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MATHEMATICAL MODEL FOR OPTIMIZING CHECK-IN DELAYS AT THE AIRPORT

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Check-in at the airport is an important aspect of air travel that can have a significant impact on the overall passenger experience. Long queues and delays at check-in counters can lead to frustration and dissatisfaction among passengers. Therefore, it is crucial to optimize the check-in service to minimize waiting time and increase overall passenger satisfaction.

The main goal of airport businesses is to minimize the costs associated with resources to maintain a fixed level of service. This can be accomplished by determining the minimum number of check-in counters that must be open during a given period of time to ensure service coverage. By opening more counters during peak hours and closing them when the demand for services decreases. The efficiency and effectiveness of service can be increased by balancing the workload between desks and employees. The proposed mathematical model aims to determine the minimum number of check-in desks that should be open during a certain period of time to ensure service coverage.

To build a mathematical model to represent the airport check-in process, let's look at the main problems we face in this process.

The time horizon *T* (generally equal to a day) has been divided in intervals with constant width *t.* All the parameters and variables of the problem are referred to each interval *t*. Demand for check-in services can be expressed in terms of the number of passengers arriving at check-in desks. The uncertainty in passenger behavior does not allow us to predict the exact distribution of arrivals at each desk during the check-in time. It can be seen that there will be intervals characterized by peaks in arrivals and intervals with low demand for services. However, to simplify the task, you can predict the arrivals at the check-in desk by analyzing historical data. The service time at the desk is the time required to process and receive a passenger. This throughput was assumed to be the same for each desk, and the value was calculated based on the analysis of queue and arrival statistics. A reasonable value is 1.5 minutes per passenger. The inverse value can be equal to the capacity of the desk. The cost of opening a desk is the amount of money needed to pay employees and other operating expenses required to keep the desk open. If this value is zero, it means that the number of employees working during a certain time interval t is fixed and there is no marginal cost of opening a desk.

The mathematical model of constraints to represent the airport check-in process is as follows:

$$min!\ \ z = \sum_j \sum_t (h_j I_{jt} + s_j x_{jt}), \quad j = 1,..,J,\ t = 1,..,N, \tag{1}$$

$$I_{jt} = I_{j(t-1)} + d_{jt} - q_{jt}, \quad j = 1,..,J,\ t = 1,..,N, \tag{2}$$

$$P_j q_{jt} \le C_t x_{jt}, \quad j = 1,..,J,\ t = 1,..,N, \tag{3}$$

$$P_j q_{jt} \le C_t, \quad j = 1,..,J,\ t = 1,..,N, \tag{4}$$

$$I_{jt} = 0, \quad j = 1,..,J,\ t = 1,..,N,\ t \text{ in } T_j . \tag{5}$$

$$q_{jt}, I_{jt} \geq 0, \qquad j = 1,..,J,\ t = 1,..,N, \tag{6}$$

$$x_{jt} = 0/1 \qquad j = 1,..,J,\ t = 1,..,N, \tag{7}$$

In these formulas, we use such quantities: T time window (usually a day); t - index of the single time interval; j - index of the single flight; N - number of intervals ($N=T/l$); J - number of flights scheduled in T; P_i- average desk service time for flight j; h_j - cost associated with the queue related to flight j; d_{jt} - service demand from passengers of the flight j in the time interval t; C_t - available check-in time based on active desks in the time interval t; I_{j0} - number of passengers of flight j waiting before desk opening; T_j- for each flight j, the set of the time intervals in which it is not possible to activate check-in desks; l - length of the considered time interval (usually 5 mins); q_{jt}- number of passengers of the flights j to be accepted in the period t; x_{jt} - variable representing the possibility of checking-in passengers for the flight j in the interval t (if x_{jt}= 1) or not (if x_{jt}= 0); I_{jt} - number of passengers in a queue for flight j at the end of the period t.

The total cost that have be minimized, consists of two components: the cost of keeping the queue and the cost of opening the desk. Constraint (2) represent the relationships linking the queues of passengers of a given flight from two consecutive time intervals. In practice, at the end of each time interval, the queue for flight j is equal to the sum of the queue from the previous interval plus the number of passengers of flight j who arrived at the desk during that interval and minus the number of passengers who were accepted during the same interval. Constraint (3) expresses that passengers from flight j can be served in time interval t if and only if the check-in desk is open; these constraints also express the maximum number of passengers that can be checked in on the basis of the desk capacity Constraint (4) express the global capacity. Constraint (5) indicates that all passengers of flight j must be checked in before the check-in desk closes for that flight.

The objective function (1) represents the minimization of the total cost as sum of the opening cost of the desks and of the queue costs. The rest of the constraints derive from the physical meaning of the introduced variables. In this way, the model (1)-(7) becomes perfectly equivalent to a very common formulation of the well known multi-item Capacitated Lot Sizing problem, which is known to be NP-hard when capacity is not constant.

Conclusion:

The proposed model was tested at Naples International Airport in Italy. Optimality was always achieved in a very limited computation time (less than 15 seconds). The results show that the model is suitable for solving real-world examples, but further research and development is needed to address practical operational constraints such as the physical location of the table and the maximum queue length.

References:

1. Bruno G., Genovese A. *A Mathematical Model for the Optimization of the Airport Check-In Service Problem*, Electronic Notes in Discrete Mathematics 36 (2010) 703–710
2. Kuppusamy P., Nandhini M., Palanivel K., Oruganti S. *Optimization Of Airport Check-InService Scheduling,* Pondicherry University https://www.academia.edu/74051291/Optimization_Of_Airport_Check_In_Service_Scheduling
3. Adacher L., Flamini M., *Optimization of airport check-in service quality focused on operational costs and passengers' satisfaction* 2021; 16(8)