Jelena PIVAC, M.Eng.[1]
(Corresponding author)
E-mail: jpivac@fpz.unizg.hr
Igor ŠTIMAC, Ph.D.[1]
E-mail: istimac@fpz.unizg.hr
Andrija VIDOVIĆ, Ph.D.[1]
E-mail: avidovic@fpz.unizg.hr
Karmela BOC, B.Eng. [2]
E-mail: karmela.boc@skole.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
[2] Rudolf Perešin Aviation Technical School
Rudolfa Fizira 6, 10410 Velika Gorica, Croatia

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OVERVIEW OF THE INFLUENCE OF LEVEL OF SERVICE ON THE AIRPORT PASSENGER TERMINAL CAPACITY

ABSTRACT

Establishing the desired quality of service (QoS) of the airport passenger terminal in order to improve operational performance is a challenge for every airport. Recent international research indicates a gradual recovery in air transport and, accordingly, the need to develop additional transport infrastructure. If the passenger terminal design in terms of infrastructure and operational capacity is not approached correctly, the level of service provided to passengers may decline. This research will focus on how the IATA Level of Service (LoS), which is provided to airport users can contribute to the optimisation of the level of service of the passenger terminal. Additionally, the impact of level of service on passenger terminal capacity assessment in relation to the diversity of air carrier business model will be analysed. Since there is no common link to uniformly describe and solve this problem, this paper will review the relevant literature in the field of passenger terminal capacity research and will analyse different approaches to solving this problem with the aim to develop a new unified concept in observing and optimising the capacity of the airport passenger terminal taking into account the types of air carrier business models.

KEYWORDS

airport; airport passenger terminal; level of service (LoS); airport passenger terminal capacity; airport terminal facilities; optimisation.

1. INTRODUCTION

Air transport is of immense importance for the economic development of any country. The air transport sector consists of a number of stakeholders, the most important of which are air carriers, passengers and air traffic control, and they all merge at the airport. It is important to point out that the way airports operate has changed throughout history. In the past, airports were operated by states, and today many airports have been privatised through some models, such as BOT (Build-Operate-Transfer). Following that strategy, it enables a competitive way of doing business in the free market while improving efficiency, service quality and safety. At the same time, other air transport stakeholders are undergoing changes in their business strategies. While air carriers are developing new forms related to business models, air traffic control is continuously monitoring and introducing new technologies in the function of enabling efficient and uninterrupted passenger transport. In the last few decades, the continuous demand growth for this type of transport has led to the undercapacity of airports. The imbalance of the airport capacity provision on the one hand and demand on the other is the most evident in aircraft delays, which leads to significant costs for airports. The emergence of bottlenecks in passenger terminals is a growing problem, especially for European airports, resulting in a reduction in the LoS [1]. Regarding the service that passengers receive at the passenger terminal, their expectations are constantly increasing. Airports must continuously find ways to achieve a level of service that will be satisfactory to the passenger.

The latest forecasts include a strong impact of COVID-19 after which a gradual recovery is predicted. Domestic and short-distance markets are expected to recover faster, while long-distance travel will be the last to return to 2019 demand levels. International Air Transport Association (IATA) predicts that the introduction of new solutions to optimise the entire transport process will be increasingly required in the future and that, according to forecasts by IATA, the number of passengers will reach pre-pandemic levels in 2023 [2].

The airport passenger terminal is a key infrastructure in which passengers can perceive and evaluate the airport based on their experience. IATA's Airport Development Reference Manual (ADRM) [3–5] states that airports should conduct regular infrastructure and operational capacity assessments to identify sources of any problems with capacity and implement corrective actions. Accordingly, airport management should proactively analyse and anticipate the need for further improvement and development of additional airport capacity. A systematic review will include an assessment of the validity of relevant studies including a careful consideration of the methods used during the research to synthesise the best evidence for future decision making.

At the global level, airports aim to achieve a level of service optimum with all its default parameters, because otherwise there is a reduction in the level of service quality itself. This research will provide guidelines for improving passenger and baggage handling process, considering all the elements for achieving an adequate LoS based on the type of air carrier business models.

The paper is structured as follows: in section 2, it is described how the LoS was established, and it is explained how the airport terminal facilities are sized in accordance with the LoS. Section 3 builds upon problem description – increasing the operational efficiency of the passenger terminal and detection of elements/parameters that can increase it. In section 4, the methods of capacity analysis of the airport terminal facilities in the passenger terminal are listed and an overview of significant research dealing with the capacity problem in the passenger terminal is given. Section 5 concludes the key findings of this review and provides recommendations for future studies.

2. SERVICE QUALITY MEASUREMENT

In the 1990s, the quality of service began to be increasingly considered in the aviation industry, while today it is gaining more and more importance. Baker states: “Quality of service is considered an essential measure of competitiveness” [6]. The air transport industry is facing an ever-improving LoS on the one hand and customer satisfaction on the other. The quality of service is one of the most important factors that are being considered in order to gain an advantage over the competition. It is important to point out that there are significant differences between user expectations and perceptions. A key requirement when defining the quality of service is understanding passenger expectations. Ostrowski et al. [7] state that only users can truly define the quality of service.

In essence, the concept of customer satisfaction is the user's response to the assessment of the perceived difference between expectations in relation to the actual performance of the service. To put it simply, customer satisfaction is defined as the relationship between expectations and perceptions (results). It occurs when the perception of the performance of a particular service exceeds the set expectations of users [8]. Some of the known models used to measure user expectations in relation to perception are VIKOR and SERQUAL [9] which represent tools for measuring customer’s expectations and performance perception of the delivered service. The essence of the mentioned models is in finding the gap or difference between the expectations of the user and his perception of the current service.

Pivac et al. [10] state that customer experience management is the experience of responding to the needs of passengers in order to achieve and/or exceed the passenger's expectations. Airports are constantly reviewing the services provided to customers to meet the growing challenges of satisfying customer needs. If elements that increase passenger satisfaction are identified, including a timely response, it is possible to increase the airport’s revenue. More and more airports are prioritising improved passenger service because they have recognised that quality customer service creates a positive impact on both the airport and its entire community. Although various programs are available today, such as Airport Council International / Airport Service Quality (ACI-ASQ), which made it possible to compare its own user experience with other airports, it is important to note that there are currently no comprehensive guidelines on how to improve the overall experience.

The management of each airport aims to understand and accept the factors that drive customer satisfaction and their perception – Key Performance Indicators (KPI's) [11]. By obtaining information on which factors affect passenger satisfaction, each airport can make certain improvements to its services. Knowing the key indicators of passenger satisfaction makes the difference between a medium and a well-ranked airport. In addition, each airport must adjust the passenger satisfaction program according to passenger needs and circumstances. Airport passenger satisfaction surveys [10] have shown that airport cleanliness, ambience, staff friendliness, ease of finding way through passenger terminal, queue length and a sense of security are among the key indicators of customer satisfaction at airports around the world. Passengers usually create a perception of the airport after their first interaction with it (e.g. in person, via the Internet, self-service). If passengers experience any factor in a negative way, taking into account that they often do not know who the actual service provider is, this experience can have a negative impact on the airport or the air carrier. The authors [12] state that the quality of the travel experience is influenced by the travel companions and the availability of commercial content.

To increase passenger satisfaction, a large number of airports use different ways of measuring passenger satisfaction when travelling through a passenger terminal. Some of the ways to measure passenger satisfaction with services are: surveys, scientific research conducted by various institutions, analysis of passenger complaints, etc. Airports are increasingly using social media as a method of getting feedback from passengers on overall satisfaction with airport services. One of the newer ways in which airports can get feedback is sentiment analysis. With this method, airports perform large-scale analysis of large unstructured textual data sets, on the basis of which key performance indicators are evaluated. Also, online reviews are increasingly being used today to help discover new aspects of service quality. In addition to being able to detect real-time passenger perception, they show voluntary feedback from users [13]. Within the topic of quality, it is important to mention the ACI-ASQ program, which is the leading method for measuring passenger satisfaction with the services provided at the airport. By exploring new ways to increase the quality of provided services and implementing them, airports can not only retain existing customers, but also gain new ones.

In general, there is a growing awareness of passengers about the quality of service, which has been recognised by air carriers and thus further strengthened their competitiveness. Various studies have been conducted that have analysed the quality elements of carrier services [14–17]. Competition between Low-Cost Carriers (LCC) and Traditional/ Full-Service Network Carriers (FSNC) is growing in the global market [18–19]. Many researchers have examined passengers' perceptions of the quality of carrier services and noted significant differences in perceptions between the FSNCs and the LCC [14, 20, 21].

At the same time, carriers themselves are becoming increasingly aware of the differences in the perception of customers using LCC services compared to the services of FSNC, so passengers' perceptions of the provided services are increasingly being analysed. The objectives of the LCC are aimed at reducing costs in order to attract cost-sensitive travellers, while increasing their market share [19]. With the aim to retain their loyal customers, FSNCs provide a higher level of service and strengthen their alliances. For the purpose of achieving business sustainability, it is becoming increasingly important to understand the key differences in perceived service quality between the FSNC and LCC users [15].

A study conducted by Chiou and Chen [22] showed that the perception of the service, taking into account three different classes, has a major impact on the FSNC passengers, while the value of the service has a large impact on the LCC passengers. Chou et al. [23] concluded that defining a lower transport price does not necessarily lead to success but on the contrary, it can negatively affect flight safety and also lead to a decline in service quality. In order to achieve the greatest usefulness of operational resources and meet the passenger expectations, it is necessary to constantly review and accordingly define what the most important attributes of service quality for each individual model of air carriers are.

2.1 Establishment of Level of Service (IATA LoS)

Motivation to measure the quality of service at airport terminal facilities emerged due to the need to improve them. The first research related to LoS dates back to the 70s of the last century. The Federal Aviation Administration (FAA) was one of the first to recognise an insufficient understanding of the relationship between capacity and the level of service. Shortly afterwards, Transportation Research Board (TRB) published a study [24] which concluded that the establishment of LoS standards is crucial in assessing the capacity of each airport terminal facility of passenger terminal.

A small number of strategic models for passenger terminal operations has resulted by establishing of the Simple Landside Aggregate Model (SLAM) [25]. This model has been recognised by future researchers in this field as a very valuable tool for analysing capacity and delays in the airport passenger terminal.

Within this topic, it is important to mention when the LoS scale was established and how it has evolved over the years. In the 1970s, Transport Canada (TC) established the LoS scale (A–F), modelled on the LoS concept in other branches of traffic, and applied them to the airport's passenger terminal [24]. Furthermore, in the early 1980s, the term "Level of Service" was first mentioned in the "Capacity/Demand Management Guidelines", issued by the Airport Associations Coordination Council (AACC) [26].

When defining the LoS scale, passenger satisfaction is the most often considered, as they are one of the major sources of airport revenue, so their needs and requirements are continuously considered. Regarding the adjustments of existing facilities, it is important to understand the current LoS of each facility (subsystem) inside the passenger terminal to determine where and how to make improvements. It can be stated that new terminals are easier to plan for a certain LoS because the designer is able to optimise the flows of a new terminal more easily than the existing one. Given that changes to terminals require large investments, it is necessary to be able to measure LoS to determine whether a particular goal has been achieved, and finally whether it is justified from an operational and economic point of view.

The peak load survey conducted by IATA in 1981 resulted in the establishment of standard definitions for assessing LoS and airport capacity [27]. To set LoS standards, experts suggested that potential congestion can be measured depending on whether the passengers are being processed, passengers are waiting to be processed or passengers are moving from one subsystem to another. According to the author [28], three basic capacity measures can be used to assess the potential congestion of airport terminal facilities of passenger terminal: static, dynamic and sustained capacity, while the Airport Development Reference Manual (ADRM) [3–5] also states the maximum and declared capacity.

2.2 Sizing the airport terminal facilities

The sizing of all components of the passenger terminal is directly related to LoS. Airports must adapt processes within the passenger terminal and consider and apply various other parameters such as LoS recommendations, satisfying the amount of traffic during peak hours. The author [29] states that capacity planning must meet the conditions of compatibility and flexibility, expandability and modularity. In order for the airport terminal facilities to be properly dimensioned, it is necessary to have some experience and advanced knowledge of operating procedures, with a combination of calculations, research and simulations.

With the aim to improve operational procedures at airport passenger terminals around the world, innovative technologies are increasingly being introduced, especially in the emerging circumstances of pandemics such as COVID-19 [30]. In order to reduce the physical contact through which the virus can easily be transmitted, what is being developed today are contactless technologies such as face recognition technology (biometrics), applications on mobile devices that the passenger uses to show the boarding pass and baggage tag as well as various sensors to check passenger temperature to identify potentially contagious passengers.

The first LoS studies date back to the 1970s. In the year 1987, the TRB conducted a study which is one of the most significant capacity assessment studies. This study found that the capacity of any facility cannot be assessed without defining acceptable LoS standards, and that there is currently a lack of initiative on how to do so. Today, the IATA ADRM is the key document in passenger terminal optimisation that continuously in its editions proposes new recommendations that many airports use when dimensioning their capacities.

Since its establishment, the LoS concept has been based on six categories, from A to F, and after 2014, LoS is divided into four categories: overdesign, optimum, suboptimum and unacceptable level of service [5]. Within these categories, the spatial and temporal parameters of passenger and baggage handling process for airport terminal facilities are presented. The current 'optimum' level of service corresponds to the former 'C' LoS. *Table 1* shows LoS guidelines in which IATA recommends the use of the optimum level, as it provides the passenger with a satisfactory level of service while providing sufficient space at the optimal cost for the airport.

An insight into the table of LoS guidelines shows that these parameters apply to only one (FSNC) air carrier business model, which questions whether it makes sense to apply the same guidelines to all other models. The guidelines provide a good basis for a further analysis of the LoS in terms of setting new parameters within a single passenger terminal taking into account various space-time requirements by users of other business models.

It is important to note that IATA, in cooperation with ACI, following the trends and new technologies development, is constantly working on recommendations that help airports in optimising and synchronising airport terminal facilities. An analysis of the literature shows that airports do not apply a certain LoS standard when optimising their terminals, because the LoS standard as such has not yet been adopted globally but is only a recommendation for sizing airports.

3. PROBLEM DESCRIPTION

The continuous development of airports and the aviation industry requires that today's passenger terminals be planned and built in a way that provides flexibility for future changes at minimal cost, while responding to changes in demand and/or changing needs of passengers, air carriers and aircraft. The authors in [31] are among the first researchers to ask methodological questions when designing passenger terminals. After the establishment of SLAM, which was the pioneer in the establishment of such optimisation models, further models are improving with technological development and are increasingly adapting to passengers. However, although the application of such models is growing in projects aimed at improving passenger flow, there is currently no exactly unified model for optimising the entire passenger terminal system, but various researchers are using different models to solve this problem [26, 32–37].

In addition to meeting the primary elements of expandability and modularity, the main elements still to be considered when building a passenger terminal are demand/capacity assessment and LoS efficiency standards [24]. In a broader sense, the factors that affect the size of the terminal are: the current and future airport capacity, the aircraft types that serve the airport and the "peak hour" passenger flow. Primarily, the capacity of the aircraft serving a particular airport determines how many passengers there will be in the passenger terminal. Based on this, the capacity of the terminal is determined. In order to achieve maximum infrastructural and operational efficiency of the passenger terminal, it is important to balance the availability of the capacity of airport terminal facilities with an adequate LoS.

It has already been mentioned that, when planning a passenger terminal, it is important to establish parameters such as waiting time (per class), and space per passenger for each airport terminal facility of passenger terminal [38]. What could further contribute to the operational efficiency of the passenger terminal is the additional classification of spatial and temporal parameters of passenger processing (space per passenger, maximum waiting times, seating capacity occupancy), according to the IATA level of service, in accordance to the specifics of air carrier business models.

When analysing the optimisation of the level of service at passenger terminals, a review of the literature showed that currently there is no classification of different levels of service within one passenger terminal according to different business models of air carriers, but rather one level is being used for all. Accordingly, the question is whether it makes sense to apply the same LoS to all business models of air carriers and their customers. Do they all need the LoS optimum? If the level of service for each model were measured separately, would the efficiency of the airport passenger terminal be increased?

3.1 LoS optimisation at airport passenger terminals

The air transport market is based on three business models of carriers: the FSNC, LCC including the hybrid LCC and the Charter Carrier (CC) business model. The largest segment of the air transport market is related to the FSNC business model, but

Table 1 – LoS guidelines [5]

LoS parameter		Space guidelines [sqm/PAX]			Max. waiting time guidelines Economy class [min]			Max. waiting time guidelines Business class/First class/Fast track [min]			Other guidelines & remarks		
		Overdesign	Optimum	Sub-optimum	Overdesign	Optimum	Sub-optimum	Overdesign	Optimum	Sub-optimum	Overdesign	Optimum	Sub-optimum
Public departure hall		> 2.3	2.0–2.3	< 2.0	n/a			n/a			Optimum proportion of seated occupants: 15–20%		
Check-in	Self-service kiosk (Boarding pass / Bag tagging)	> 1.8	1.3–1.8	< 1.3	< 1	1–2	> 2	< 1	1–2	> 2			
	Bag drop desk (queue width: 1.4–1.6 m)	> 1.8	1.3–1.8	< 1.3	< 1	1–5	> 5	< 1	1–3	> 3			
	Check-in desk (queue width: 1.4–1.6 m)	> 1.8	1.3–1.8	< 1.3	< 10	10–20	> 20	< 3	Business class 3–5	> 5			
								< 1	First class 1–3	> 3			
Security control (queue width: 1.2 m)		> 1.2	1.0–1.2	< 1.0	< 5	5–10	> 10	< 1	Fast track 1–3	> 3			
Emigration control (Outbound passport control) (queue width: 1.2 m)		> 1.2	1.0–1.2	< 1.0	< 5	5–10	> 10	< 1	Fast track 1–3	> 3			
Gate holdrooms / Departure lounges	Seating	> 1.7	1.5–1.7	< 1.5	n/a			n/a			Optimum proportion of seated occupants: 50–70% Maximum Occupancy Rate:		
	Standing	> 1.2	1.0–1.2	< 1.0							< 60	60–70%	> 70%
Immigration control (Inbound passport control) (queue width: 1.2 m)		> 1.2	1.0–1.2	< 1.0	< 5	5–10	> 10	< 1	Fast track 1–5	> 5			
Baggage reclaim	Narrow body aircraft	> 1.7	1.5–1.7	< 1.5	< 0	0/15	> 15	< 0	0/15	> 15	The first waiting time value relates to „first passenger to first bag". The second waiting time value relates to „last bag on belt" (counting from the first delivery).		
	Wide body aircraft	> 1.7	1.5–1.7	< 1.5	< 0	0/25	> 25						
Customs control		> 1.8	1.3–1.8	< 1.3	< 1	1–5	> 5	< 1	1–5	> 5	Waiting times refer to a procedure when 100% of the passengers are being checked by Customs		
Public arrival hall		> 2.3	2.0–2.3	< 2.0	n/a			n/a			Optimum proportion of seated occupants: 15–20%		

the share of traditional flights has changed over the years in benefit of low-cost flights [39]. The progression of low-cost carriers around the world brings a change of conception in the airport business model that specifically integrates the requirements of low-cost carriers. With the expansion of low-cost carriers into the air transport market, new requirements are emerging from the aspect of improving technological processes.

The rise of low-cost carriers requires adapting the industry to their requirements and needs [40]. A complete understanding of the needs of low-cost carriers can help airport management provide customised services to this growing business model. Lawton and Solomko [41] found that efficient passenger terminal is the most sought-after requirement of low-cost carriers. De Neufville [42] investigated how infrastructure and airport terminal facilities are being developed at low-cost airports and he also identified characteristics that lead to operational efficiency and reduced services. Within this topic, it is important to mention the charter business model which is characterised by lower costs, thus directly competing with other business models of carriers. The paper [43] presents a simulation model that enables the examination of the impact of charter passengers on the facilities of the passenger terminal and enables the assessment of the level of service offered to them. The literature [44] considers differences in the patterns of arrivals of passengers at airports and it has been observed that charter passengers arrive at the airport much earlier than their flight. Also, the aforementioned literature states that the arrival of passengers in groups leads to discomfort and reduces offered level of service.

Although traditional carriers have the largest offer of services, which means better quality of service, their price is slightly higher. Therefore, passengers are increasingly deciding for low-cost carriers whose fare is more affordable, and whose growth negatively affects the business of network carriers. It can be stated that due to the increase of low-cost carriers, their influence on airports is also growing. There are many factors that will dictate the characteristics of the terminal to be used by low-cost carriers compared to network carriers. The new model of services offered by low-cost carriers, which include a smaller volume of services, is changing the traditional look of the passenger terminal. The business model of low-cost carriers requires short turnaround time and limited time the passenger spends processing on airport terminal facilities (dwell time) [24], while the LoS targets of the LCC are generally below the LoS optimum proposed by the IATA. The interior design of the low-cost terminal will reflect the low-cost approach. In addition to the above, it can be stated that the forecast of passenger profiles is very important for the airport to be able to establish an adequate terminal design. In this way, the terminal will be able to provide a satisfactory level of service to passengers, generate sufficient revenue from this type of passenger and finally achieve maximum operational efficiency [45].

An analysis of the infrastructure of European, Asian and American airports, which increasingly serve low-cost carriers, found that a significant number of Low-Cost Carrier Terminals (LCCTs) have been built as a result of the growth of low-cost carriers worldwide. An example of such a terminal is the Kuala Lumpur International Airport. The growth of LCCT, as a result of the growth of the LCC, has led to the concept of fewer facilities in terminals offered to airport users, which is closely related to the reduction of costs associated with the development and operation of terminals [45]. Taking into account the LCC passenger profile, the airport should define the optimal level of service intended for this type of passenger and include it in the terminal design.

The author [46] was among the first to predict the growth of the LCC, and consequently the adaptation of passenger terminals to them. However, the potential problem of such terminals lies precisely in different expectations from the aspect of air carriers, passengers and airport management. After gaining insight into the research of other authors [42, 45, 46], it can be concluded that there are conflicting expectations of passengers, air carriers and airport management regarding the provision of services to passengers of these types of terminals.

3.2 Making optimal decisions

The concept of queuing system is commonly used in service delivery systems to ensure efficient operation of the system. Airport queues require effective airport management strategies to ensure better LoS at all components of the passenger terminal. The use of models for queue analysis aims to describe the process and predict the behaviour of the system due to changes [35]. Within this topic, it is important to mention queuing theory, which represents an analytical method used by a large number of researchers when analysing passenger terminal capacity, especially in application with simulation tools [32, 33, 35]. In order to assess the functionality of a system, the traffic intensity is used. It is determined by the intensity of arrivals and the intensity of service, and is described by the equation as follows:

$$\rho = \lambda / \mu \tag{1}$$

where ρ is the traffic intensity, λ is the intensity of arrivals, and μ is the intensity of service. Passenger arrivals are usually discrete random variables (they take on a finite number of values) and are obtained, e. g. by counting the passengers. The times between arrivals are continuous random variables (they take on any value from an interval or an infinite value). Furthermore, the service process shows stochastic variations, and the probability or expectation of the average number of passengers being processed is used for this process. The average number of passengers that can be served in time t "μ" is defined by the service capacity or the average service time expressed in seconds per passenger "$1/\mu$". According to [35], for each arrival in a service system, each subsequent arrival occurs after an exponential time with the parameter $\lambda+\mu$ and the probability $\lambda/(\lambda+\mu)$. Based on this, the probability of service completion and passenger departure is given as $\mu/(\lambda+\mu)$. Also, the following equations are used to model the queuing theory:

$$L_s = 0 \cdot P_0 + 1 \cdot P_1 + 2 \cdot P_2 + \ldots + n \cdot P_n = \frac{\lambda}{\mu - \lambda} \tag{2}$$

$$L_q = \frac{\lambda}{\mu - \lambda} - \frac{\lambda}{\mu} = \frac{\lambda^2}{\mu(\mu - \lambda)} \tag{3}$$

$$W_q = L_q \cdot \frac{1}{\lambda} = \frac{1}{\mu - \lambda} \tag{4}$$

$$W_s = W_q \frac{1}{\mu} = \frac{1}{\mu - \lambda} \tag{5}$$

$$P_n = \left(1 - \frac{\lambda}{\mu - \lambda}\right)\left(\frac{\lambda}{\mu}\right)^n \tag{6}$$

L_s represents the average number of passengers in a queue, while P_0 to P_n indicates the number of passenger arrivals in the system. L_q in the equation represents queue length. W_q in the equation represents the average waiting time. W_s in the equation represents the average delay time in the system. The P_n represents the probability that there are n customers in the system. Any queuing system in which $\rho>1$ is described as an unstable system, which means that random arrivals are relatively higher than departures [47]. This means that the system is overloaded and that the waiting time continues indefinitely. Unstable queues are most often analysed using discrete time models or stochastic models to estimate the performance of a time-dependent system. Differential equations and Monte Carlo simulations serve the purpose of examining the time-dependent behaviour of unstable queuing systems. If, for example, check-in counters at the airport passenger terminal are taken, in order to minimise waiting, a larger number of counters can be put into operation where, as a result, passengers will not wait. Also, only the required number of counters (100% utilisation of active counters) can be set. Any service system includes costs incurred as a result of waiting and costs incurred due to incomplete utilisation of service points (in this case check-in counters in the passenger terminal) [32]. *Figure 1* shows the relationship between the customer's waiting cost and service capacity cost.

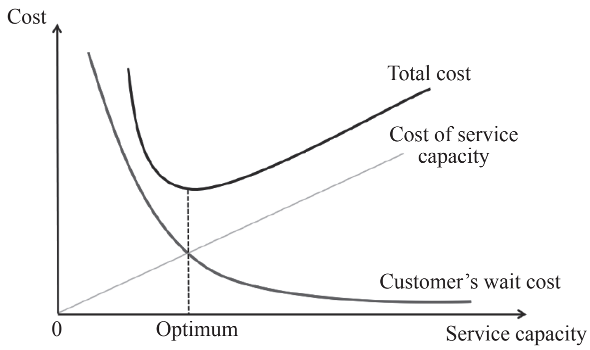

Figure 1 – Service capacity cost vs. customer's waiting cost [32]

The goal of airport management should be making optimal decisions in order to achieve maximum operational and economic performance. The emergence of queues at the airport terminal facilities has a major impact on the passenger terminal operational efficiency. One way to solve the problem is to determine the optimal number of counters in order to minimise the total costs (waiting costs and unused service unit). In order to reduce waiting and optimise flows in the passenger terminal, aside from number of counters, the number of security lanes or the number of gates can be increased. The ultimate aim of queuing management is to reduce the total cost of service capacity and the cost of customers waiting for service, while increasing customer satisfaction with services at the airport passenger terminal.

4. METHODS FOR OPTIMISING PASSENGER TERMINAL CAPACITY

Designers of today's passenger terminals at airports have to meet a wide range of different needs. Although the efficiency and flexibility of the passenger terminal remains a priority, designers must consider different ways to design and build terminals and environments that support the highest level of passenger service. All this should be realised in order to build adequate infrastructure and operational efficiency of the passenger terminal [5, 24]. To make the passenger terminal operationally efficient, various security requirements, procedures, needs of all stakeholders such as air carriers or airport operators must be taken into account and implemented in the correct way. Furthermore, airport passenger terminal operability is sensitive to frequent technological changes and adjustments of parameters such as the introduction of regulatory requirements, adaptation to new business strategies, introduction of new information technologies, etc. These parameters have an impact on the operational efficiency of the passenger terminal, so it is important to ensure its flexibility in accordance with changes, trends and possible contingencies. When planning a passenger terminal, designers must also be innovative in ways of creating areas that increase non-aeronautical revenues [12].

4.1 Methods of capacity analysis of airport passenger terminals

The complexity of flows during the passenger and baggage handling process is the most pronounced during peak demand. Given that the intensity of passenger and baggage varies in flows within the hour, knowing that hourly data on the number of passengers are not sufficient to design the passenger terminal capacity, various methods have been developed to calculate the capacity of the airport passenger terminal. The most common methods are critical path method, queuing models and simulation modelling [48]. ADRM [3–5] states that the most commonly used methods for capacity estimation are, in addition to simulation modelling, direct observation of the operations and capacity equations for determining theoretical capacity and LoS given the traffic volume and available area. Most of the scientific literature recommends choosing a simulation method when developing a new conceptual design and for estimating the future passenger terminal capacity. An analysis of passenger waiting times by Guizzi et al. [33] showed that the total time passengers spend at the airport is as follows: 48% of time they spend moving in a traffic flow, 25% of their time they are waiting, 4% of their time is spent in doing formalities such as embarkation or process acceptance and 23% of time they spend on retention in commercial facilities.

4.2 Existing models and tools

Researchers in this field want to solve the problem of capacity in air transport in different ways. Only studies that provide precise and accurate outcome results were selected. This review will assess the quality of the included studies, after which conclusions based on evidence will be made. The variety of methods and the presentation of their application in capacity optimisation can help future researchers in making decisions about which method to use. Given that there is growing number of research in this field, it is necessary to provide a comprehensive analysis, synthesise conclusions about methods and suggest the best method. In the following part, a critical evaluation and synthesis of relevant studies on a specific topic is made and conclusions based on the results of the review are given.

Authors [34] were among the first who compared two models for assessing the passenger terminal efficiency. Those are the AIRLAB simulation model and the SLAM analytical model. The aim of both models was to analyse airport terminal facilities of the passenger terminal, providing, among other things, an assessment of the capacity of a certain airport terminal facility, the ability to process the maximum number of passengers per hour, and the level of service of a certain airport terminal facility in relation to international recommendations like, e.g. the IATA manual. AIRLAB was one of the first discrete-event simulation models relating to departing, arriving and transferring passengers in passenger terminal, including their baggage. This model is not a description of a specific terminal, but can be adapted to model any terminal configuration by adjusting the parameters appropriately [49]. This model emphasises flexibility in defining and applying alternative operational policies in the terminal and in modelling passenger behaviour. It provides a graphical display of the LoS achieved on each airport terminal facility over a period of time and an animation of the work within the terminal. SLAM is a model that extracts the necessary inputs from statistics that are usually collected by each airport. The analysis usually refers to peak hours and this model uses an equation that can be applied to any airport terminal facility, as follows:

$$IoS = \frac{Area}{AP \cdot ADT} \tag{7}$$

where *IoS* represents the Index of Service (IoS) for a particular airport terminal facility, *Area* refers to the area of a particular facility, *AP* denotes the number of arriving passengers within a peak hour, while *ADT* represents the average "dwell" time a passenger spends on an airport terminal facility. The above-mentioned formula can be used to obtain results very easily, and at the same time, it represents a precise method for obtaining the LoS of the space of each facility. For example, if the area in front of the check-in covers 1,300 m^2, the number of arriving passengers at the check-in during the peak hour is 3,300, and the average dwell time is 0.15 (hours), then the IoS for that facility is 2.62 (m^2 per passenger), which means that the corresponding LoS is Over-Design. This research paper is extremely important because the authors, with their research and approach, "opened the door" for other researchers in terms of LoS and capacity research. The main disadvantage of the simulation method (AIRLAB) lies in the amount of computation time, which is not surprising considering that the model is based on a low-budget platform characteristic of the time when the research was done, in 2001. In accordance with that, the results are shown in a visual way very concisely. The greatest advantage is manifested in the flexible application of the model to various airports. Considering the year of publication of this article, and the parameters that the authors took into account when modelling the terminal, such as processing times or waiting times, it can be concluded that the authors detected important parameters well. Looking at today's parameters that are considered, they have not changed to a greater extent. Although both the AIRLAB and SLAM model the airport terminal, they describe different needs and can be considered complementary [34].

The author [35] created a simulation model using the SimEvents toolbox in MATLAB for the implementation of analytical models, which was developed in previous research, for the queuing process at the check-in. The model was developed on the basis of air travel demand data from two airports (Manchester and Leeds-Bradford) in the UK for model validation. Differences in Simulation Model (SM) and Analytical Model (AM) outputs were attributed to variations in discrete time events, and related to average queue length, average number of arrivals, average waiting time and throughput. The use of a simulation model aims to describe the process and predict the behaviour of the system due to changes. The research concluded that the simulation results are desirable and recommended to airport managers because they are more realistic since they are based on discrete time analysis. In this research, a combination of simulation and analytical methods was also used, but the fundamental difference compared to the work [34] is in the description of the methods and the interpretation of the results, which are explained in detail. Various elements such as variations in discrete time events that depict reality are taken into account, therefore providing more reliable results, which older papers [34, 50] did not take into account. The authors consider and simultaneously recommend this article for researchers dealing with this issue. The inputs are precisely defined (taking into account stochasticity, variations), and the outputs and visualisation of the results are well structured, which makes it easier for the reader to follow the paper. The shortcoming of this paper is that it only deals with check-in counters without considering the Common Use Self Service (CUSS) that is being increasingly used today.

Considering the new trend present in airports and that is the introduction of new technologies, the authors recognised their importance and decided to go one step further. The authors in [32] presented a simulation-based optimisation method that takes into account only the operation of an unmanned system such as self-check-in kiosks and automatic immigration screening. The model was developed by using the ARENA simulation and modelled by using the queuing theory. They created a simulation of the passenger terminal on self-check-in systems, in which the model settings were described in detail, and they clearly presented the research results and what they determined. The negative aspect of this work is manifested in the inaccuracy of the data since the values of the data on passengers are arbitrary. In accordance with the above, it can be concluded that a high degree of relevance has not been achieved and it is necessary to collect more detailed data (processing times, queuing times) in order to obtain more reliable results. In conclusion, the authors consider that airports can use the results of this research to create a plan for the establishment of self-service systems (through which a conclusion about the success of the research can be made).

In their paper [33], the authors developed a simulation model that can predict the delay (by using the ARENA software) based on the theory of discrete events. This model takes into account the available capacity and the fact that the number of passengers depends on the day of the week and the time of day, and on the different and unpredictable behaviour of passengers. The importance of this model lies in the ability to define at any time of the year, depending on the amount of traffic at the airport, the optimal number of check-in counters that will be sufficient to check all passengers in accordance with planned flights, while ensuring a satisfactory level of service for departing passengers. The present paper is written similarly to other papers in this field and presents the issue of queue management in the passenger terminal in a systematic and comprehensive way, taking into account additional parameters such as passenger behaviour and the number of passengers per day of the week. One of the advantages of the analysed paper is that it has good traceability, i.e. the research results are presented in a logical and comprehensible manner, and less knowledgeable readers can easily follow the course of the paper. The authors fulfilled the purpose of the research and confirmed by the obtained simulation that congestion is reduced by reducing waiting time. In this way, QoS to users (air carriers and passengers) is simultaneously increased and airport costs are reduced. By providing flexibility to the configuration and operational characteristics of a wide range of passenger terminals, the model described in this paper provides quality analysis and results and advances research in this field.

The doctoral dissertation [26] deals with the time that passengers spend processing or waiting in the airport terminal facilities, on the example of the passenger terminal of Franjo Tuđman Airport in Zagreb. Based on the analysis and obtained data, a model was created that helps to optimise the capacity of the passenger terminal in relation to all three main models of air carriers taking into consideration its maximum usage during peak hours. The author also developed an application for optimising airport capacity and negotiating with carriers. The present doctoral dissertation provides very detailed analysis of each segment of the passenger terminal traffic flow at the airport. At the Franjo Tuđman Airport, the existing infrastructure capacities were tested, on the basis of which new technical, technological and capacity solutions were proposed. The model, which is part of the invented and verified Airport Management Strategy Software (AMSS) application, solves this problem by first determining, through various traffic and economic parameters, what the operational capacities of the airport are, what the LoS that can be provided is and how the airport can make maximum use of its capacities. The contribution of this research is manifested in the applicability of this model (developed application) to various airports, and it is also a recommendation by the author for future researchers in this field, particularly for researchers who examine LoS in relation to different air carrier's models.

The scientific paper [36] analysed the passenger terminal capacity of Ülenurme Airport in Estonia. The conducted research determined the specifics and possibilities of the regional airport for optimising the capacity of the passenger terminal in order to provide the service at the desired level. The result of this research can be used as a basis for modelling regional airport terminals. In addition to the above, possible measures to increase the capacity of the regional airport were also offered. The observation method used by the researchers is somewhat more simplified than other methods, but for this very reason it can be a good example of how to optimise the capacities of passenger terminals in a simpler way, without using more complex simulation and analytical models. This research uses direct observation of the operations and capacity equations for determining theoretical capacity and LoS given the traffic volume and available area and is recommended by the authors when considering the airport's capacity optimisation possibilities. It can be stated that it represents a scientific contribution in terms of optimising the passenger and baggage handling process.

The scientific paper [37] proposes an optimisation model that determines the optimal number of check-in counters and security control units in order to minimise the costs. The model estimates the cost of check-in counters and security control units while estimating the level of passenger satisfaction. At the same time, the simulation model reproduces the actual scenario of terminal operation and passenger behaviour and calculates the cost side value. The tests were conducted on a case study of Napoli Airport, Italy. This is a preliminary study and the solution is applicable to only one carrier. The end result could be useful for optimising the existing passenger terminals (departing passengers), but also for estimating the capacity of a new passenger terminal for a new airport. This scientific paper presents an interesting and somewhat different approach to the optimisation of the passenger terminal, which combines different methods. The shortcoming of this research is primarily manifested in the application to only one air carrier, which is justified by the statement that it is a preliminary study. In any case, the authors consider that the paper is a good basis for future research and can serve as a high-quality and comprehensible example of how to determine the optimal number of check-in counters and control units and how to minimise costs. The reviewed paper provides quality analysis and results and advances research in this field.

The University of Mathematics and Statistics (Ontario, Canada) has developed a linear programming model that reduces the total operating hours of the check-in system, ensuring a satisfactory level of customer service [50]. The result of this alternative method shows a significant improvement in the performance of the passenger terminal as it allows for shorter queues, reduces waiting times and increases the percentage of satisfied users. As part of this paper, a sensitivity analysis on changes in the passenger's number and service rates was performed. The stated method tries to achieve the best outcome in a mathematical model whose conditions are expressed by linear conditions. The authors consider this method very useful in cases of achieving given conditions, for example maximum profit or minimum cost within the passenger terminal.

Table 2 shows a comparative view of the methods that were used for the purpose of optimising the passenger terminal with the stated contribution of each research.

Different approaches are certainly preferred depending on what exactly is to be achieved and in what way. Accordingly, an overview of different methods was given, and conclusions and recommendations were made to guide future researchers in using certain methods when optimising capacity. With the given review and its ranking, the authors wanted to point out the variety of methods that can be applied to optimise the passenger terminal. By comparing the implemented methods in the analysed papers, it can be concluded that the simulation models showed the highest accuracy (reliability). Conducting simulations at airport terminal facilities, and especially on self-service systems, is a very topical and demanding field. Although today's models have improved and are increasingly adapted to users, many researchers are still working on developing new models, following the situation and trends in the market, which will help optimise the business processes of passenger terminals. In that regard, the benefit of this paper, which provides an overview of developed models in this field, is also obvious.

An analysis of the papers identified that similar input parameters (service time, numbers of servers, etc.) were used when setting up the model, while more recent papers consider additional parameters such as variability and stochasticity. Also, it was noticed that some authors used arbitrary data, which negatively affected the paper's relevance. Following those mentioned above, the author's recommendation is to collect accurate data in order to obtain more reliable results. By comparing the scientific articles, it can be determined that various authors combine several methods precisely to achieve the highest accuracy. Based on the insight into the results of the conducted research, the authors of this article concluded that the combination of simulation and analytical methods is the most desirable one, considering that the mentioned combination can achieve the highest accuracy when defining capacity and simultaneously improve LoS. Simulations in scientific and research papers are used in such a way to perform a large number of experiments, that is, to change certain input parameters and observe the effects they cause. The main advantage of simulation is the possibility of processing a large amount of data in a relatively short time and repeating the procedure with different input parameters. In accordance with the recommendations of most of the professional and scientific literature, bearing in mind numerous advantages, simulation models are widely used in passenger terminal modelling. The authors consider that using different methods is an excellent way to assess an airport terminal. The shared use of two models, one of which must be based on simulations, can provide all the information needed to develop a correct and accurate analysis of any airport. As the airport terminal flows and its processes are complex, there is no one unique methodology or solution which will fully optimise its operations. Due to that, the author recommends using more complex methods, including a combination of several methods, to obtain greater accuracy

Table 2 – Methodologies used in the presented research

Reference	Analytical method	Simulation method	Other methods	Scientific contribution	Airport	Rank 1-5
Andreatta et al. [34]	SLAM	AIRLAB		– animation of the operations within the terminal – graphical and textual presented outputs	– Milan Airport – Venice Airport	5
Adeke [35]	Queuing theory	SimEvents (MATLAB)		– modelled queuing process at the airport check-in system	– Manchester Airport – Leeds-Bradford Airport	4
Da Un et al. [32]	Queuing theory	ARENA		– optimised operation of unmanned systems (self-check-in kiosks and automatic immigration screening) – based on queuing model	-	4
Guizzi et al. [33]		ARENA		– optimised check-in desks and security control – optimised costs and created development scenarios	– Napoli Airport	4
Štimac [26]			Optimisation method - Airport Management Strategy Software (AMSS)	– optimised passenger terminal capacity (in relation to all three main models of air carriers), – developed an application for optimising airport capacity and negotiating with carriers	– Franjo Tuđman Airport (Zagreb)	5
Nommik [36]			Direct observation of the operations and capacity equation	– offered measures for increasing regional airport terminal capacity	– Ülenurme Airport	2
Adacher et al. [37]			Optimisation algorithm, based on the surrogate method that integrates a simulation module	– determined optimal number of check-in counters and security control units – calculated the cost side value	– Napoli Airport	3
Cao [50]			– linear programming method – sensitivity analysis	– reduced total operating hours of the check-in system – improved passenger terminal performances	– Ottawa Airport	3

and reliability. For smaller airports with less traffic, it is always possible to use a simpler approach, such as direct observation of operations and the terminal capacity equation. Some of the more significant simulation tools that need to be mentioned are ArcPORT and CAST. These tools offer solutions that facilitate investment optimisation and reduce the passenger terminal operating costs and are currently one of the most commonly used in the application of such solutions at airports. These tools provide a platform for analysing and visualising the flow of passengers, aircraft, baggage and cargo to various users within the airport infrastructure such as airports, air carriers, air traffic controllers and other civil aviation authorities.

Within this topic, it is important to mention the Quality Function Deployment (QFD) tool, which was considered an effective tool for continuous service improvement, quality planning and decision making. QFD is a useful tool for identifying, prioritising and integrating user needs into its design, which is of great help to airport management when planning airports [51]. With the help of the QFD method based on the Fuzzy methodology, the parameters of strategic airport design can be evaluated in order to meet the service expectations of individual business models of air carriers. The authors in [52] process/evaluate the parameters of the strategic design of airports in Thailand through the integration of the LCC needs using the QFD method based on Fuzzy.

Changes in the share between business models and changes in air carrier strategies affect the determination of the optimal relationship between a satisfactory level of service within passenger terminals, which directly affects airport business. It is realistic to expect that in the future, airports will increasingly adapt their own infrastructure to the requirements of different business models. Therefore, it is necessary to understand the needs and requirements of each business model in order to achieve maximum efficiency within a single passenger terminal. The literature review shows that low-cost and charter carrier impact on airports in terms of the level of service has not been sufficiently researched.

In conclusion, forecasts of future demand for air carrier business models facilitate strategies/ business models and long-term airport development. Previously, traditional regression analysis techniques have been used to predict air transport demand such as [53–55], but in recent years, suggested artificial intelligence prediction techniques such as genetic algorithm (GA) and artificial neural networks (ANN) [56-58] can be found in the literature. Artificial intelligence models have proven to be more powerful and have greater predictive power than traditional statistical methods. Given the growing importance of LCC for the global market, it is necessary to ensure an accurate and reliable forecast for them and determine the need for more LCC and capital investment. Accurate forecasts strengthen airport management in planning and making decisions for the future.

5. CONCLUSION

Lack of airport passenger terminal capacity is becoming an increasingly important problem due to the continuous passenger traffic increase. Capacity is the most important parameter of a passenger terminal, which shows in what condition it is, what its potentials are, and also what its shortcomings are in terms of bottlenecks or lack of capacity. Therefore, airports are constantly trying to optimise their infrastructure capacity. It is important to balance the availability of capacity of airport terminal facilities with an adequate LoS in order to achieve passenger terminal capacitive and operational efficiency. This paper shows how the LoS has been established and how it has improved over the years. An evaluation of the quality of the included papers was given after which conclusions and recommendations were made.

In recent decades, various methods have been developed that optimise the passenger terminal capacity and focus on the passenger needs. Furthermore, it is important to point out that the efficiency of the terminal cannot be assessed only by operational approach, but other parameters such as passenger processing time, ambience and comfort, ease of wayfinding, available space per passenger and other parameters affect consideration of service quality. Although there is no globally adopted LoS standard, the LoS recommendations given by IATA are used by most airports. IATA's LoS concept takes into account the most important factors influencing the understanding of the level of service, which IATA is continuously improving in terms of defining possible new parameters and space-time values of existing parameters.

There are various methods by which the capacities of airport terminal facilities in the airport passenger terminal can be dimensioned, such as network models, queue models and simulations. However, most of the literature mentions the choice of simulation method for assessing the efficiency of the LoS for existing terminal, i.e. for assessing when certain contents of the terminal will no longer meet the demand at the acceptable LoS. Airports should conduct regular capacity assessments to identify sources of capacity problems as well as provide appropriate solutions. There is no universal method for solving the problem of the available airport passenger terminal capacity, so it is necessary to use and try to solve the problem with different methods and techniques. Furthermore, given the forecasts that predict a gradual recovery in air transport at the global level, it can be concluded that the application of the level of service in the optimisation of the airport terminal facilities will be relevant in the future.

The paper offers an overview of significant literature with the topic of the passenger terminal process optimisation. The systematic review included an assessment of the validity of the studies, including a careful consideration of the methods used during the research, and finally, guidelines for future decision-making were adopted. The diversity of methods was analysed, where they were ranked, and their applications in capacity optimisation were presented, which can help future researchers in making decisions about which method to use. By comparing the applied methods in the analysed works, it can be concluded that the simulation models showed the highest accuracy (reliability). The authors consider that the use of different methods, one of which must be based on simulations, is the best way to evaluate the airport terminal. Future research should provide answers to whether it is possible to improve the efficiency of the terminal if an additional classification of space-time parameters of passenger processing is made according to the specifics of air carrier business models. The review of relevant papers dealing with solving the problem of passenger terminal capacity aims to develop a completely new concept in the observation of passenger terminal capacity.

Jelena PIVAC, mag. ing. traff.[1]
E-mail: jpivac@fpz.unizg.hr
doc. dr. sc. **Igor ŠTIMAC**[1]
E-mail: istimac@fpz.unizg.hr
red. prof. dr. sc. **Andrija VIDOVIĆ**[1]
E-mail: avidovic@fpz.unizg.hr
Karmela BOC, dipl. ing[2]
E-mail: karmela.boc@skole.hr
[1] Sveučilište u Zagrebu
Fakultet prometnih znanosti
Vukelićeva 4, 10000 Zagreb, Hrvatska
[2] Zrakoplovna tehnička škola Rudolfa Perešina
Rudolfa Fizira 6, 10410 Velika Gorica, Hrvatska

PREGLED UTJECAJA RAZINE KVALITETE USLUGE NA KAPACITET PUTNIČKOG TERMINALA ZRAČNE LUKE

Uspostava željene kvalitete usluge putničkog terminala zračne luke u cilju poboljšanja operativnih performansi predstavlja izazov za svaku zračnu luku. Recentna međunarodna istraživanja u zračnom prometu ukazuju na postupni oporavak zračnog prometa i u skladu s time potrebu za razvojem dodatne prometne infrastrukture. Ukoliko se dizajnu putničkog terminala u smislu infrastrukturnog i operativnog kapaciteta ne pristupi ispravno može doći do pada razine kvalitete usluge koja se pruža putnicima. U središtu ovog istraživanja bit će prikazano kako uspostava razine kvalitete usluge definirana od strane IATA-e može doprinijeti u optimiranju razine kvalitete usluge putničkog terminala, te će se analizirati utjecaj razine kvalitete usluge na dimenzioniranje kapaciteta putničkog terminala u odnosu na raznolikost poslovnih modela zračnih prijevoznika. S obzirom da ne postoji zajednička poveznica, kojom bi se taj problem jednolično opisao i riješio, u ovom radu bit će dan pregled relevantne literature iz područja istraživanja kapaciteta putničkog terminala, te će biti analizirani različiti pristupi rješavanju navedenog problema koji za cilj ima razvijanje novog unificiranog koncepta u promatranju i optimiranju kapaciteta putničkog terminala zračne luke uzimajući u obzir vrste poslovnih modela zračnih prijevoznika.

KLJUČNE RIJEČI

zračna luka; putnički terminal zračne luke; razina kvalitete usluge (LoS); kapacitet putničkog terminala; dimenzioniranje sadržaja; optimizacija.

REFERENCES

[1] Belobaba PP, Odoni AR, Barnhart C. *The Global Airline Industry*. John Wiley & Sons Ltd., Chichester, United Kingdom, 2009.

[2] International Air Transport Association (IATA). https://www.iata.org/en/publications/store/20-year-passenger-forecast/ [Accessed 11th Apr. 2022].

[3] International Air Transport Association (IATA). *Airport Development Reference Manual (ADRM)*. 9th edition. Montréal, Canada; 2004.

[4] International Air Transport Association (IATA). *Airport Development Reference Manual (ADRM)*. 10th edition. Montréal, Canada; 2014.

[5] International Air Transport Association (IATA): *Airport Development Reference Manual (ADRM)*. 11th edition. Montréal, Canada; 2019.

[6] Baker DM. Service quality and customer satisfaction in the airline industry: A comparison between legacy airlines and low-cost airlines. *American Journal of Tourism Research*. 2013;2(1): 67–77. doi: 10.11634/216837861302317.

[7] Ostrowski PL, O'Brien TV, Gordon GL. Service quality

and customer loyalty in the commercial airline industry. *Journal of Travel Research*. 1994;32(2): 16–24. doi: 10.1177/004728759303200203.

[8] Tse DK, Wilton PC. Models of consumer satisfaction formation: An extension. *Journal of Marketing Research.* 1988;25(2): 204–212. doi: 10.2307/3172652.

[9] Albacete Saez CA, et al. Service quality measurement in rural accommodation. *Annals of Tourism Research.* 2007;34(1): 45–65. doi: 10.1016/j.annals.2006.06.010.

[10] Pivac J, Vince D, Štimac I, Boc K. Analiza kvalitete usluge u putničkom terminalu zračne luke s aspekta putnika. *Zbornik radova 20. međunarodnog simpozija o kvaliteti Kvaliteta – jučer, danas, sutra.* 2021. p. 157–174. doi: 10.52730/LLGN5445.

[11] National Academies of Sciences, Engineering and Medicine. *Improving the airport customer experience.* Washington, DC: The National Academies Press; 2016.

[12] Livingstone A, Popovic V, Kraal BJ, Kirk PJ. Understanding the airport passenger landside retail experience. In: Israsena P, Tangsantikul J, Durling D. (Eds.) *Research: Uncertainty Contradiction Value - DRS International Conference 2012, 1-4 July, Bangkok, Thailand.* 2012. p. 1–18. https://dl.designresearchsociety.org/drs-conference-papers/drs2012/researchpapers/78.

[13] Mudambi SM, Schuff D. What makes a helpful review? A study of customer reviews on Amazon. Com. *MIS Quarterly.* 2010;34(1): 185–200. doi: https://doi.org/10.2307/20721420.

[14] Haddad RE. Exploring service quality of low cost airlines. *Services Marketing Quarterly*. 2019;40(4): 301–315. doi: 10.1080/15332969.2019.1665901.

[15] Ahn TH, Lee TJ. Service quality in the airline industry: Comparison between traditional and low-cost airlines. *Tourism Analysis*. 2011;16(5): 535–542. doi: 10.3727/108354211X13202764960582.

[16] Morash EA, Ozment J. Toward management of transportation service quality. *Logistics and Transportation Review*. 1994; 30, 115–140.

[17] Young C, Lawrence C, Lee M. Assessing service quality as an effective management tool: The case of the airline industry. *Journal of Marketing Theory and Practice*. 1994;2(2): 76–96.doi: 10.1080/10696679.1994.11501652.

[18] Han H, Hwang J. In-flight physical surroundings: Quality, satisfaction, and traveller loyalty in the emerging low cost flight market. *Current Issues in Tourism*. 2017;20(13): 1336–1354. doi: https://doi.org/10.1080/13683500.2014.960371.

[19] O'Connell JF, Williams G. Passengers' perceptions of low cost airlines and full service carriers: A case study involving Ryanair, Aer Lingus, Air Asia and Malaysia Airlines. *Journal of Air Transport Management*. 2005;11(4): 259–272. doi: 10.1016/j.jairtraman.2005.01.007.

[20] Lim J, Lee HC. Comparisons of service quality perceptions between full service carriers and low cost carriers in airline travel. *Current Issues in Tourism*. 2019;23: 1261-1276. doi: 10.1080/13683500.2019.1604638.

[21] Koklic MK, Kukar-Kinney M, Vegelj S. An investigation of customer satisfaction with low-cost and full-service airline companies. *Journal of Business Research*. 2017;80: 188–196. doi: 10.1016/j.jbusres.2017.05.015.

[22] Chiou YC, Chen YH. Factors influencing the intentions of passengers regarding full service and low cost carriers: A note. *Journal of Air Transport Management*. 2010;16(4): 226–228. doi: 10.1016/j.jairtraman.2009.11.005.

[23] Chou CC, et al. An evaluation of airline service quality using the fuzzy weighted SERVQUAL method. *Applied Soft Computing*. 2011;11(2): 2117–2128. doi: 10.1016/j.asoc.2010.07.010.

[24] Transportation Research Board. *ACRP Report 25 - Airport passenger terminal planning and design, Volume 1: Guidebook, Airport Cooperative Research Program*. Washington, USA; 2010.

[25] Brunetta L, Right L, Andreatta G. An operations research model for the evaluation of an airport terminal: SLAM (Simple Landside Aggregate Model). *Journal of Air Transport Management.* 1999; 161–175. doi: 10.1016/S0969-6997(99)00010-1.

[26] Štimac I. *Optimiranje udjela prijevoznika u kapacitetima zračne luke*, Ph.D. Thesis. Fakultet prometnih znanosti, Zagreb, 2017.

[27] Zagrafos KG, et al. *Modelling and managing airport performance*. 1st edition. Chichester, UK: John Wiley and Sons Ltd; 2013.

[28] Svrcek T. *Planning level decision support for the selection of robust configurations of airport passenger buildings*. MIT, Dept. of Aeronautics & Astronautics, Flight Transportation Laboratory. FTL Report No. R94-6, 1994.

[29] Pavlin S. *Aerodromi I*. Zagreb: Fakultet prometnih znanosti; 2006.

[30] Hae Choi J. Changes in airport operating procedures and implications for airport strategies post-COVID-19. *Journal of Air Transport Management*. 2021;94. doi: 10.1016/j.jairtraman.2021.102065.

[31] Odoni AR, de Neufville R. Passenger terminal design. *Transportation Research.* 1992;26A(1): 27–35.

[32] Kim D-U, Jie M-S, Choi W-H. Airport simulation based on queuing model using ARENA. *International Journal of Advanced Science and Technology*. 2018;115: 125–134. doi: 10.14257/ijast.2018.115.12.

[33] Guizzi G, Murino T, Romano E. A discrete event simulation to model passenger flow in the airport terminal. *Proceedings of the Applied Computing Conference*. 2009.

[34] Andreatta G, Brunetta L, Righi L, Jacur GR. *Simulation vs. analitical models for the evaluation of an airport landside.* http://www.aerohabitat.eu/uploads/media/25-01-2010_-_Simulation_vs_Analytical_models_-_Airport_side_Brunetta_Andreatta.pdf.

[35] Adeke PT. Modelling of queuing process at airport check-in system: A case study of Manchester and Leeds-Bradford airports. *Nigerian Journal of Technology (NIJOTECH).* 2018;37(1). doi: 10.4314/njt.v37i1.5.

[36] Nommik A, Antov D. Modelling regional airport terminal capacity. *16th Conference od Reliablity and Statitiscs in Transportation and Communication, RelStat 2016, 19-22 Oct. 2016, Riga, Latvia.* 2016.

[37] Adacher L, Flamini M, Guaita M, Romano E. A model to optimize the airport terminal departure operations. *20th EURO Working Group on Transportation Meeting, EWGT 2017, 4-6 Sep. 2017, Budapest, Hungary*. 2017. doi: 10.1016/j.proeng.2017.01.083.

[38] Pivac J, Štimac I, Bračić M, Steiner S. Utjecaj razine

kvalitete usluge na dimenzioniranje putničkog terminala zračne luke. *Zbornik radova Kvaliteta – jučer, danas, sutra*. 2020. p. 323–345. doi: 10.30657/hdmk.2020.20.

[39] International Civil Aviation Organization (ICAO). *Economic development*. https://www.icao.int/sustainability/pages/low-cost-carriers.aspx [Accessed 5th May 2022].

[40] Pandey MM. Evaluating the strategic design parameters of airports in Thailand to meet service expectations of low-cost airlines using the fuzzy-based QFD. *Journal od Air Transport Management.* 2020. doi: 10.1016/j.jairtraman.2019.101738.

[41] Lawton T, Solomko, S. When being the lowest cost is not enough: Building a successful low fare airline business model in Asia. *J. Air Transp. Manag*. 2005;11: 355–362. doi: 10.1016/j.jairtraman.2005.03.001.

[42] De Neufville R. Low-cost airports for low-cost airlines: Flexible design to manage the risks. *Transp. Plan. Technol*. 2008. doi: 10.1080/03081060701835688.

[43] Wong JT, Liu TC. Development and application of an airport terminal simulation model. A case study of CSK Airport. *Transportation Planning and Technology*. 1998;22: 73–86. doi: 10.1080/03081069808717620.

[44] Ballis A, Stathopoulos E, Sfakianaki E. Sizing of processing and holding air terminal facilities for charter passengers using simulation tools*. International Journal of Transport Management.* 2002.

[45] Sabar R, Anuar NK, Abdullah R. Preferences of low-cost passengers, low cost airlines and airport management on Low Cost Terminal (LCT) facilities development model. *International Journal of Supply Chain Management*. 2018;7(6): 150–157.

[46] Barrett SD. How do the demands for airport services differ between full-service carriers and low-cost carriers? *Journal of Air Transport Management*. 2004;10(1): 33–39. doi: 10.1016/j.jairtraman.2003.10.006.

[47] Jain JL, Mohanty SG, Bohm W. *A course on queuing models*. New York: Chapman & Hall/CRC; 2007. doi: https://doi.org/10.1201/b15892.

[48] Pavlin S. *Aerodromi II - Planiranje aerodroma*. Zagreb: Fakultet prometnih znanosti, Sveučilište u Zagrebu; 2014.

[49] Brunetta L, Romanin-Jacur G. *A flexible model for the evaluation of an airport terminal*. Department of Pure and Applied Mathematics, University of Padova; 2001.

[50] Caot Y, Nsakanda LA, Pressman I. *A simulation study of the passenger check-in system at the Ottawa International Airport*. SCSC; 2003.

[51] Bulut E, Duru O, Huang ST. A multidimensional QFD design for the service quality assessment of Kansai International Airport, Japan. *Total Qual. Manag. Bus. Excel*. 2016;29(1–2): 202–224. doi: 10.1080/14783363.2016.1174058.

[52] Pandey M, Singh D, Jayraj R, Damodaran K. Evaluating the success factors for development and sustenance of low-cost regional airports in India using fuzzy multi-criteria decision making method. *Journal of Applied Economic Sciences*. 2018;13(1): 89–100.

[53] Sivrikaya O, Tunç E. Demand forecasting for domestic air transportation in Turkey. *Open Transp.* J. 2013;7: 20–26. doi: 10.2174/1874447820130508001.

[54] Priyadarshana M, Fernando AS. Modeling air passenger demand in Bandaranaike international airport Sri Lanka*. J. Bus. Econ. Policy.* 2015;2(4): 146–151.

[55] Alsumairi M, Tsui KWH. A case study: The impact of low-cost carriers on inbound tourism of Saudi Arabia. *J. Air Transp. Manag*. 2017;62: 129–145. doi: 10.1016/j.jairtraman.2017.04.001.

[56] Srisaeng P, Baxter GS, Wild G. Forecasting demand for low cost carriers in Australia using an artificial neural network approach. *Aviation.* 2015;19(2): 90–103. doi: 10.3846/16487788.2015.1054157.

[57] Srisaeng P, Baxter G, Richardson S, Wild G. A forecasting tool for predicting Australia's domestic airline passenger demand using a genetic algorithm. *J. Aerosp. Technol. Manag.* 2015;7(4): 476–489. doi: 10.5028/jatm.v7i4/475.

[58] El-Din MM, Farag M, Abouzeid A. Airline passenger forecasting in Egypt (domestic and international). *Int. J. Comput. Appl*. 2017;165(6): 1-5. doi: 10.5120/ijca2017913113.