Journal of Service Science and Management, 2022, 15, 206-225
https://www.scirp.org/journal/jssm
ISSN Online: 1940-9907
ISSN Print: 1940-9893

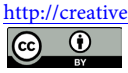
Evaluation of the Elements of Ageing-Friendly Service Level for the Smart Construction of Major Hub Airports in China

Xiaoyang Guo[1], Ruiling Han[1,2*], Zongzhe Li[1], Xiang Zhou[1]

[1]College of Geographical Sciences, Hebei Normal University, Shijiazhuang, China
[2]College of Home Economics, Hebei Normal University, Shijiazhuang, China
Email: *hrl309@163.com

How to cite this paper: Guo, X. Y., Han, R. L., Li, Z. Z., & Zhou, X. (2022). Evaluation of the Elements of Ageing-Friendly Service Level for the Smart Construction of Major Hub Airports in China. *Journal of Service Science and Management, 15,* 206-225.
https://doi.org/10.4236/jssm.2022.153013

Received: March 28, 2022
Accepted: June 25, 2022
Published: June 28, 2022



Abstract

The smart construction of hub airports is generally mature, but there are differences in ageing-friendly services. Based on the DEMATEL-AHP method, this paper analyzes the influencing factors and differences in the development level of ageing-friendly services in four major hub airports in China (Beijing Daxing International Airport, Shanghai Pudong International Airport, Guangzhou Baiyun International Airport, and Shenzhen Baoan International Airport). The paper finds that: the indicators of the degree of full passenger service in the four major hub airports have the highest influence value as active elements within the ageing-friendly service level indicator system, while full escort service and special passenger or caring service counters are most likely to be influenced by other indicator elements; the degree of full passenger self-service, priority travel service access, and baggage check-in security system or manual check-in service are the core elements that influence the ageing-friendly level the core elements that influence the improvement of the ageing-friendly service level at hub airports determine the trend direction of the overall ageing-friendly service level; immigration processing services and hand luggage security check information management system service are mostly shown as the cause elements; the service scope covered by the ageing-friendly service content at hub airports has little difference, but the emphasis of the ageing-friendly service is different.

Keywords

Hub Airport, Smart, Ageing-Friendly, Service Level, Elements

1. Introduction

The accelerating pace of ageing in China coexists with the phenomenon of social

"unfitting for old age" (Gong & Yin, 2019). From 1982 to 2019, the number of people over 65 years of age increased from 49.91 million to 176.03 million, accounting for 4.9% to 13.5% of China's total population, and the elderly dependency ratio increased from 8.0% to 19.8%, with China expected to surpass Japan as the world's the country with the highest level of ageing in the world (Xu, 2010). The contradiction between the growing need for a better life and the "unfit for old age" of social provision has gradually come to the fore, focusing on the changes in social mobility and elderly care patterns caused by the development of smart technology (Gong & Yin, 2019), and the conflict between the application of smart technology and the humanistic nature of elderly services (Li, 2018). For example, the urban transportation system lacks barrier-free facilities and signage guidance, and the bus system has long transfer distances (Li & Chen, 2020); the elderly care system in the smart medical industry has difficulties in meeting the spiritual needs of different levels of audience groups (Wu, 2021); home care is gradually becoming smart, but the new smart community elderly care service model covers a narrow range of targets, and the acceptance of various smart terminals by elderly groups is low (Zhou, 2021); the financial system such as insurance companies and commercial institutions refuse to accept cash, and non-financial services are cumbersome to operate (Guo, 2021).

With the popularity and convenience of civil aviation transportation, the probability of senior citizens taking civil aviation transportation is gradually increasing. According to data from "Go.com", as of September 2018, the number of tickets for senior citizens aged 60 years and above accounted for 6.2% of the total number of tickets; In 2020, over 70% of older travellers choose not to travel with their children, but as older travellers are slower to think and move, and choose to travel alone with little experience of air travel, they can be unfamiliar with both the process and content of airport services (Liu, 2018). Moreover, current airport services are somewhat inadequate in terms of ageing fitness: the scenarios of smart services in various parts of the airport are not conducive to the understanding and application of elderly travellers (Wang, 2020a), and elderly travellers and elderly travellers with disabilities create a burden of using smart electronic devices (Sun, 2021). In the context of epidemic prevention and control normality, even highly educated elderly travellers need external assistance to complete the travel checklist and health code information in the face of the popularity of intelligent services (Wang, 2021); elderly travellers generally have difficulties in using various smart security digital devices and need guidance from airport service staff (Tian & Xue, 2021). The intelligent upgrading of various service facilities for air travel has not provided personalised services for the needs of elderly travelers, and a mismatch between the supply of air services and travel demand has emerged (Yu, 2021).

In May 2020, the Civil Aviation Administration of China (CAAC) released the first batch of "I do practical things for the masses" tasks, including "facilitating air travel for the elderly", which explicitly mentions retaining offline sales windows,

supporting cash payment and voucher printing, improving manual counter services, and setting up priority ticketing windows, special waiting areas or green channels for the elderly. In September and December 2020, China's Ministry of Industry and Information Technology issued the "Guidance on Promoting Information Accessibility" and the "Special Action Plan for Internet Application Ageing and Accessibility Retrofitting" respectively, focusing on special activities for Internet application ageing and accessibility retrofitting nationwide, and focusing on solving the difficulties encountered by the elderly and other special groups in using intelligent technologies such as the Internet. In November 2020, the State Council issued the Implementation Plan on Effectively Addressing the Difficulties of Using Smart Technology for the Elderly, and the Civil Aviation Administration (CAA) has been thoroughly implementing the work requirements of the document as it relates to the travel of elderly passengers to create a convenient and warm travel experience for them.

Smart airports are one of the distinguishing marks of world-class airports and are the future direction of airports. They place more emphasis on passenger-centric operations, using technologies such as the Internet of Things and cloud computing to organically integrate and collaborate with airlines, passengers, aircraft, and airports, while ensuring parallel operations in aviation and non-aviation areas (ground services, airport commerce, airline catering, parking, etc.), relying on digital intelligent systems for efficient service and management, and providing visual presentation and intelligent support to users (Kan & Sun, 2019). At present, there are richer independent results on technical applications of smart airports and ageing-appropriate research, such as the technical applications of smart airports mainly focus on Internet technology (Zhao & Li, 2021), 5G technology (Wang, 2020b), big data and cloud computing technology (Ji, 2020), Augmented Reality (AR)technology (Zhang, 2021), artificial intelligence technology (Yang, Fan & An, 2020) in airport construction, operation (Huang et al., 2020), use, management and marketing of airports, the informatization of airports (Xie, 2020) and the active creation of digital airports (Keskin & Salman, 2020); foreign studies on ageing-friendly services mainly cover ageing-friendly services in the field of pedagogy (Sliepenbeek et al., 2021), the evaluation of the gaps in social services and security for older people (Hoffman, Webster, & Bynum, 2020), the design of ageing-friendly services for people with dementia in rural areas (Marshall et al., 2018), the improvement and expectations of social services for older people in the Autonomous Community of Galicia (Iglesias-Souto et al., 2008). Domestic research on ageing has focused on the social impacts of ageing (Dieteren et al., 2020), the impact of household carbon emissions (Fan et al., 2021), and the challenges faced by older people in terms of adaptation and leisure (Dattilo et al., 2018), the technological applications of smart ageing such as the Smart Ageing Spatial Positioning System (Yu & Wang, 2021), the practice and countermeasures of community-based home care services based on big data (Jing, 2020), the spatial distribution characteristics of urban nursing homes in

China and their influencing factors (Jiang et al., 2021), etc. However, there are relatively few studies on the ageing appropriateness of smart airports, and the existing studies mainly focus on three points: 1) the development and design of ageing-friendly service products for airports, such as intelligent walking sticks (Zhang & Liu, 2020) and ageing-friendly navigation APP (Zhang, 2020). 2) The ageing-friendly construction of intelligent travel in civil aviation (Sun, 2021) and countermeasures, including improving the standardized service system and basic service facility functions for travel of the elderly population, cultivating more stable air travel products, optimizing the travel quality of elderly passengers, and creating personalized civil aviation travel service scenarios (Yu, 2021), etc. 3) The construction of ageing-friendly integration of civil aviation, such as ageing-friendly solutions for the integration of urban and civil transportation (Li & Chen, 2020), the behavioural patterns exhibited by elderly passengers choosing airport ground transportation modes (Chang, 2013), and the development and guarantee of elderly products for civil aviation + tourism (Lu, 2021; Yang, 2021), etc.

The development and renovation of ageing-friendly airports have great potential and is an effective way to expand domestic demand for civil aviation services. At present, the ageing-friendly construction of airports mainly focuses on the transformation of ageing-friendly products and the establishment of concepts. For example, Hohhot Airport has formulated a "one-stop, full-process" service model for security checks for the elderly; Ganzhou Airport has carried out training on ageing-friendly services for airport service personnel to improve the quality of genuine services for elderly passengers; Jiangxi Airport Group has made solving the difficulties of using intelligent technology for the elderly a key service task for the year; Guangxi Beihai Airport has issued the "Beihai Airport Air Transport Service Plan for the Elderly" to strengthen the service skills training for airport employees facing elderly and other special passengers and to improve the quality of services comprehensively. The market size of smart airports in China after "the 13th Five-Year Plan" is 22.5 billion RMB; the current market size of smart security check lanes is expected to be about 16 billion RMB by 2023. Since the development of ageing-friendly construction initiatives in different airports in China is different and uneven, in order to effectively present the current situation of ageing-friendly development in China's airports, this paper firstly uses the DEMATEL method to determine the impact elements, central elements, and cause elements of ageing-friendly service levels in China's four major hub airports (Beijing Daxing International Airport, Shanghai Pudong International Airport, Guangzhou Baiyun International Airport, and Shenzhen Baoan International Airport). The article then uses the DEMATEL-AHP model to identify the comprehensive impact degree based on the actual existing ageing-friendly service contents of the four major hub airports, and conducts a comparative study on the ageing-friendly service levels of each of the four major hub airports according to four parts: smart airport construction, intelligent security check system, security check service, and special service. Taking the hub

airports as representative objects, the article analyses the ageing-friendly service levels of airports on the basis of intelligent construction, and provides theoretical suggestions and case bases for the comprehensive promotion of intelligent and ageing-friendly synergistic development of airport services.

2. Study Data and Subjects

2.1. Data Sources and Processing

Firstly, based on the statistics from 2006-2020, "Civil Aviation from Statistics", "China Statistical Yearbook", "China City Statistical Yearbook", "Beijing Statistical Yearbook", "Guangzhou Statistical Yearbook", "Shenzhen Statistical Yearbook", "Shanghai Statistical Yearbook", etc., we obtained the traffic data of the top 50 airports in the world in terms of passenger throughput in China in 2019, of which Shanghai Pudong International Airport ranked 8th, Guangzhou Baiyun International Airport ranked 11th and Shenzhen Baoan International Airport ranked 26th; while Beijing Daxing International Airport was officially opened in 2019 and the passenger throughput had exceeded 16 million in 2020 **Figure 1**, so Daxing Airport (referred to as Daxing Airport), Pudong Airport (referred to as Pudong Airport), Baiyun Airport (referred to as Baiyun Airport) and Baoan Airport (referred to as Baoan Airport) as the research object of this paper.

2.2. Study Subjects

From 2005 to 2019, the number of flight departures at Pudong Airport, Baiyun Airport and Baoan Airport increased by 2.5 times, 2.32 times and 2.44 times respectively, passenger circulation increased by 4.36 times, 4.03 times and 7.41 times respectively, the growth rate of passenger traffic increased by 3.22 times, 2.99 times and 3.26 times respectively, and passenger traffic increased by 3.28 times, 2.93 times and 6.06 times respectively. In 2020, China's civil aviation passenger traffic fell by 38.2% year-on-year under the impact of the COVID-19, and passenger throughput at four airports was also affected by the Epidemic, with international flights most significantly affected.

Of the four hub airports, Daxing Airport is the world's largest single airport terminal and a mega hub for integrated international air transport links emerging from a digital context. At present, Daxing Airport cooperates with more than 60 domestic and foreign airlines and operates 179 routes to 149 cities, covering 179 destinations around the world. Pudong Airport is one of the three major gateway complex hubs in China and the number one transportation hub airport in East China. Its airport has 220 routes and 297 cities, connecting a total of 297 destinations in 47 countries and regions around the world. As the largest comprehensive transportation hub in South China, Baiyun Airport is one of the important international aviation hubs of the "One Belt, One Road" initiative and the "Air Silk Road", and is also the core hub airport of the Guangdong, Hong routes to 232 cities, including more than 90 international and regional destinations. Baoan Airport has a total of 188 routes and a network of 133 domestic

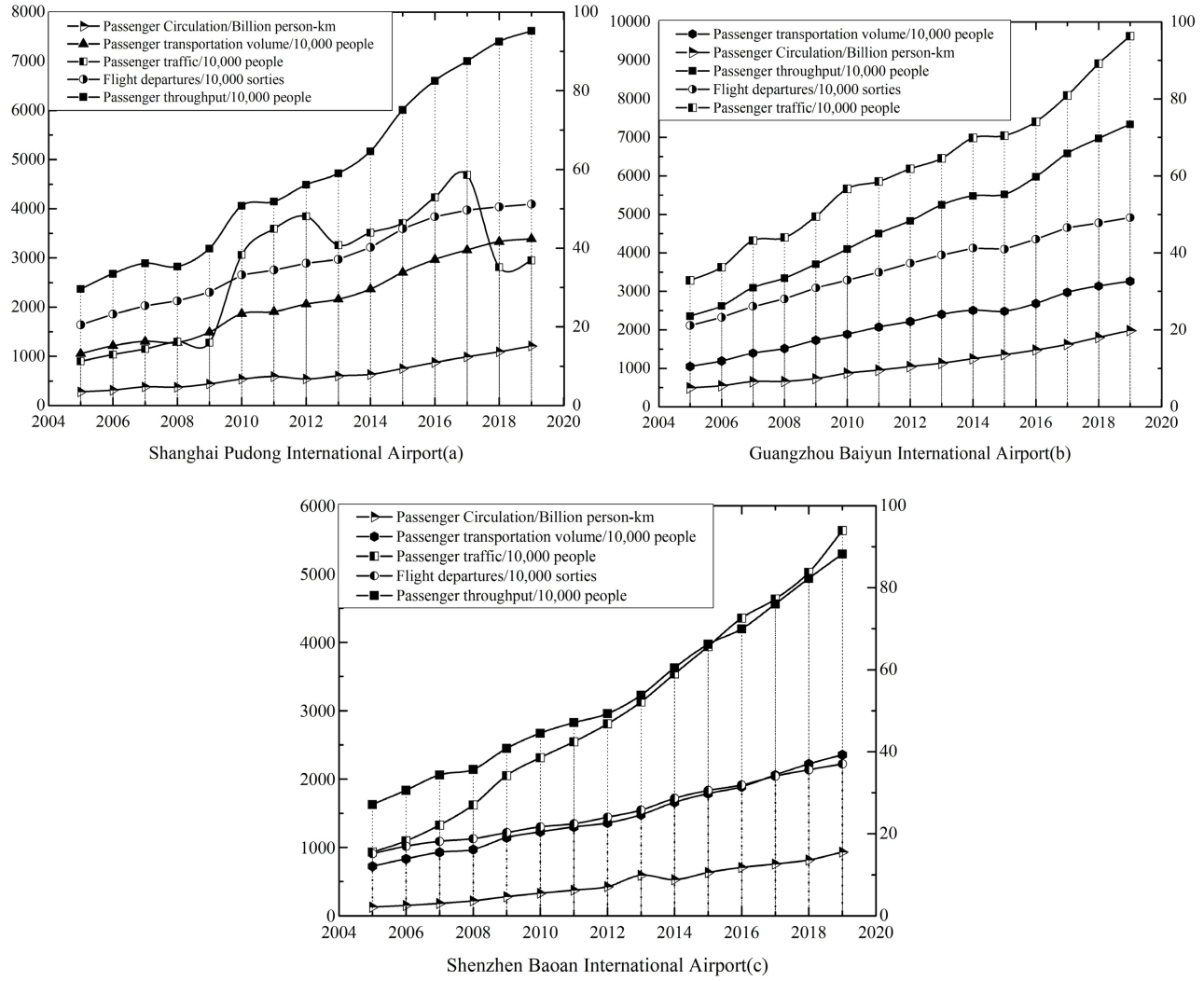


Figure 1. Change in flight departures, passenger circulation, passenger traffic, passenger transporation volume and passenger throughput at hub airports.

passenger routes, with over 1000 daily departures and landings, making it one of the busiest airports in the world.

3. Research Methodology and Indicator System

3.1. DEMATEL Method

The DEMATEL method is a methodology proposed by scholars A. Gabus and E. Fontela from the Battelle Laboratory in the USA for the analysis of complex and difficult problems. It is a method of systematic analysis using graphical and matrix tools (Qian, Xu, & Ma, 2021) and is mainly used to solve complex problems involving multiple objectives and attributes. Applying it to the study of airport ageing can help in the assessment of the correlation between the elements of each indicator.

1) The direct relationship matrix is used to express the degree of association between elements obtained by two-by-two comparison of the indicator elements

through expert consultation methods, drawing on existing research (Chang, 2013) and setting a scale of 0 - 4, with 0 indicating no influence and the higher the number, the stronger the association.

$$A=\begin{bmatrix} 0 & A_{12} & \cdots & A_{1n} \\ A_{21} & 0 & \cdots & A_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ A_{n1} & A_{n2} & \cdots & 0 \end{bmatrix}=\left(A_{ij}\right)_{n\times n} \tag{1}$$

$$N=\left(\frac{d_{ij}}{\sum_{j=1}^{n} d_{ij}}\right)_{n\times n} \tag{2}$$

In the formula, "A" represents the direct relationship matrix, $1\le i\le n$, $1\le j\le n$, and when $i=j$, $A_{ij}=0$, indicating that factor Ai has no direct influence on factor A_j; if there is a direct influence, it is expressed as A_{ij}. *"N"* is the result of normalising the matrix *"A"* by summing the elements of each row and taking the maximum value, *"n"* represents the number of indicators and d_{ij} represents the degree of influence of indicator i on indicator j.

2) The combined impact matrix is used to assess the importance of each indicator element in the evaluation system. Specifically expressed as:

$$T=\left(N+N^2+N^3+\cdots+N^k\right)=\sum_{k=1}^{\infty} N^k \tag{3}$$

$$T=N\left(I-N\right)^{-1} \tag{4}$$

In the formula, "T" represents the integrated impact matrix; "I" is the unit matrix, i.e. a matrix with diagonal element values of 1 and other elements of 0.

3) The degree of influence, degree of being influenced, degree of centrality and degree of cause are expressed as:

$$D_i=\sum_{j=1}^{n} t_{ij}\left(i=1,2,3,\cdots,n\right) \tag{5}$$

$$C_i=\sum_{j=1}^{n} t_{ji}\left(i=1,2,3,\cdots,n\right) \tag{6}$$

$$M_i=D_i+C_i \tag{7}$$

$$R_i=D_i-C_i \tag{8}$$

In the formula, D_i represents the degree of influence, indicating that the more influential elements in the system will affect the system trend and the development of other elements in the system. C_i represents the degree of being influenced and indicates the elements within the system that are susceptible to the influence of other elements. M_i is the centrality, which indicates the position of t_{ij} in the evaluation index system and the degree of its role, the larger M_i indicates that it is in the core position in the index system and the greater the degree of its role on other indicators.

3.2. AHP Model

AHP is a multi-objective decision analysis method that combines qualitative and

quantitative analysis methods (Zhao et al., 2014). It mainly uses the YAAHP meta-decision software to decompose complex problems into a number of levels and a number of factors to establish a hierarchical structure model; followed by a comparative judgement of the importance of indicators among themselves; by calculating the maximum eigenvalues of the judgement matrix and the corresponding eigenvectors, the weight values of different indicator elements at the programme level on the decision target are derived. Specifically:

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \left(i, j = 1, 2, 3, \cdots, n\right) \tag{9}$$

In the formula, a_{ij} represents the importance of indicator i to indicator j; $\bar{a}_{ij}$ represents the normalised indicator element.

$$\bar{W}_i = \sum_{j=1}^{n} \bar{a}_{ij} \left(i, j = 1, 2, 3, \cdots, n\right) \tag{10}$$

In the formula, $\bar{W}_i$ represents the vector obtained by summing the normalized judgment matrix by rows, which is further normalized to yield the eigenvalues $W = \left(\bar{W}_1, \bar{W}_2, \bar{W}_3, \cdots, \bar{W}_n\right)^{\mathrm{T}}$.

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{\left(AW\right)_i}{nW_i} \tag{11}$$

$$CR = \frac{CI}{RI} \tag{12}$$

In the formula, $\lambda_{\max}$ represents the maximum eigenvector, CR represents the random consistency ratio, CI represents the consistency index, and RI represents the average random consistency index. The larger the value of CI, the greater the deviation of the judgment matrix from full consistency; conversely, the closer it is to full consistency. When $CR < 0.1$, the judgement matrix has acceptable consistency; conversely, the judgement matrix needs to be amended.

3.3. DEMENTAL-AHP Combined Impact Degree

As both the AHP model and the DEMATEL method are based on the importance and weights of each factor indicator obtained through an expert questionnaire, this paper combines the two by multiplying and normalizing the combined weights of each indicator element with the centrality (Chang, 2013), in order to calculate the combined impact degree Y_i of each influencing factor indicator.

$$Y_i = \frac{M_i W_i}{\sum_{j=1}^{n} M_j W_j} \tag{13}$$

In the formula, Y_i represents combined influence, M_i represents centrality and W_i represents combined weight.

3.4. Ageing-Friendly Evaluation Index System for Hub Airports

The comprehensive ageing-friendly evaluation of hub airports is a complex

process. Based on the existing ageing-friendly construction initiatives in domestic hub airports, smart airports and ageing-friendly specific research features, this paper conducted index selection and identified four evaluation contents: smart airport construction, intelligent security check systems, security check services and special services, and identified nearly 50 original indicators in following the principles of scientificity, operability, independence and relevance. In order to meet the principles of principal component and independence of indicators, principal component analysis and independence analysis were conducted on the original indicator system, and finally 4 primary indicators, 11 secondary indicators, and a total of 28 specific indicators were determined to constitute the comprehensive evaluation index system of ageing-friendly smart airport Table 1. All data used in the DEMATEL-AHP model analysis is derived from the evaluation results of experts and frontline staff. Based on the expert consultation method, questionnaires were distributed to relevant research experts and academics, airport service staff, passengers and others to obtain the basic data for the study.

4. Analysis of the Elements of Each Indicator for the Evaluation of the Ageability of Hub Airports

4.1. Elements Influencing the Level of Ageing-Friendly Services at Hub Airports

The influence degree value of passenger full self-service (A_1) is higher in all four hub airports, 4.3682, 4.1945, 4.1486 and 4.4048 respectively Figure 2(a), which is significantly higher than other indicators, showing that it is the most important element influencing the level of ageing-friendly services in airports. The negative attribute of the A_1 indicator also reflects the fact that the smart terminals of airport services are "unfit for old age" and that elderly passengers find it difficult to complete all aspects of airport services on their own with the help of smart devices, thus highlighting the problem of the disconnect between airport wisdom and age-friendliness. By airport, Daxing Airport's dual-view, dual-channel X-ray security system service (A_{13}) has the greatest positive impact on the level of age-friendly services at the airport (4.1298). The system's sunken design helps to achieve the dual function of screening elderly passengers and passing baggage, reducing the number of security checks while taking into account the physical fitness of elderly passengers themselves. Pudong Airport's hand luggage screening information management system service (A_7) performs well in terms of ageing (3.6480), which enables information management of the entire passenger screening process through centralised integration of information. Baiyun Airport's international security screening information management system service (A_6) performs well (3.7255), with its integrated information management of the departure system, baggage security X-ray machine system and CCTV surveillance system based on passenger information, providing an important guarantee of flight safety at the airport. The wheelchair elderly passenger service (A_{28}) at Baoan Airport is highly ageing-friendly (4.0456). The initiative is aimed at elderly

Table 1. Comprehensive evaluation index system for ageing-friendly smart airports.

Tier 1 indicators	Tier 2 indicators	Indicator Marker	Evaluation content	Indicator attributes	Combined weighting of indicators
Smart airport construction	Smart Terminal	A_1	The extent of full self-service for passengers	−	0.06
		A_2	Baggage tracking and positioning with radio frequency identification	+	0.0101
		A_3	Immigration processing services	+	0.0094
		A_4	5G+Smart Scenario Application Fit	+	0.0367
		A_5	The extent of digital media placement	+	0.0179
Intelligent Security Screening System	IoT systems	A_6	International Security Screening Information Management System Services	+	0.0977
		A_7	Hand luggage Security Screening Information Management System Service	+	0.0488
	Security Screening Information System	A_8	Intelligent Passenger Security Screening System Service	+	0.0156
		A_9	"e-Security" online booking service	+	0.0468
	Intelligent return basket system	A_{10}	Automatic pick-up service for empty baskets of luggage	+	0.0306
		A_{11}	Automatic empty basket transfer and sorting service	+	0.0102
	X-Ray Machine Systems	A_{12}	Millimeter-wave security gates pass inspection	+	0.0347
		A_{13}	Dual view and dual channel X-ray security system services	+	0.0069
Security Screening Services	Ticketing session	A_{14}	Self-service or manual telephone ticketing service	+	0.1032
	Check-in session	A_{15}	Self-service or manual check-in service	+	0.0525
	Consignment session	A_{16}	Baggage check-in security service or manual check-in service	+	0.0223
	Security Screening Sessions	A_{17}	Featured Services Security Screening App	+	0.0397
	Boarding session	A_{18}	Scanning with AR glasses	+	0.0125
Special Services	Services for the whole process chain at the airport	A_{19}	Senior Care Edition App or WeChat applet	+	0.0095
		A_{20}	Health Screening Service for the Elderly	+	0.0052
		A_{21}	Priority travel service access	+	0.1031
		A_{22}	The extent to the achievement of a full escort service	+	0.0363
		A_{23}	Airport Passenger Service Centre	+	0.0066
		A_{24}	Special Passenger Service Counter or the Caring Service Counter	+	0.0129
		A_{25}	Caring Seat Exclusive Service for Elderly Passengers	+	0.0225
		A_{26}	Volunteer Assistance Service Process Nodes	+	0.0171
		A_{27}	Electric car pick-up service for elderly passengers	+	0.0493
		A_{28}	Wheelchair elderly passenger service	+	0.0819

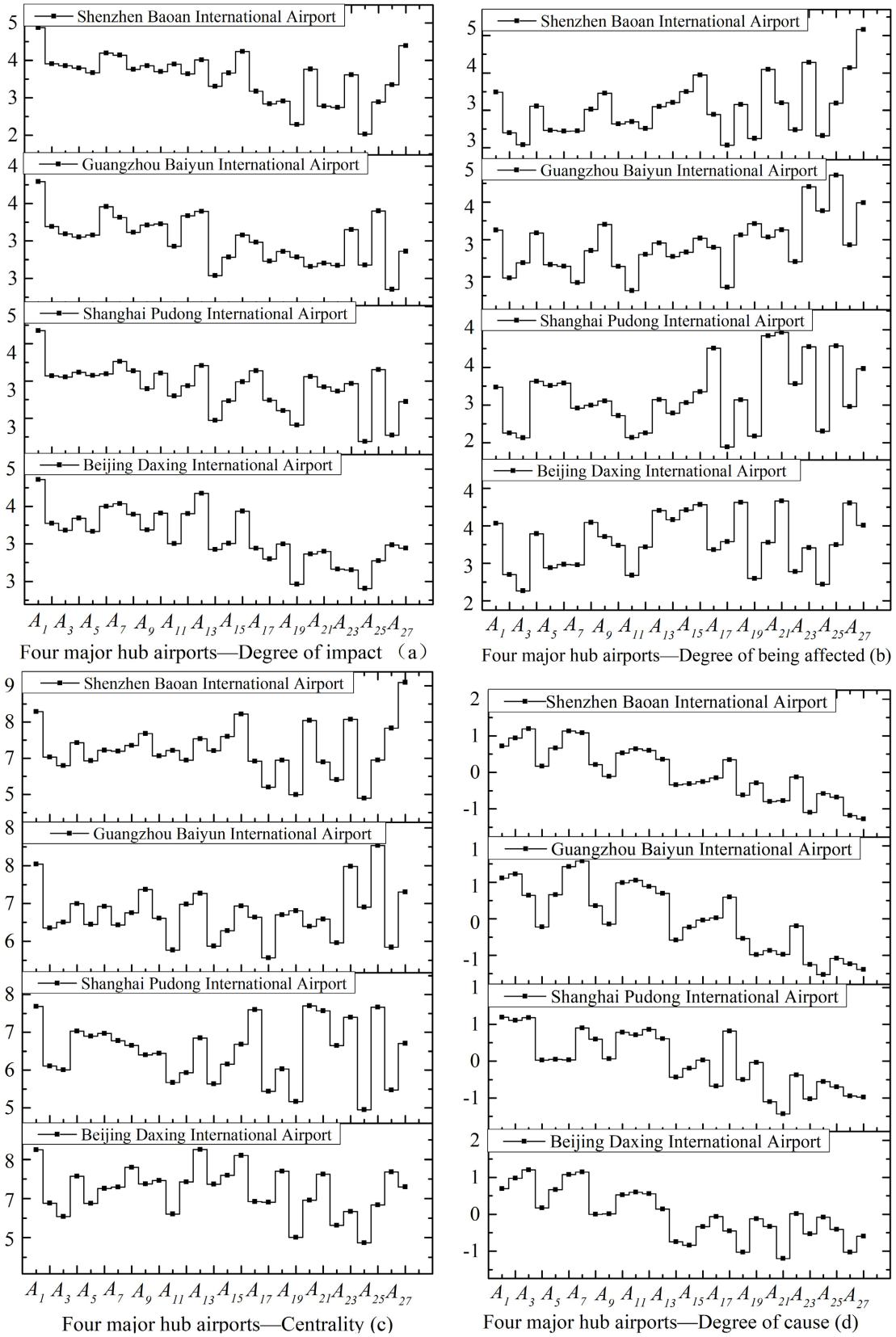


Figure 2. Changes in the degree of impact (a), degree of being affected (b), degree of centrality (c) and degree of cause (d) at the four major hub airports.

passengers and elderly passengers with disabilities, who are assisted by airport service staff to go through the wheelchair passenger service procedures and sent to the caring security channel, achieving both wisdom and ageing.

The main indicator elements with low impact at the four major hub airports are the Caring Seat Exclusive Service for Elderly Passengers (A_{25}) and the Electric car pick-up service for elderly passengers (A_{27}). The impact degree values of the A_{25} indicator for Daxing Airport, Pudong Airport and Baoan Airport are 2.4784, 2.2262 and 2.2725 respectively, reflecting the different emphasis on the content of ageing-friendly services at hub airports, indicating that more seats should be provided for elderly passengers and the allocation of resources for elderly passenger services should be optimised. Baiyun Airport has an impact degree value of (2.3388) for indicator A_{27}, indicating that the airport has not adequately considered the relationship between airport terminal distance and the experience of older passengers.

The highest influenced values for each of the ageing indicator elements at the four hub airports are mainly manifested in two ways and are displaying a high degree of ageing characteristics **Figure 2(b)**: The highest values at Daxing Airport and Pudong Airport are both for the extent to the achievement of a full escort servicee (A_{22}), at 4.1890 and 4.2271 respectively; Baiyun Airport and Baoan Airport have higher values for special passenger service counter or the caring service counter (A_{24}), at 4.1660 and 4.4353 respectively, indicating that A_{22} and A_{24} are subsidiary elements of the level of ageing-friendly airport services and are influenced by other indicator elements are higher. Due to the high level of wisdom of A_1 indicator, the level of ageing of hub airports decreases; while A_{22} and A_{24} as the influenced elements are influenced by A_1 but their attributes are positive, i.e. the level of ageing of hub airports fluctuates, but the overall trend is still better. As a result, the four hub airports have been able to increase their ageing-friendly services by increasing the number of ageing-friendly measures at the full escort service and special passenger or caring service counters to offset the negative impact of A_1. By airport, the A_{22} indicators of Daxing and Pudong airports are directly related to the quality of ageing services, which is mainly reflected in the fact that staff are assigned to accompany and guide the airport during the formalities of all services. Baiyun Airport and Baoan Airport's A_{24} indicator is an excellent indicator of ageing-friendly services, providing a "one-stop" check-in service for a clearly defined target group. For example, Baoan Airport has arranged for airport volunteers to provide on-site service guidance and battery-operated pick-up service for elderly passengers in need, so as to create a healthy and safe travel environment and convenience for elderly passengers.

4.2. Core Influencing Factors for Ageing-Friendly Service Levels at Hub Airports

The outcome values for the centrality of each indicator element vary considerably between the four hub airports **Figure 2(c)**. The highest centrality value of the ageing-friendly indicator elements at Daxing Airport is the extent of full self-service

for passengers (A_1) (8.1197), while the highest centrality values at Pudong Airport, Baiyun Airport and Baoan Airport are for the volunteer assistance service process nodes (A_{26}) (8.0245), priority travel service access (A_{21}) (7.5478), baggage check-in security service or manual check-in service (A_{16}) (8.0821), reflecting that the four major hub airports have better reconciled the contradictions between smart and ageing-friendly development. Of these, the A1 indicator is characterized by a combination of self-service and intelligence, and Daxing Airport has realized that passengers can walk through the airport with a single face from ticketing, check-in, shipping, security check and boarding; Although the smart terminal at Baoan Airport is fully self-service, it focuses on the symbiotic relationship between self-service and manual service, both of which take care of the needs of elderly passengers in the use of the service. Pudong Airport's A_{21} indicator applies to all aspects of ageing-friendly airport services, including priority ticketing, customs clearance, security screening and boarding, to complete the entire airport process in a shorter time. Baiyun Airport provides a caring service for elderly passengers by providing volunteers to assist them with "health code" checks and manual advice and guidance to ensure their smooth travel. With the A16 indicator service at Baoan Airport, passengers can not only complete the steps required for baggage check-in on their own, but also retain a manual check-in counter for the baggage check-in process.

The main indicator elements with low centrality in the four major hub airports are caring seat exclusive service for elderly passengers (A_{25}) and scanning with AR glasses (A_{18}). Daxing Airport, Pudong Airport and Baoan Airport have the lowest A_{25} indicator centrality, at 5.0273, 4.8525 and 5.0600 respectively, indicating that the target groups of the three airports' caring seat services are not clear enough and their service protection capacity is insufficient. Baiyun Airport has a low A18 value (5.2301), which as a centrality factor will have an important impact on the airport's ageing friendliness. The ageing friendliness service of Baiyun Airport can be improved by improving the boarding reminder service for elderly passengers.

4.3. Causal Correlates of Ageing-Friendly Service Levels at Hub Airports

The four major hub airports also show variability in the indicators with higher Reason Levels, with Daxing, Pudong and Baoan airports having higher reason level values for Immigration processing services (A_3) at 1.0699, 0.8478 and 1.0587 respectively; Baiyun Airport's Hand Baggage Security Information Management System Service (A_7) has a high reason value (1.0444), indicating that the above indicators influence the level of ageing-friendly services at the airport.

The four hub airports with a lower value of cause were Pudong Airport and Daxing Airport for the extent to the achievement of a full escort service (A_{22}), Baiyun Airport for the caring seat exclusive service for elderly passengers (A_{25}), and Baoan Airport for the wheelchair elderly passenger service (A_{28}) with −1.0703, −1.0330, −1.0033, and −1.1274 respectively **Figure 2(d)**. As the reason

degree value is less than 0, it is identified as an outcome element and subject to intelligent and age-friendly conversions in baggage services, security services, etc. The four major hub airports have gradually placed emphasis on the improvement of service facilities and functions for elderly groups, and are therefore the product of the combined effect of airport ageing-friendly service initiatives, reflecting the rapid development of ageing-friendly services at the four major hub airports.

Specifically, the immigration clearance system is mainly used to process the relevant country's entry card, visa-on-arrival application form and customs declaration form at self-service machines. As the system eliminates the manual filling step, it is suggested that Daxing Airport, Pudong Airport and Baoan Airport could have a special content module for the elderly passenger group, taking full advantage of priority travel service access (A_{21}) at Pudong Airport to realise the arrival service needs of elderly passengers separately from those of non-elderly passengers. The senior care version of the application app or applet launched at Daxing Airport reduces barriers to service by highlighting key functions, enlarging fonts, enhancing colour contrast and simplifying operations to prioritise the pushing of service modules for senior passengers in all aspects of the airport. Baiyun Airport's hand luggage security screening Information management System Service (A_7) is a key element of the airport's ageing-friendly baggage screening module; caring seat exclusive service for elderly passengers (A_{25}) is a typical example of the level of ageing-friendly services at this airport. By setting up a caring seat area, elderly passengers are cushioned at various process points of airport services, and the physical needs of elderly passengers are effectively considered.

5. Comprehensive Impact Degree Analysis of the Level of Ageability of Hub Airports

A comprehensive analysis of ageing-friendly service levels at the four major hub airports found that the higher combined impact values were concentrated in four indicators: International security screening Information management system service (A_6), self-service or manual telephone ticketing service (A_{14}), priority travel service access (A_{21}) and wheelchair elderly passenger service (A_{28}). The highest value indicators of comprehensive influence of Daxing Airport, Pudong Airport and Baiyun Airport are A_{14} (0.1041), A_{21} (0.1208) and A_6 (0.0998) respectively, and Baoan Airport has a higher value of A_{28} indicator (0.1100), indicating that the above four indicators are comprehensive influence elements of the degree of ageing-friendly development of the airport. Therefore, the four indicators can be listed as the core evaluation indicators of the level of ageing-friendly services in airports.

The comprehensive impact of ageing-friendly service content at the four major hub airports, in descending order, is Baoan Airport (0.6684) > Pudong Airport (0.5904) > Daxing Airport (0.5075) > Baiyun Airport (0.3276) **Figure 3**. The

ageing-friendly services at Baoan Airport are relatively complete and of the highest level, while the ageing-friendly services at Daxing Airport and Pudong Airport are well-organized and the service measures are in place, while the ageing-friendly services at Baiyun Airport are relatively few in number and the level of ageing-friendly services needs to be improved. In terms of the number of indicators covered by ageing-friendly services at each airport, Daxing Airport has 14, Pudong Airport and Baoan Airport both have 13, and Baiyun Airport has 11. The coverage of ageing-friendly services at hub airports is roughly the same but the content varies. Among them, four indicators, namely the extent of full self-service for passengers (A_1), baggage tracking and positioning with radio frequency identification (A_2), 5G + smart scenario application Fit (A_4) and self-service or manual check-in service (A_{15}), have achieved full coverage of ageing- friendly service content in the four major hub airports. Special Passenger Service Counter or the Caring Service Counter (A_{24}) covered three airports. The seven indicator services, including the Immigration processing services (A_3) and the International Security Screening Information Management System Services (A_6), cover two airports. In addition, 12 indicator services such as the extent of digital media placement (A_5) and International security screening Information management system services (A_6) are covered by only one airport.

Through a comprehensive comparative analysis of the ageing-friendly level of the four hub airports in terms of service content, the average ranking of the four hub airports is Special Services (0.1667) > Security Screening Services (0.1305) > Smart Airport Construction (0.1276) > Smart Security Screening System (0.0982) in that order (**Figure 4**). It can be shown that the level of ageing-friendly of special services is generally high, while the level of ageing-friendly of intelligent security screening systems still remains to be improved. Pudong Airport is the best performance in terms of smart airport construction and smart security system, which is conducive to the perfect development of smart airport ageing-friendly services. The security screening services at both Daxing and Baoan airports are highly ageing-friendly and meet the basic travel needs of elderly passengers.

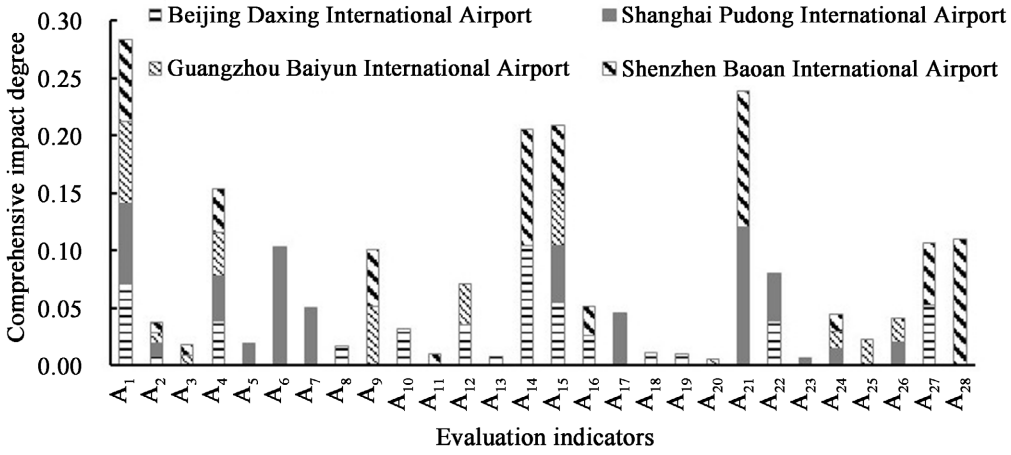


Figure 3. Comparison of ageing-friendly service offerings at the four major hub airports.

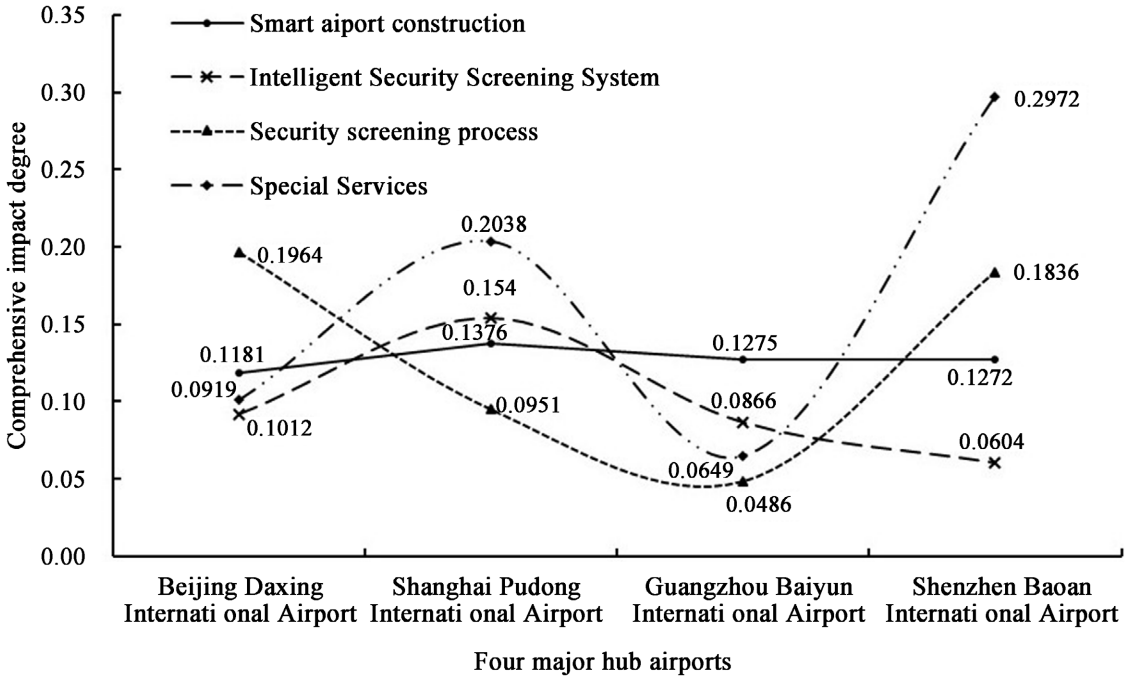


Figure 4. Comparison of average ageing-friendly service levels at the four major hub airports.

Baoan Airport has the highest level of ageing-friendly services, with the largest proportion of the airport's ageing-friendly content and a wide range of services that meet their basic travel needs while guaranteeing the personalised travel rights of older passengers.

6. Conclusion and Discussion

6.1. Conclusion

This paper takes Beijing Daxing International Airport, Shanghai Pudong International Airport, Guangzhou Baiyun International Airport, and Shenzhen Baoan International Airport as the subjects of this study. The different elements of the ageing-friendly service level evaluation indicators of the four major hub airports were determined, and it can be found that each evaluation indicator element has different performance and influence in the hub airports due to the difference in measurement methods. The details are as follows:

1) In terms of influencing factors, the indicator of the degree of full passenger service as an active element has the highest value of influence within the ageing-friendly service level indicator system. However, full escort service, special passengers, or caring service counters are most likely to be influenced by other indicator elements, which interact with each other and together contribute to an overall positive trend in the level of ageing-friendly services at hub airports.

2) In terms of core influencing factors, the main indicators include: the degree of full passenger service, access to priority travel services, baggage check-in security systems, or manual check-in services, which are the core factors influencing the improvement of the ageing-friendly level and determine the trend direction

of the overall ageing-friendly service level of the hub airport.

3) In terms of cause-effect correlation elements, arrival clearance services and hand luggage screening information management system services are mostly expressed as cause elements and are more driving for ageing-friendly services at hub airports; The extent to which the full process of escort service is achieved, the exclusive use of caring seats for elderly passengers and the wheelchair elderly passenger service show the effectiveness of the ageing-friendly service construction of the hub airport with a high level of ageing.

4) The range of services covered by ageing-friendly services at hub airports is not significantly different, but the focus of ageing-friendly services is different. The overall impact of ageing-friendly service content at the four major hub airports, in descending order, is Baoan Airport > Pudong Airport > Daxing Airport > Baiyun Airport. The ageing-friendly service level of different service modules at hub airports has an inverse correlation with the degree of intelligence of the service content, in the descending order of special services (0.1667) > security screening services (0.1305) > smart airport construction (0.1276) > intelligent security screening system (0.0982).

6.2. Discussion

To improve the level of ageing-friendly services at the four hub airports, this paper makes the following recommendations, taking into account the above research findings.

1) Preserve the traditional services familiar to older people. On 24 November 2020, the State Council issued the "Implementation Plan on Effectively Solving the Difficulties of Using Smart Technology for the Elderly", which proposes that the familiar lifestyles of the elderly must be preserved in the course of daily services. For example, in the ticketing process, senior travellers can complete the ticketing process at the airport and receive guidance on the service process, or choose to purchase tickets by phone; in the health code checking process, senior travellers are provided with a paper-based channel to complete the information by reading their ID card, presenting a paper certificate, having a friend or relative do it on their behalf or having one person bound to multiple health codes for epidemic prevention and other alternative measures.

2) Extending the use of priority for the elderly passenger group in all aspects of airport services. By setting up senior passenger service counters, senior passengers can enjoy priority check-in, security, and boarding services, including the establishment of "Senior Citizen Priority Service" signs at all information counters, ticket counters and other manual service windows, as well as at the caring corridors; Apply for extended priority for the elderly customer group in the process of ticketing, customs clearance, security checks and boarding, as well as in the immigration clearance service.

3) Increasing the range and proportion of in-airport guiding services. Specialised information guides are available in the main areas of the terminal and at the manual information counters, providing personalised guidance at different

points in the service process (check-in, baggage check, security, boarding). The number of volunteer service points at hub airports could be increased in due course to provide real-time answers and guidance for elderly travellers with questions about their flights. At the same time, there is still a requirement to increase the proportion of intelligent ageing-friendly products and services such as intelligent service robots at hub airports.

4) Improve the construction of talent teams and enhance the comprehensive service guarantee capacity. By accurately identifying the needs of elderly passengers, airport service staff scientifically deploy service resources within the airport. For example, hub airports should continue to optimise and improve accessibility protection facilities, clarify the rules and specific processes for elderly passenger services, and establish effective professional teams for ageing-friendly services. The ageing-friendly services at hub airports should be implemented "first before people arrive, measures should be taken", by improving the construction of a team of professionals in each service module of the airport, enhancing professionalism, and providing worry-free travel services for the elderly passengers.

In addition, this study takes the four representative hub airports in China as the main research object, and the research perspective is limited to domestic hub airports. In the future, we can focus on the comparative study with international airports for detailed discussion, actively promote the implementation and improvement of smart ageing initiatives in international airports in response to the existing problems, and enhance the wisdom and ageing level of airports, so as to provide experience and reference for the ageing construction of smart airports at home and abroad.

Acknowledgements

This study was supported by the National Natural Science Foundation of China (No.42071266), the Natural Science Foundation of Hebei Province (D2021205003), and the Third Batch of Young Talents Program of Hebei Province.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Chang, Y.-C. (2013). Factors Affecting Airport Access Mode Choice for Elderly Air Passengers. *Transportation Research Part E-Logistics and Transportation Review, 57,* 105-112. https://doi.org/10.1016/j.tre.2013.01.010

Dattilo, J., Mogle, J., Lorek, A. E. et al. (2018). Using Self-Determination Theory to Understand Challenges to Aging, Adaptation, and Leisure among Community-Dwelling Older Adults. *Activities, Adaptation & Aging, 42,* 85-103. https://doi.org/10.1080/01924788.2017.1388689

Dieteren, C. M., Samson, L. D., Schipper, M. et al. (2020). The Healthy Aging Index Ana-

lyzed over 15 Years in the General Population: The Doetinchem Cohort Study. *Preventive Medicine, 139,* 106193. https://doi.org/10.1016/j.ypmed.2020.106193

Fan, J. S., Zhou, L., Zhang, Y. et al. (2021). How Does Population Aging Affect Household Carbon Emissions? Evidence from Chinese Urban and Rural Areas. *Energy Economics, 100,* 105356. https://doi.org/10.1016/j.eneco.2021.105356

Gong, X. H., & Yin, J. Z. (2019). Exploration of "Internet + Elderly Service" Mode in the New Era. *Modern Economic Information, 1,* 365.

Guo, Z. Y. (2021). "Ageing-Friendly" Financial Services Speed up the Penetration of Elderly People's Lives. *Economic Daily, 8,* 007.

Hoffman, G. J., Webster, N. J., & Bynum, J. P. W. (2020). A Framework for Ageing-Friendly Services and Supports in the Age of COVID-19. *Journal of Aging & Social Policy, 32,* 450-459. https://doi.org/10.1080/08959420.2020.1771239

Huang, Y. S., Zhou, F., Zhou, J. F. et al. (2020) Smart Airport Construction in the 5G Era. *Civil Aviation Management, 2,* 55-58.

Iglesias-Souto, P. M., Taboada Ares, E. M., Dosil Maceira, A. et al. (2008) Knowledge and Expectations among Older Adults of Social Services for the Elderly in the Autonomous Region of Galicia (Spain). *Revista espanola de Geriatria y Gerontologia, 43,* 353-361. https://doi.org/10.1016/S0211-139X(08)75190-4

Ji, X. D. (2020). Design and Research of Intelligent Airport Management Platform Based on Big Data Technology. *Information Systems Engineering, 7,* 40-41.

Jiang, L., Chen, X. Y., & Zhu H. (2021). Spatial Distribution Characteristics of Urban Nursing Homes in China and Their Divergent Causes. *Journal of Geography, 76,* 1951-1964.

Jing, S. (2020). The Practical Logic and Countermeasures of Community Home-Based Elderly Care Service under the Dimension of Innovative Big Data. *Humanities and Social Sciences, 8,* 78-85. https://doi.org/10.11648/j.hss.20200802.15

Kan, J. J., & Sun H. (2019). Discussion on the Construction of Intelligent Airport. *China Science and Technology Information, 20,* 32-33.

Keskin, B., & Salman B. (2020). Building Information Modeling Implementation Framework for Smart Airport Life Cycle Management. *Transportation Research Record, 2674,* 98-112 https://doi.org/10.1177/0361198120917971

Li, C. J., & Chen, L. Y. (2020). Reflections on the Ageing Countermeasures of Urban Transportation in the Context of Aging. *Shandong Transportation Science and Technology, 1,* 30-32.

Li, P. (2018). A Review of Research on the Development of Intelligent Elderly Care in China. *Finance and Accounting Research, 10,* 72-76, 80.

Liu, S. B. (2018). There Is a "Gold Mine" in the "Silver Hair" Market. *China Civil Aviation News, 11,* 002.

Lu, N. (2021). The Wiser the Appointment, the Warmer It Should Be. *China Culture Daily, 09,* 007.

Marshall, F., Basiri, A., Riley, M. et al. (2018). Scaling the peaks research protocol: Understanding the Barriers and Drivers to Providing and Using Dementia-Friendly Community Services in Rural Areas—A Mixed Methods Study. *BMJ Open, 8,* e020374. https://doi.org/10.1136/bmjopen-2017-020374

Qian, Y. T., Xu, S., & Ma, M. L. (2021). Research on Key Success Factors of Sponge City PPP Projects Based on AHP-DEMATEL. *Journal of Zhejiang University of Technology (Social Science Edition), 46,* 614-622.

Sliepenbeek, M., Smits, C., Spelt, E. J. et al. (2021). Older Adults' Active Involvement in

an Undergraduate Program in Gerontology: Motives and Meaning. *Gerontology & Geriatrics Education, 42,* 516-527. https://doi.org/10.1080/02701960.2019.1669588

Sun, W. J. (2021). Promoting the Construction of Ageing-Friendly Intelligent Travel in Civil Avition. *China Civil Aviation News, 02,* 004.

Tian, Y. D., & Xue, Z. W. (2021). Urumqi International Airport Makes Elderly-Friendly Services Warmer in the Age of Intelligence. *China Civil Aviation New, 07,* 003.

Wang, L. G. (2020a). Analysis of the Application of 5G in Airport Construction. *Information Communication, 4,* 161-162.

Wang, S. Y. (2020b). When I Am Old, I Really Hope. *China Civil Aviation News, 12,* 002.

Wang, S. Y. (2021). Service "Ageing" Shows Humanistic Care. *China Civil Aviation News, 01,* 002.

Wu, X. F. (2021). Research on the Integration Development of Intelligent Medical and Health Care. *Intelligent Building and Smart City, 2,* 27-29.

Xie, L. (2020). Research on Application of Emerging Technologies in Smart Airport. *Journal of Simulation, 8*.

Xu, X. H. (2010). The "Silver Hair Tide" Is Surging in the Airline Market for Senior Passengers. *China Civil Aviation News, 10,* 002.

Yang, Y. Y., Fan, C. J., & An, A. Z. (2020). Research on the Application of Artificial Intelligence in the Construction of Intelligent Civil Aviation. *Intelligent Computers and Applications, 10,* 214-215, 219.

Yang, Y. Z. (2021). Reflections on the Ageing-Friendly Construction and Renovation of Scenic Spots. *China Tourism News, 03,* 003.

Yu, T. T., & Wang, R. P. (2021). Design and Implementation of a Smart Elderly Positioning Management System Based on Wireless Communication Network. *EURASIP Journal on Wireless Communications and Networking,* **2021**, Article No. 147. https://doi.org/10.1186/s13638-021-02021-2

Yu, X. P. (2021). Reflections and Suggestions on Creating Air Travel Service Scenarios for the Aging Population. *Air Transport Business, 7,* 30-32.

Zhang, J. (2021). Research on the Application of AR Technology in Airports. *Changjiang Information Communication, 34,* 35-38.

Zhang, S. L. (2020). *Research on the Ageing-Friendly Design of Navigation App under the Vision of Smart Travel*. M.D. Thesis, Guilin University of Technology.

Zhang, T. M., & Liu, Y X. (2020). Research on the Design of Intelligent Elderly Mobility Products. *Industrial Design, 11,* 123-124.

Zhao, W., & Li, F. R. (2021). A Study on the Impact of the Internet on Civil Aviation Strategy. *Research in Technology Economics and Management, 2,* 101-105.

Zhao, Z. X., Zhao, T. J., Chen, S. Y. L. et al. (2014). A Study on the Ecological Pattern Security Evaluation of Mountain Towns Based on GIS-AHP Method: An Example of the Northern New Area of Chongqing. *Modern Urban Research, 8,* 74-78.

Zhou, J. (2021). Study on the Countermeasures of Home Care in Taiyuan's Smart Community. *Shanxi Economic Daily, 08,* 004.