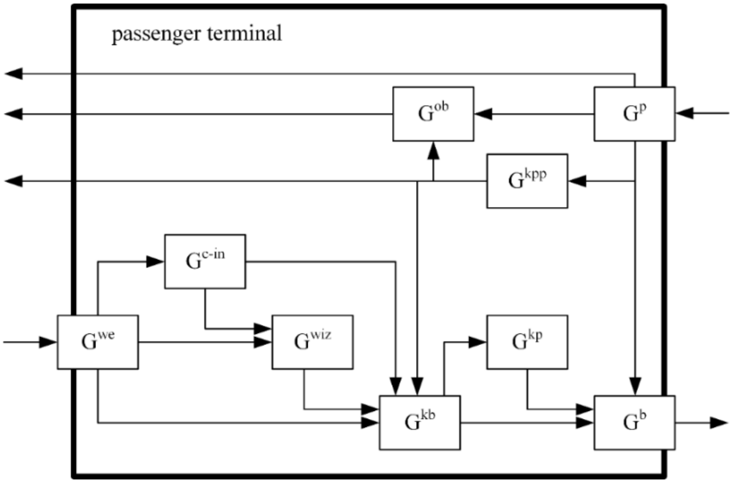

Fig. 1. Diagram of passenger service operation at WRO

$$G_{PTRZ}(\Psi,\Gamma,\Xi)=\begin{pmatrix} G^{p}\left(\psi^{p},\gamma^{p},\xi^{p}\right), \\ G^{b}\left(\psi^{b},\gamma^{b},\xi^{b}\right) \end{pmatrix} \tag{13}$$

In order to minimise the number of possible graphs of passenger service operations, the presented graphs (10-13) assume that the passenger performs all subsequent elementary operations. For passengers whose service excludes individual elementary operations, the variables ψ and γ will not be assigned and such operations will be rejected.

3. Model of LoS evaluation at the airport

The objective of this paper is to design a model that will provide logistic support in the management of passenger service operations at the airport. A concept model is shown in Fig. 2. An assumption of the model is to determine the value of the LoS index in relation to operating scheduling of individual stations and counters where individual operations are performed and with selected passenger service operation methods. The concept is that the user enters the flight timetable and resources he plans to allocate to the service. The model also identifies passenger structures that describe each flight. In response, the user gets a quantitative rating of the system by the passenger.

It is essential to define profiles for those passengers with access to different terminal zones and those who differ in experience and the purpose of air travelling. Based on the knowledge gained by the experts employed at the airport and the available literature (Caves and Pickard, 2000, de Barros et al., 2007; Hongwei and Yauha, 2016; Martel and Senevirante, 1990), the following division of passengers into groups is proposed: PP, PO, PTR, PTRZ – divided by the type of travel: business (B), holiday (H) and migration (M). Thus, the set of passengers to be analysed will include of subsequent subsets of passenger groups:

$$P = PP^{B}, PP^{L}, PP^{M}, PO^{B}, PO^{L}, PO^{M}, PTR^{B}, \\ PTR^{L}, PTR^{M}, PTRZ^{B}, PTRZ^{L}, PTRZ^{M} \tag{14}$$

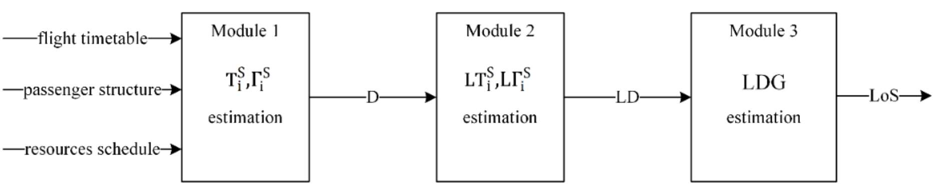

Fig. 2. LoS evaluation model

To simplify further discussion of the concept, the notation will be reduced to the symbol S that may assume subsequent values of integers 1,2,3…, 12. Whenever it is said that a passenger is included in group S=1, this means passenger membership in group PP^B.
Every subsequent passenger P_i (where the subscript *i* means the number of the subsequent passenger) will be assigned to a group of attributes (set of variables):

$$P_i = \langle S, \Psi_i^S, \Gamma_i^S \rangle \tag{15}$$

where:
S – variable describing membership in a group;
$\Psi_i^S = \langle \psi^{we}{}_i^S, \psi^{c\text{-}in}{}_i^S, \ldots \rangle$ – set of instances when the passenger appears in subsequent elementary operations to be performed;
$\Gamma_i^S = \langle \gamma^{we}{}_i^S, \gamma^{c\text{-}in}{}_i^S, \ldots \rangle$ – set of service times for subsequent elementary operations to be performed for the passenger.

As presented in Chapter 2, the graphs of passenger service operations make it possible to design a mesoscopic simulation model (Module 1, Fig. 2) with an aim to determine individual waiting times and service times for each passenger in each elementary operation. Since this paper continues the authors' current research, the design and functioning of the simulation model was discussed in detail in the authors' other publications (Kierzkowski and Kisiel, 2017a, 2017b). In the following text, the authors will focus on the presentation of a new model functionality – determination of the value of the LoS index (Module 2 and 3, Fig. 2). The presented version of an expanded model assumes that the user enters input data (flight timetable, operating schedule of service stations and counters, methods used to perform elementary operations and the number of passengers in flights with a division into percentage shares in individual groups S. Based on the completed tests on a real system, the simulation model must be equipped with the estimated functions of random variables suitable to determine ψ, γ and probability that the variables ξ will assume individual values. Based on the instant of appearance, service times of subsequent passengers and available service stations, the aim is to determine waiting times in the queue for all passengers that perform a given elementary operation. A completed computer simulation provides a set of data:

$$D = \langle T_i^S, \Gamma_i^S \rangle \tag{16}$$

where
$T_i^S = \langle \tau^{we}{}_{i=1}^S, \ldots, \tau^{we}{}_{i=n}^S ; \tau^{c\text{-}in}{}_{i=1}^S, \ldots, \tau^{c\text{-}in}{}_{i=n}^S ; \ldots \rangle$ – set of waiting times for subsequent *i* passengers before all subsequent elementary operations are performed for each passenger (noted membership in the set *S*);
$\Gamma_i^S = \langle \gamma^{we}{}_{i=1}^S, \ldots, \gamma^{we}{}_{i=n}^S ; \gamma^{c\text{-}in}{}_{i=1}^S, \ldots, \gamma^{c\text{-}in}{}_{i=n}^S, \ldots \rangle$ – set of service times for subsequent *i* passengers for all subsequent elementary operations performed for each passenger (noted membership in the set *S*).

In the obtained data set, it is necessary to discard variables relating to operation of the elementary graph G^{we}; this is required due to the already mentioned fact that the graph represents an artificial operation that is not recognised as a queueing system and no evaluation by passengers will be made. Based on the reduced data set (16), one must compute values of LoS indices for each element in the data set (16) (Module 2, Fig. 2). For this purpose, the method proposed by Anderson et al. (2008) can be applied. It consists of the following stages:

A. The survey conducted among passengers, relating to quantitative evaluation of subsequent elementary operations with simultaneous acquisition of data relating to times of operation performance and queuing times;
B. Estimating the regression function for variables τ, γ in all elementary operations;
C. Determining the value of LoS indices for data set D.

The method of this procedure applied during tests on a real system is presented in the publication Anderson et al. (2008). It also describes an algorithm and a mathematical model used for statistical inference, as described in section B, C.
Completed inference (Module 2, Fig. 2) returns a set of data relating to individual estimated evaluations of elementary operations for each passenger, in accordance with the following notation:

$$LD = \langle LT_i^S, L\Gamma_i^S \rangle \tag{17}$$

where:
$LT_i^S = \langle l\tau^{c\text{-}in\,S}_{i=1}, \dots, l\tau^{c\text{-}in\,S}_{i=n}; \dots; l\tau^{wiz\,S}_{i=1}, \dots, l\tau^{wiz\,S}_{i=n}; \dots \rangle$ – set of evaluations of waiting times for subsequent *i* passengers before all subsequent elementary operations are performed for each passenger (noted membership in the set S);
$L\Gamma_i^S = \langle l\gamma^{c\text{-}in\,S}_{i=1}, \dots, l\gamma^{c\text{-}in\,S}_{i=n}; \dots; l\gamma^{wiz\,S}_{i=1}, \dots, l\gamma^{wiz\,S}_{i=n}; \dots \rangle$ – set of evaluations of service times for subsequent *i* passengers for all subsequent elementary operations performed for each passenger (noted membership in the set S).

Another step is to determine a set of estimated global evaluations of passenger service operations at the airport (Module 3, Fig. 2):

$$LDG = \langle LDG^S_{i=1}, \dots, LDG^S_{i=n} \rangle \tag{18}$$

where:
LDG_i^S – global evaluation for the *i-th* passenger, with memberships in the group S;

A universal notation used to determine the LDG indices can be expressed using multiple regression:

$$LDG_i^S = w_0 + \sum_{j=1}^{m} w\tau_j{}^S \cdot l\tau^{j\,S}_i + \sum_{j=1}^{m} w\gamma_j{}^S \cdot l\gamma^{j\,S}_i \tag{19}$$

where:
LDG_i^S – independent variable expressing the predicted system evaluation given by the *i-th* passenger, included in the group S,
w_0 – fixed term;
j – index of a subsequent operation name, where (1 – c-kin, 2 – wiz, …)
$w\tau_j{}^S, w\gamma_j{}^S$ – weights assigned to evaluations of waiting time and completion time of the operation *j*, for group S;
$l\tau^{j\,S}_i, l\gamma^{j\,S}_i$ – evaluations given by the *i-th* passenger from the group S, as regards waiting time and duration of the operation *j*.

The dependent variable is the estimated evaluation that the passenger would give under specific conditions of waiting and performance of subsequent elementary operations (predictors). Multi-attribute evaluation taking into account several predictors, relating to the determination of indices LDG_i^S, requires that significance of individual elementary operations should be considered. In order to determine the values of individual weights and the fixed term, it is possible to apply various methods as follows: AHP (Analytic Hierarchy Process) (Saaty, 1978), ANP (Analytic Network Process) (Khan and Faisal, 2008) and LS (least squares) (Kisiel et al., 2013).

$$LoS = \langle LoS^{S=1}, \dots, LoS^{S=12} \rangle \tag{20}$$

where LoS – set of global evaluations;
LoS^S – global evaluation of the LoS index for the passenger group S.

$$LoS^S = \frac{1}{p} \cdot \sum_{k=1}^{p} LDG_k^S \tag{21}$$

where LoS^S – global evaluation of LoS for the passenger group S;
LDG_k^S – another evaluation *k* from the set (18), included in the group S.

The proposed method at the output of module 3 (Fig. 2) returns a set of global evaluations (20) for each passenger group S. The global evaluations in individual groups are determined based on the arithmetic mean of the partial evaluations made by subsequent passengers (21).

4. Discussion

In the presented work, a model was proposed that can be used as complementary to the standards specified by IATA. IATA presents a qualitative LoS rating indicator, which allows to classify a given airport to a specific category. This model, however, is useful in practical process management. It allows you to evaluate various scenarios for the implementation of the process knowing the flight plan and the amount of available resources. In this way, you can find the best system configuration. Analyzes can be carried out for any time periods and any boundary conditions assumed by process managers.
When talking about LoS, there can be distinguish other important indicators that are considered very often (eg maximum queuing time, space in square meters). In this model, however, they are considered as secondary. Of course, space in square meters is

important when designing a system. Here this system is already built and functioning. If we have limited available resources, then longer waiting in check-in and shorter in security checkpoint may be more beneficial or some other configurations. This model looks globally at passenger satisfaction.
However, the disadvantage still remains the introduction of input data on the stream of notifications and service times, as well as the verification of such a model.

5. Conclusions

This paper presents a new approach to the scheduling of resources required to perform passenger service operations at airports. The approach takes into account the index of level of service. The presented evaluation model for the system assumes that the user is required to enter data such as flight timetable, passenger structure and operating schedule of the stations and counters dedicated to individual operations. Necessary calculations require tests on a real system to use the regression and multiple regression methods as well as a simulation model that has been described in the author's other scientific publications.
The application of the proposed approach may result in direct benefits for airports given by increased profits generated by non-aeronautical activity. Bearing in mind the level of service, it is possible to forecast streams of passenger relocations within the terminal and adapt the working schedule of technical resources in individual operations so that the highest possible evaluation indicator of service quality can be achieved. This will translate into waiting time in queueing systems reduced to a minimum and increased revenues generated by non-aviation activity. Such an approach also makes it possible to apply dynamic management by changing the number of available technical resources in the function of time in subsequent elementary operations.
The proposed method assumes the use of linear regression whose suitability of application was analysed in scientific publications presented in references to this paper. Nevertheless, the next stage of the research will involve verification of the model based on real data and extension of the model to be able to apply fuzzy inference.

References

[1] ANDERSON, R., CORREIAA, A.R., WIRASINGHE, S.C. DE BARROS, A.G., 2008. Overall level of service measures for airport passenger terminals. Transportation Research Part A: Policy and Practice, 42(2), 330-346.
[2] BEZERRA, G.C.L, GOMES, C.F., 2016. Measuring airport service quality: A multidimensional approach. Journal of Air Transport Management, 53(2016), 85-93.
[3] CAPSE, 2016. Airport service evaluation report, 2016.
[4] CAVES, R.E., PICKARD, C.D., 2000. The satisfaction of human needs in airport passenger terminals. Transport, 147(1), 9-15.
[5] CORREIA, A.R., WIRASINGHE, S.C., 2007, Development of level of service standards for airport facilities: Application to Sao Paulo International Airport. Journal of Air Transport Management, 13, 97–103.
[6] CORREIA, A.R., WIRASINGHE, S.C., DE BARROS A.G., 2008, Overall level of service measures for airport passenger terminals. Transportation Research Part A, 42, 330–346.
[7] DE BARROS, A.G., SOMASUNDARASWARAN, A.K., WIRASINGHE S.C., 2007. Evaluation of level of service for transfer passengers at airports. Journal of Air Transport Management, 13(5), 293–298.
[8] DKMA, 2014, Four steps to a great passenger experience (without rebuilding the terminal), DKMA.
[9] HONGWEI, J., YAHUA, Z., 2016. An investigation of service quality, customer satisfaction and loyalty in China's airline market. Journal of Air Transport Management, 57, 80-88.
[10] JACYNA-GOŁDA I., 2015. Decision-making model for supporting supply chain efficiency evaluation. Archives of Transport, 33(1), 17-31, DOI: 10.5604/08669546.1160923.
[11] JAFERNIK, H., SKLORZ, R. 2015. Initiatives to reduce fuel consumption and CO2 emissions during ground operations. Scientific Journal of Silesian University of Technology. Series Transport. 2015, 89, 47-55, DOI: 10.20858/sjsutst.2015.89.5.

[12] KHAN, S, FAISAL, M.N., 2008. An analytic network process model for municipal solid waste disposal options. Management Waste Management, 28(9), 1500-1509.

[13] KIERZKOWSKI, A., KISIEL, T., 2017. A model of check-in system management to reduce the security checkpoint variability. Simulation Modelling Practice and Theory, 74, 80-98.

[14] KIERZKOWSKI, A., KISIEL, T., 2017. Simulation model of security control system functioning: A case study of the Wroclaw Airport terminal. Journal of Air Transport Management Part B, 64, 173-185.

[15] KISIEL, T., VALIS, D., ZAK, L., 2013. Application of regression function - two areas for technical system operation assessment, Carpathian Logistics Congress, CLC' 2013: Cracow, Poland, December 9th-11th 2013, Tanger: 1-9.

[16] KOUCKY, M., VALIS, D., 2007. Reliability of sequential systems with a restricted number of renewals, Risk, Reliability and Societal Safety, Vols 1-3, Taylor & Francis: 1845-1849

[17] MALARSKI, M., 2006. Inżynieria Ruchu Lotniczego, Oficyna Wydawnicza Politechniki Warszawskiej

[18] MARTEL, N., SENEVIRATNE, P.N., 1990. Analysis of factors influencing quality of service in passenger terminal buildings. Transportation Research Record 1273, TRB, National Research Council, Washington, DC.

[19] SAATY, T., L., 1978. Exploring the interface between hierarchies, multiple objectives and fuzzy sets. Fuzzy Sets and Systems, 1(1), 57-68.

[20] VINTR, Z., VALIS, D., 2007. Modeling and Analysis of the Reliability of Systems with One-shot Items. 2007 Annual Reliability and Maintainability Symposium, Orlando: 380-385, doi: 10.1109/RAMS.2007.328106

[21] ŻAK, J. 2004. Identification of the most important road transportation decision problems. Archives of Transport, 16(2), 89-109.