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Measuring Beijing’s international air connectivity and suggestions for improvement post COVID-19

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ABSTRACT

This study empirically measures Beijing’s international air connectivity through descriptive statistics and various connectivity indexes. In particular, we comprehensively benchmark Beijing’s international air connectivity with other major international exchange centers and gateway airports around the world. It is found that, although Beijing has direct flights to a comparable number of foreign destinations, the city still significantly lags behind other major counterparts in international air connectivity. This is due to Beijing’s inferior connection quality in terms of flight frequency, number of seats, flying distance, and its poor international transfer capability. Moreover, a gravity-type model is applied to investigate the determinants of Beijing’s route-level direct flight traffic. An index of potential market size is calculated for a sample including candidate overseas airports without direct flights with Beijing. It is found that Beijing has already opened direct flights to most of the candidate airports that have high market potentials. The air transport market potentials to major B&R (Belt-and-Road) cities are very low. However, given China’s growing trade and economic ties with the B&R countries, Beijing could consider more favorable policies in support of direct flight operations to B&R countries. It is more important for Beijing to upgrade air connectivity quality by liberalizing restrictions on flight frequency and airfare. The newly opened Beijing Daxing Airport adds valuable capacity for Beijing to better explore international connectivity. Although COVID-19 pandemic forces Beijing to shut down international flight operations until now, the city needs to formulate clearer long-term strategies to improve international its air connectivity.

1. Introduction and background

International air connectivity refers to the convenience in moving people or goods between points of two countries through air transport (e.g., Burghouwt and Redondi, 2013). A well-connected international air transport system is essential for a country’s economic development as it facilitates the trade, FDI and other international exchanges (Fu et al., 2010; Baker et al., 2015; Winston and Yan, 2015; Matsumoto et al., 2016; Chen and Lin, 2020). Cristea (2011) has found that better air connectivity stimulates the bilateral merchandise trade. Banno and Redondi (2014) found that better international air connectivity would also attract FDI, contributing to faster regional economic development.

Based on Canadian context, Oum et al. (2019) suggested a more liberalized bilateral air transport would lead to better international air connectivity, which then promotes Canadian’s service trade export and import. Moreover, Cheung et al. (2020) found that well-developed international air connectivity can accelerate the growth of air traffic, improve the competitiveness of airports and increase the influence over other cities.

China has become the second-largest airline market in the world since 2005, following US (Zhang and Round, 2008; Wang et al., 2014, 2018). Its major hub airports, namely Beijing Capital, Shanghai Pudong and Hongqiao, Guangzhou Baiyun, have also ranked among the world’s busiest airports. For example, from 1978 to 2019, the annual passenger
throughput of Beijing Capital Airport increased from 1.03 million to 100 million, ranking first in Asia and second in the world, just following Atlanta International Airport (CAAC, 2019). China experienced fast growth in the passenger traffic and overall connectivity improvement. However, this is mainly driven by its domestic market, while the international air connectivity of those hub airports has still been lagging behind its major Asia-pacific counterparts, such as Hong Kong International Airport, Seoul Incheon Airport, Singapore Airport, Tokyo Narita Airport and Haneda Airport (Fu et al., 2015). Such underdevelopment could be attributed to China’s relative restrictive air service agreements (ASAs) signed with other countries (Adler et al., 2014; Wang et al., 2020). Compared with other major airline markets, China has yet actively signed open skies agreements (OSAs) (Liu and Oum, 2018). Other neighboring countries such as Singapore and South Korea have almost fully liberalized their international airline market, greatly improving their international air connectivity (Tan, 2010; Zhang and Findlay, 2014; Choi et al., 2019; Chang et al., 2020; Bilotkach et al., 2020).

When compared with other established airport gateways and international exchange centers, namely, London, New York, Tokyo, Dubai, Singapore, Hong Kong, Seoul, Beijing has poorer international air connectivity development. Even within China, other secondary Chinese cities have also been actively utilizing China’s OSAs with Japan, Korea and ASEAN to expand direct international flights (Liu and Oum, 2018). Beijing is however subject to more restrictive aviation policy than other cities in exploring its international air connectivity. This is due to Beijing’s extremely constrained airport capacity and its political status as China’s capital. Despite existing inferior policy environment, it is still vital for Beijing to further develop its international air connectivity. China is also ambitious to improve transport link with Belt-and-Road (B&R) countries, but the air connection has far lagged behind other transport modes (i.e., maritime shipping and China-Euro Express Rail) (Wang et al., 2020; Zhou et al., 2021). Thus, Beijing still has potential to explore air connectivity with B&R countries.

Despite existing inferior development, Beijing also has several other obvious advantages to further improve its international air connectivity. First, the opening of the second international airport, Daxing Airport, at the end of 2019, greatly relieves Beijing’s airport capacity constraint. This new airport has comparable design capacity as Beijing Capital Airport, offering plenty of capacity to expand Beijing’s international air network (Hou et al., 2021). Beijing would benefit from such available capacity in developing transfer hub functions to serve more inter-continental markets between China/Asia Pacific and North America/Europe, thus effectively competing with existing international hubs in Asia, such as Singapore, Hong Kong, Seoul and Tokyo.

Second, Beijing has huge local air traffic demand to overseas destinations. Such lucrative market could sustain both domestic and overseas airlines’ profitable operations. Airlines are thus eager to expand markets from Beijing to other major overseas destinations, but are constrained mainly by Beijing’s tight airport capacity control and China’s restrictive ASAs regarding routes involving Beijing (Zhang and Zhang, 2021). Once the market is more liberalized, the market mechanism could play an effective and major role in improving Beijing’s international air connectivity.

In order to generate more scientific policy and managerial implications, it is essential to first provide quantitative measurements to accurately evaluate its international air connectivity and benchmark with major other counterparts (both domestic and overseas). Although several previous studies have identified Beijing’s problem of underdeveloped international air connectivity, these discussions are mainly qualitative, while quantitative measurements are still lacking to help better understand the true status of Beijing. Thus, this study aims to develop and calculate a series of statistics and connectivity indexes based on Beijing’s real airline and airport operating data. Specifically, this study proposes and calculates an “international air connectivity index” that accounts for not only the number of foreign destinations, but also various flight characteristics, such as flight frequency, traveling distance, seat capacity, direct, transfer, etc. Such a method is in the spirit of the recent advanced air connectivity literature (e.g., Malighetti et al., 2008; Palieri et al., 2010; Zhang et al., 2017; Zhu et al., 2018, 2019a,b).

In addition, this study proposes a “transfer capacity” index calculated with airports’ detailed flight scheduling and airport capacity data. This index serves to measure the airport’s capacity in handling international flight transfers, indicating its ability serving transfer hub for international flights. The above indexes are calculated for Beijing and other major counterparts for benchmarking.

Moreover, this paper also proposes and estimates a gravity-type model adapted from Li et al. (2020) to measure the market potential of direct flight routes between Beijing and other overseas destinations. This investigation would shed light on the determining factors for Beijing to open direct flights with particular foreign cities. It also helps identify promising overseas cities for airlines to launch direct flights from Beijing. The government and Beijing airports can also refer to the analyses results to tailor effective favorable policies in support of these promising routes when expanding the international air connectivity.

The rest of the paper is organized as follows. Section 2 measures and benchmarks the international air connectivity of Beijing and its major counterparts. Specifically, an overall international connectivity index and airport transfer capability index would be calculated and discussed in this section. In Section 3, we propose and estimate a gravity-type model to measure the determining factors on Beijing’s direct flight traffic. And then, a market potential index is calculated to identify the promising overseas candidate routes for Beijing to open direct flights. Section 4 contains concluding remarks.

2. Beijing’s international air connectivity

2.1. Descriptive measurements

This subsection provides some simple descriptive measurements to depict Beijing’s general pattern of international air connectivity, in terms of the number and distribution of overseas destinations and flight frequencies. With the opening of Daxing Airport in September of 2019, the city has formed a multi-airport system. Air China is the dominant carrier in Beijing Capital Airport with more than 60% of the passenger throughput. The carrier remained its operations in Beijing Capital Airport, together with its Star Alliance member carriers. Other major Chinese airlines, namely China Eastern and China Southern, have been allocated to the new Beijing Daxing Airport, with OneWorld and SkyTeam membered foreign airlines (Hou et al., 2021).

The flight operation used in this study is collected from TravelSky, which is the real ticket-booking data showing the origin and destination airports (number of stops and intermediate transfer airports), the

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2 Cheung et al. (2020) has developed “Global Airport Connectivity Index (GACI)” to comprehensively measure the global network connectivity of major airports in the 2006–2016 period. Beijing and Shanghai have seen dramatic connectivity growth. Beijing is even ranked first in GACI as of 2016. However, GACI considers the airport’s all connections (both domestic and international). Given the extraordinary growth of Chinese domestic market, Beijing’s connectivity improvement is likely to be driven by its domestic market connectivity.

3 New Daxing airport also has a high-speed rail (HSR) station co-located. There is HSR line linking Daxing airport with China’s existing large-scale domestic HSR network. Thus, there is a huge potential to develop air-HSR inter-modal cooperation at Daxing Airport, offering integrated domestic HSR feeding service for international flights.

4 TravelSky is the largest aviation data service company in China. It is a state-owned company to operate China’s air ticket booking and is integrated with IATA’s global air ticket reservation system.
ticketing and operating airlines. It is noted that we only consider the operating airlines, such that the code-sharing (particularly between alliance members) can be handled. Our data is collected for September 2019 (just before the COVID-19 pandemic). Beijing served direct flights to a total of 103 overseas airports in 53 countries with a monthly number of 4453 international flight departures, among which 4438 were from Beijing Capital Airport and 115 from Beijing Daxing Airport. Beijing Daxing Airport was just formally opened in September of 2019, and many airlines had been undergoing the operational transfer from Beijing Capital Airport, such that Daxing Airport’s throughput was still very low. As would be shown later, the COVID-19 pandemic had hit China since January 2020, and Beijing Daxing Airport was shut down for a long period, hindering its traffic growth. Therefore, our description of Beijing’s international air connectivity is primarily based on Beijing Capital Airport. Table 1 summarizes Beijing’s international flight distributions and the detailed overseas destinations.

Beijing has the largest number of international direct flights to its Northeast Asian neighbors, Japan and South Korea. Especially, most of the direct flights serve from Beijing to Seoul and Tokyo. This clearly demonstrated the very close economic ties between the economic/political centers among these Northeast Asian countries. Moreover, Beijing has a significant number of direct flights to ASEAN destinations such as Singapore and Thailand. This is sensible in that Southeast Asia has become China’s most important overseas tourist destination. Thailand has recently replaced Japan to serve the largest number of Chinese overseas tourists (Liu and Oum, 2018). The routes to Northeast and Southeast Asia are short-to-medium haul, which can be served by narrow-bodied aircraft (i.e., A320 and B737), such that very high flight frequencies can be sustained (as shown in Table 1(b)), improving the traffic flow and connectivity. It should also be noted that, although China has signed OSAs with Japan and ASEAN countries, Beijing Capital Airport is excluded from the agreements. Once the ASA restrictions were lifted, we would expect further growth of direct flights from Beijing to these regions. For the inter-continental destinations, Beijing mainly develops direct flights with the US, the UK, Russia, the UAE and the UK (United Arab Emirates). The US, Germany, the UK, Russia are the major trading partners with China, such that more direct flights can be sustained with more bilateral traffic flow. The UAE is the major international transfer hub for Asia-Europe routes, with its dominant carrier, Emirates Airlines, as one of the largest international airlines in the world.

We also summarize the statistics of international direct flights for other major domestic and overseas counterparts as shown in Table 2. Beijing significantly lags behind other major international exchange centers and transfer hub cities. London, New York, Tokyo and Hong Kong are the world’s financial and commercial service centers. Their numbers of direct international flights far exceed that of Beijing, suggesting much larger route-level flight frequencies (i.e., route density). These cities also embrace more liberalized international air transport policy, contributing to their more efficient international airline operations (Wang et al., 2014). Dubai has served the largest number of overseas airports and destination countries among our selected airports. This is due to its major transfer hub functions, which utilize the hub-and-spoke network structure to quickly expand its network for routes between Asia-Pacific and Europe. It is thus clear that Beijing has yet developed a comparable international air network as other major international exchange centers and transfer hubs. Even domestically, Beijing appears to be underdeveloped than Shanghai in international air network.

As discussed in Section 1, it is essential for China to build a well-connected air network with B&R countries. This would support China’s sustainable economic and trade relationships. Since the China-US trade conflicts in 2016, the trade and FDI of China with B&R countries have grown dramatically. Air transport is important to facilitate people flow and time-sensitive cargo transport. Beijing, as the capital of China, plays a leading role in decision-making, including strengthening the source of policy communication and providing more policy guidance and support, so this could be the primary city to develop air connectivity with B&R countries. Table 3 shows the B&R countries with direct flights from Beijing. Beijing has only opened direct flights to 33 B&R countries, while there are already more than 150 countries signing B&R agreements with China. The flight frequencies between Beijing and B&R countries are also very low. The direct flights between other Chinese cities to these B&R countries are even much fewer. In addition to the economic factors, the very restrictive bilateral ASAs between China and B&R countries are also to blame. For example, Wang et al. (2020) suggested that China has very poor international air connectivity with B&R countries in Central Asia, although China has replaced Russia as the largest trading partner in this region. The political and cultural barriers could hinder air connectivity development, limiting the further economic growth potential. In other words, the underdeveloped air connectivity may fail to further strengthen China’s economic relationship with these B&R countries. Major cities in China, especially Beijing, still have great potential to explore the international air connectivity with these B&R countries.

Similar to most of other world major international airports, COVID-19 has badly hit Beijing’s international air connectivity. There is a two-way relationship between air connectivity and COVID-19 pandemic. Air transport policies to cut off air connectivity significantly slowed the spread of COVID-19 pandemic, while COVID-19 pandemic also has a negative impact on air connectivity (e.g., Zhang et al., 2020a; Sun et al., 2021b,c). To sustain the successful domestic pandemic control, China has implemented the “Five-One policy” since late March 2019 to strictly avoid import case risk (Czerny et al., 2021; Zhang et al., 2020a,b,5). Beijing, as the capital city of China, is subject to even stricter control on

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Table 1
The summary of direct international flights of Beijing (December 2019).

| Rank | Country | No. of departing flights |
|------|---------|-------------------------|
| 1    | Japan   | 726                     |
| 2    | US      | 511                     |
| 3    | South Korea | 505               |
| 4    | Thailand | 389                    |
| 5    | Russia  | 239                     |
| 6    | Singapore | 186                 |
| 7    | Germany | 165                     |
| 8    | Canada  | 144                     |
| 9    | UAE     | 122                     |
| 10   | UK      | 116                     |

Source: TravelSky.

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Table 1 (continued)
(b). Top foreign destination cities

| Rank | Airport code | City | No. of Departing flights |
|------|--------------|------|-------------------------|
| 1    | ICN          | Seoul | 301                     |
| 2    | BKK          | Bangkok | 275                   |
| 3    | HND          | Tokyo | 261                     |
| 4    | SIN          | Singapore | 186                |
| 5    | KIX          | Osaka | 177                     |
| 6    | NRT          | Tokyo | 151                     |
| 7    | GMP          | Seoul | 124                     |
| 8    | LHR          | London | 104                  |
| 9    | SVO          | Moscow | 102                 |
| 10   | DXB          | Dubai | 92                      |

Source: TravelSky.

5 The flight data involved in our research are the actual operating flights rather than scheduled flights. The flights are passenger aircraft, while the all-cargo freighter flights are excluded.
6 The Five-One policy refers to, for one foreign country, there can only be one international route, and there is only one operating airline to operate only one flight per one week.
affected by many factors, such as the route distance, aircraft size, and the statistics, while air connectivity could be a complex measurement that is

Beijing has quite distinct patterns of flight and network characteristics network structure (e.g., the flight transfer). Moreover, it is clear that international air travels recovers with the adverse impact of COVID-19 long-term strategy to improve its international air connectivity after the revival of international air connectivity. Thus, Beijing still needs to international flights since the implementation of the Five-One policy, and most of Beijing’s international flights have been transferred to other Chinese airports. It would take a much longer time for the international airline market to recover than the domestic market (Rothengatter et al., 2021). However, with the large scale and fast vaccination around the world, the international air travel is expected to rebound. Many countries are evaluating the recognition of the vaccination across countries. Although there are still challenges and obstacles, the vaccine passport and travel bubbles have been seriously considered or even implemented among some countries (Sun et al., 2021d). Such a move would speed up the revival of international air connectivity. Thus, Beijing still needs to evaluate its current condition (before the pandemic) and formulate a long-term strategy to improve its international air connectivity after the international air travels recovers with the adverse impact of COVID-19 pandemic attenuating.

2.2. Air connectivity and transfer capability index

The discussions in subsection 2.1 are based on simple descriptive statistics, while air connectivity could be a complex measurement that is affected by many factors, such as the route distance, aircraft size, and the network structure (e.g., the flight transfer). Moreover, it is clear that Beijing has quite distinct patterns of flight and network characteristics compared to other major counterpart cities, such as Hong Kong, New York, London, Tokyo, Singapore, Dubai and Shanghai. Thus, to more accurately measure and benchmark Beijing’s international air connectivity with other international exchange centers and air transfer hubs, it is necessary to adopt a more comprehensive and sophisticated air connectivity index.

Specifically, this paper adopts the air connectivity index developed by Zhu et al. (2019b), which has also been used by Wang et al. (2020) and Zhang et al. (2020a,b) to measure air and other transport modes’ network connectivity. This connectivity index accounts for both the capacity (i.e., frequency, aircraft size) and service quality (i.e., flying distance/travel time, number of transfers) of each flight (called as one connection in the relevant literature). It then aggregates these connectivity of all individual flights/connections into one connectivity index at the airport level. First, the index considers the influence of different aircraft sizes or capacities (i.e., the seat capacity). This is measured by a variable, $D_{xya}$, which is calculated based on the aircraft size and seat number used by one particular flight. As shown in Eq. (1), for one flight $a$ from city $x$ to city $y$, $Seat_{xya}$ is the passenger capacity counted by the number of seats, and $D_{xya}$ is the square root of the ratio of the capacity of this flight to the largest capacity of one aircraft available in the market.

$$D_{xya} = \left(\frac{\text{Seat}_{xya}}{\text{maxSeat}_{xy}}\right)^x \sqrt{L_{xya}}$$

A larger aircraft provides more seats and a comfortable in-vehicle environment, reflected by a larger value of $D_{xya}$. In addition, this index considers the negative impact of flying distance and additional transfers on air connectivity. The travel distance from city $x$ to city $y$ of flight $a$ is $l_{xya}$ and $\text{min}_{xya}$ is the shortest adjusted travel length in the market, we get the travel length discount variable $D_{xya}'$ as follow as shown in Eq. (2). It is noted that for the indirect flights with additional transfers, its travel distance has been further discounted to reflect the inconvenience to the passengers (i.e., a lower air connectivity ceteris paribus).

$$D_{xya}' = \sqrt{\frac{\text{min}_{xya}}{l_{xya}}}$$

Then the connectivity of the connection between city $x$ to city $y$ provided by flight $a$ can be calculated as the multiplication term below, which is basically discounting the flight frequency by its capacity and flying distance factors.

$$\text{Connectivity}_{xya} = \sum_a \text{Frequency}_{xya} \times D_{xya} \times D_{xya}'$$

where the Frequency$_{xya}$ is the flight frequency of flight $a$ from city $x$ to
city y in the calculated period. Then, the air connectivity index of city x can be obtained by aggregating its connectivity indexes to all the destination cities, which is expressed as Eq. (4) below.

\[ \text{Connectivity}_x = \sum \text{Connectivity}_y \]

(4)

As discussed earlier, Beijing lags significantly in serving as the international transfer hub, despite its substantial total air passenger traffic. Such poor transfer function is partly exhibited by its very low share of international transfer passengers. From the flight operational perspective, Beijing’s lack of capability to handle international transfer flights can also be inferred by its exiting international flight schedules. Specifically, this is reflected by its theoretical capability to connect different international flights to expand the international airline network. Thus, we also propose a transfer capability index using the real flight operational data to measure Beijing’s and other counterparts’ capability of serving international transfer flights. It should be noted our measurement only considers the transfers between two international flights, while the feeding flights between domestic and the international segments are not counted. Such measurement is better to reflect the competitiveness of one airport as the international transfer hub, excluding the impact of its domestic catchment. Such development of international transfer function is essential for Beijing to compete with Singapore, Seoul, Taipei and Dubai as a hub to link Asia-Pacific to Europe or North America.

First, we assume the relationship between transfer time and the theoretical transfer possibility as follows. t is the time interval between the scheduled arrival time (STA) of the previous flight and the scheduled departure time (STD) of the subsequent transfer flight. \( f(t) \) is the transfer possibility function of transit time, which is a probability ranging from 0 to 1. There is a time period \( [t_1, t_2] \), to demonstrate the feasible time for two flights to transfer. \( t_1 \) can be regarded as the minimum connection time for two flights, while \( t_2 \) is the maximum connection time as passengers and airlines cannot wait for too long due to high time cost. When \( t \in [t_1, t_2] \), the previous and the subsequent flight has the feasibility to transfer (i.e., \( 0 < f(t) < 1 \)). When \( t < t_1 \) or \( t > t_2 \), the transfer possibility \( f(t) \) is equal to 0. There also exists a best suitable time \( t_2 \) for two flights to make transfer, where \( t_2 \in [t_1, t_2] \), such that \( f(t_2) = \max f(t) = 1 \). It is also assumed that, when \( t \in [t_1, t_2] \), \( f(t) \) is a monotonically increasing function. When \( t \in (t_1, t_2) \), \( f(t) \) is a monotonically decreasing function. It is smooth over near the optimal transit time \( t_2 \), such that \( \lim_{t \to t_2^-} f(t) = \lim_{t \to t_2^+} f(t) = 0 \). The function \( f(t) \) is specified as Eq. (5), also depicted in Fig. 2.

\[
\begin{align*}
    f(t) &= \begin{cases} 
        0, & t < t_1 \\
        a_1t + b_1t + c_1, & t_1 \leq t < t_2 \\
        a_2t + b_2t^2 + c_2t + d_2, & t_2 \leq t < t_3 \\
        0, & t \geq t_3 
    \end{cases} \\
\end{align*}
\]

(5)

The above assumptions suggest the following equalities must be held for \( f(t) \)

\[
\begin{align*}
    f(t_1) &= a_1t_1 + b_1t_1 + c_1 = 0 \\
    f(t_2) &= 2a_1t_1 + b_1 = 0 \\
    f(t_2^+) &= a_2t_2 + b_2t_2 + c_1 = 1 \\
    f(t_3) &= a_2t_3 + b_2t_3 + c_2t_3 + d_2 = 1 \\
    f(t_2^-) &= 3a_1t_2 + 2b_2t_2 + c_2 = 0 \\
    f(t_2^+) &= a_2t_2 + b_2t_2 + c_2t_2 + d_2 = 0 \\
    f(t_3^-) &= 3a_1t_3 + 2b_2t_3 + c_2 = 0
\end{align*}
\]

(6)

Here, \( f(t_2^+) \leq \lim_{t \to t_2^-} f(t_2) \), and \( f(t_2^+) \leq \lim_{t \to t_2^+} f(t_2) \), similar with \( f(t_1) \) and \( f(t_3) \). In addition, \( f(t_2^+) = \lim_{t \to t_2^-} \frac{f(t_2) - f(t_2^-)}{t - t_2^-} \) and \( f(t_2^+) = \lim_{t \to t_2^+} \frac{f(t_2) - f(t_2^+)}{t - t_2^+} \).
According to Eq. (6), we can get the solution of $a_1, b_1, c_1$ and $a_2, b_2, c_2$, so we have the following Eq. (7).

$$
\begin{align*}
0, & & t < t_1 \\
\frac{1}{2}\left( \frac{t_2 - t_1}{t_1 - t_2} \right)^2 + \frac{1}{2}\left( \frac{t_1 - t_2}{t_2 - t_1} \right)^2 + \frac{1}{2}\left( \frac{t_2 - t_1}{t_1 - t_2} \right)^2, & & t_1 \leq t < t_2 \\
\frac{2}{t_1 - t_2} - \frac{t_1 + t_2}{t_1 - t_2}, & & t_2 \leq t < t_1
\end{align*}
$$

(7)

We refer to previous studies by Zhang et al. (2017). $t_1$ is valued at 2 h as most the international airports in the world stipulate the minimum connection time for two subsequent flights as at least 1.5 h. Therefore, the most appropriate transfer time $t_2$ is determined at 5.5 h. We also consider the connectivity index, for one flight departing from airport $i$ transferring at the international airport $m$, as arriving at airport $j$, we also define its capacity factor by considering the number of seats, which is expressed as Eq. (8).

$$
q_{mj} = \frac{\min(m_{im}, m_{jm})}{S}
$$

(8)

where $S$ is the maximum number of seats for all flights in our sample; $m_{im}$ denotes the total number of seats for all flights from airport $i$ to airport $m$; $m_{jm}$ denotes the total number of seats of each sampled airport $m$. In our estimation, we try to suggest the potential direct routes for Beijing to explore its potential for a selected sample of overseas destinations. With such a potential index, we can make suggestions on the promising destinations and existing overseas destinations. Then, based on the estimation results, we can calculate an index to indicate the direct flight passenger potential for a selected sample of overseas destinations. With such a potential index, we can make suggestions on the promising destinations and relevant policy supports.

### Table 4

| City     | International connectivity index | Transfer capability index |
|----------|----------------------------------|---------------------------|
| Beijing  | 995                              | 452.40                    |
| Shanghai | 1957                             | 660.09                    |
| Hong Kong| 2278                             | 1126.81                   |
| Tokyo    | 1676                             | 315.87                    |
| Singapore| 4399                             | 863.47                    |
| Dubai    | 4191                             | 980.11                    |
| New York | 2860                             | 516.54                    |
| London   | 4493                             | 711.19                    |

Source: calculated by the authors.

7 International flight transfer calls for a longer time interval between subsequent flights. This is because the international transfer passengers need to go through customs and have stricter security checks at the transfer hubs. The long-haul international flights would also ask for flight crews to change shifts between flights, also lengthening the transfer interval time. We inquired the actual time of ticket purchasing by passengers who had transfer requirements at Beijing Capital Airport and Shanghai Pudong Airport in 2019, and found that 5.5 h was the most appropriate transfer time.

3. Determinants and potential of direct flight traffic

By examining the international air connectivity of Beijing and benchmarked with its major counterparts, it shows the necessity for the city to improve and to catch up with the world leaders. In this section, we try to suggest the potential direct routes for Beijing to explore its international air network. First, we estimate a gravity-type model to measure the determining factors of direct flight traffic between Beijing and existing overseas destinations. Then, based on the estimation results, we calculate an index to indicate the direct flight passenger potential for a selected sample of overseas destinations. With such a potential index, we can make suggestions on the promising destinations and relevant policy supports.

3.1. Gravity-type model

Previous studies suggested that the gravity model can also be applied to measure OD air traffic (Zhang and Zhang, 2016). Zhang et al. (2018) reviewed several factors contributing to or hindering the bilateral air traffic between two cities. For example, economic development, closer cultural ties and liberalized market competition are the conducive factors, while the flying distance and higher ticket prices increase the air travel cost and decrease the airline traffic. To formally examine the determining factors of Beijing’s direct international flight traffic on the
route level, by referring to Wang et al. (2020), we adopt a gravity model as specified in a logarithm form as follows.

\[
\ln P_{ijt} = \alpha_0 + \alpha_1 \ln \text{Dist}_{ijt} + \alpha_2 \ln \text{AirportSize}_{\text{Foreign} j} + \alpha_3 \ln \text{AirportHHI}_{\text{Foreign} j} + \alpha_4 \ln \text{Transfer}_{\text{Foreign} j} + \alpha_5 \ln \text{Yield}_{ijt} + \alpha_6 \ln \text{HHI}_{ijt-1} + \alpha_7 \ln \text{language} + \varepsilon_t + \eta_j + \rho_{ijt}
\]

(10)

where the subscript \(i\) indicates Beijing and \(j\) is a foreign destination city. The variables in Eq. (10) are defined as follows.

- \(P_{ijt}\): average non-directional number of direct flight passengers between Beijing \(i\) and a foreign airport \(j\) in time \(t\);
- \(\text{Dist}_{ijt}\): flying distance between Beijing \(i\) and foreign airport \(j\) in kilometers;
- \(\text{AirportSize}_{\text{Foreign} j}\): number of total departing passengers at the foreign airport \(j\) in time \(t\);
- \(\text{AirportHHI}_{\text{Foreign} j}\): number of total departing passengers at Beijing \(i\) in time \(t\);
- \(\text{AirportHHI}_{\text{PEK} j}\): airline market HHI index (Herfindahl-Hirschman Index) at foreign airport \(j\) in time \(t\);
- \(\text{AirportHHI}_{\text{PEK} j}\): airline market HHI index at Beijing \(i\) in time \(t\);
- \(\text{Transfer}_{\text{Foreign} j}\): the share of passengers transferred from Beijing \(i\) to foreign airport \(j\) in the total number of passengers on the direct flights between Beijing \(i\) and foreign airport \(j\) in time \(t\);
- \(\text{Transfer}_{\text{Foreign} j}\): proportion of passengers from Beijing \(i\) to foreign airport \(j\) who then fly to other destinations in the total number of passengers from Beijing \(i\) to airport \(j\) in time \(t\);
- \(\text{Yield}_{ijt}\): average yield on the route between Beijing \(i\) and foreign airport \(j\) in time \(t - 1\). The unit is USD/km;
- \(\text{HHI}_{ijt-1}\): route-specific HHI index for the route between Beijing \(i\) and foreign airport \(j\) in time \(t - 1\);
- \(\text{language}\): a dummy variable equaling to one if the official or majority language of destination country is Chinese. These regions include Hong Kong, Macau, Taiwan and Singapore;
- \(\varepsilon_t\): a vector of time-specific error terms;
- \(\eta_j\): route-specific error term;
- \(\rho_{ijt}\): a purely random error term.

The gravity model is applied to estimate for the sample including all the direct international routes originating from Beijing, and the period considered spans from January to December of 2018. The direct flight passenger traffic data \(P_{ijt}\) is obtained from the TravelSky. \(\text{AirportSize}_{\text{Foreign} j}\) and \(\text{AirportHHI}_{\text{PEK} j}\) indicate the potential airline traffic market size, playing a similar role as controlling for the GDP and populations for the destination cities. The data for these two variables are also available from TravelSky. The airport HHI indexes for Beijing and foreign airports are calculated as the sum of squared market shares of each operating airline at Beijing or foreign destination airport, respectively. They help measure airline market concentration or airline dominance at Beijing and foreign destination airports. Whether a more concentrated airline market will benefit or harm the airline traffic is uncertain. On one hand, high airline concentration suggests the monopoly power of particular airlines and lack of competition at the airport, which would raise the average ticket price to harm the traffic. On the other hand, airline dominance indicates its hub status, suggesting better network connection and services for passengers (i.e., Borenstein, 1989; Richard, 2003). The transfer passenger variable \(\text{Transfer}_{\text{PEK} j}\) and \(\text{Transfer}_{\text{Foreign} j}\) are used to measure the contribution of transfer passengers through Beijing or the foreign airport on the direct flight traffic between Beijing and the foreign airport, and they can be obtained from IATA AirportIS database. Moreover, the flying distance \(\text{Dist}_{ijt}\) is one major impediment for direct air passenger flow, with the data obtained from the TravelSky. The variable \(\text{language}\) is a dummy variable used to capture the cultural ties within the great China circle, including the regions, Macau, Hong Kong, Taiwan and Singapore. Such similar culture would also be conducive to facilitating bilateral air passenger flow ceteris paribus.

In addition, this gravity model also includes two route-level variables, \(\text{Yield}_{ijt}\) and \(\text{HHI}_{ijt}\). \(\text{Yield}_{ijt}\) is the average yield on the route, that is, the average airfare per kilometer. A higher yield suggests a more expensive traveling cost, damaging the air traffic. \(\text{HHI}_{ijt}\) is the route-level HHI, calculated as the sum of the squared traffic shares of each operating airline, and a larger route-level HHI causes less airline competition on the route. It is noted that these two variables are lag one phase to partly address the endogeneity which results from the mutual decisive relationship between air traffic and the route-level airline pricing and competition.

To estimate the gravity model, we tried several alternative identification methods. First, the ordinary least squares (OLS) was used on the pooled data while also controlling the monthly time effects. Second, the fixed effects (FE) estimation is used to further control the route-specific error term \(\eta_j\), which can be regarded as the unobserved time-invariant factors. However, FE does not allow us to identify coefficients for those time-invariant variables, such as route distance and other dummy variables. Thus, FE estimates are mainly referred to as the robustness checks. Finally, we use the random-effects (RE) approach, using the panel data properties of our samples, to provide a more efficient comparison to the OLS estimates.

The estimation results are collated in Table 5. Although the lagged values are used, the first three columns still report the results, excluding the variables \(\text{Yield}_{ijt-1}\) and \(\text{HHI}_{ijt-1}\) to eliminate any potential endogeneity. The last three columns show the results by including all the variables. First, the flying distance is a very significant impediment for direct flight traffic between Beijing and other foreign destinations. This is consistent with our observations in Section 2 that most of Beijing’s direct flights fly to Northeast and Southeast Asian countries, while the inter-continental flights are much fewer. Moreover, Beijing’s direct flight traffic is significantly larger than those larger scale foreign airports, while not driven by Beijing’s own passenger traffic volume. This is suggested by the significantly positive signs of \(\text{AirportSize}_{\text{Foreign} j}\) in all columns of Table 5, while the signs of \(\text{AirportHHI}_{\text{PEK} j}\) are not statistically significant. When referring to the FE and RE estimations, we found a higher HHI at the foreign airport would reduce direct flight traffic from Beijing to this airport, suggested by the significantly negative signs of \(\text{AirportHHI}_{\text{Foreign} j}\). Thus, the monopoly power of airlines in foreign airports could hinder the direct flight traffic from Beijing. On the other hand, the hub status of Air China in Beijing proves to stimulate its direct international flights, as the dominance of Air China also helps improve the service quality as discussed earlier.

In addition, both \(\text{Transfer}_{\text{PEK} j}\) and \(\text{Transfer}_{\text{Foreign} j}\) are statistically positive, as shown in the last three columns of Table 5. That is, the transfer passenger flow at either Beijing or foreign airport helps increase the traffic for the direct flights linking Beijing and this foreign airport. Such empirical result clearly suggests that it is essential for Beijing to develop its transfer function and to prioritize developing direct flights to major overseas hub airports. As suggested in subsection 2.2, Beijing has lagged behind other major counterparts to serve international transfer traffic, but the opening of the new Beijing Daxing Airport also offers several conducive factors for Beijing to develop in the international transfer hub in Northeast Asia. Last, a higher route-level airline concentration proves to discourage the direct flight traffic, indicated by the significantly negative sign of \(\text{HHI}_{ijt-1}\). Promoting more intense airline competition on Beijing’s international routes is thus important to further stimulate the passenger traffic, which calls for further liberalization of China’s international air policy involved Beijing. The average ticket
price level seems to play a minor role to affect the international direct flight traffic at Beijing.

3.2. Index of potential market size

The gravity model estimations in subsection 3.1 help shed light on the determinants of Beijing’s direct flight traffic to different overseas destinations. The results are also helpful to infer the market potential for those overseas destinations currently without direct flight service from Beijing. According to Wang et al. (2020), the index of the potential direct destinations. The results are also helpful to infer the market potential for the determinants of Beijing flight market size for each destination foreign airport can be calculated those overseas destinations currently without direct flight service from

The index of potential market size is shown in Table A1 (please see the appendix). The table also distinguishes the airports with and without existing direct flights from Beijing. First, among the 112 candidate airports, 82 airports have already opened direct flights with Beijing, and they get higher index values, which indicates that Beijing has fully considered the potential market size of these destination cities before. Further, this result indicates the validity of this index since the most viable routes have been successfully identified. Table 2(a) shows that Beijing has a comparable number of overseas destinations compared with other major counterparts. Therefore, Beijing’s poor air connectivity is mainly attributed to its lower flight frequency and underdeveloped transfer service.

Among the 100 busiest airports, Beijing has yet opened direct flights to Phoenix, Minneapolis, Philadelphia, Washington, Charlotte, Orlando, Salt Lake City, and Fort Lauderdale in the US, Warsaw in Poland, Oslo in Norway, Bogota in Colombia, Palma in Spain, Antalya and Istanbul (SAW) in Turkey, Bangalore in India, and Cancun in Mexico. Although these airports are not ranked the top in the list of the index shown in Table A1, they still have relatively higher market potential than many airports with direct flights from Beijing. There is an apparent great market potential for Beijing to explore more US destinations to open direct flights. However, the current bilateral ASA between China and the US is still restrictive to limit more direct flights between the two countries (Lei et al., 2016). Moreover, it is observed that the new direct flights from Beijing to Warsaw and Oslo were opened in October 2019 and May 2018, a total of 112 foreign airports, and many of them have already opened the direct routes with the candidate airport, such as Salt Lake City, and Fort Lauderdale in the US, Warsaw in Poland, Oslo in Norway, Bogota in Colombia, Palma in Spain, Antalya and Istanbul (SAW) in Turkey, Bangalore in India, and Cancun in Mexico. Although these airports are not ranked the top in the list of the index shown in Table A1, they still have relatively higher market potential than many airports with direct flights from Beijing. There is an apparent great market potential for Beijing to explore more US destinations to open direct flights. However, the current bilateral ASA between China and the US is still restrictive to limit more direct flights between the two countries (Lei et al., 2016). Moreover, it is observed that the new direct flights from Beijing to Warsaw and Oslo were opened in October 2019 and May 2019, respectively, which suggests that this estimated index has reference significance for the opening of international routes in Beijing in the future.

In terms of B&R countries, their values of potential market size index

| Table 5 | Gravity model estimation results. |
|--------|----------------------------------|
|        | OLS | FE | RE | OLS | FE | RE |
| **InDist** | -0.783*** | -0.860*** | -0.345*** | -0.543*** |
| (0.0145) | (0.112) | (0.00892) | (0.0818) |
| **lnAirportSize.Foreign** | 0.589*** | 0.739*** | 0.674*** | 0.380*** | 0.605*** | 0.526*** |
| (0.0144) | (0.120) | (0.00898) | (0.0438) | (0.0435) |
| **lnAirportSize_PEK** | -0.0643 | -0.244 | -0.163 | 0.254* | -0.0123 | 0.888 |
| (0.176) | (0.252) | (0.103) | (0.176) | (0.150) |
| **lnAirportHHI.Foreign** | 0.0979*** | -0.216*** | -0.139*** | 0.115*** | -0.142*** | -0.0530 |
| (0.0178) | (0.0769) | (0.00650) | (0.00978) | (0.0439) | (0.0530) |
| **lnAirportHHI_PEK** | -1.129 | 0.782 | 0.888 | 0.735** | 1.398*** | 1.518* |
| (0.717) | (0.995) | (0.994) | (0.166) | (0.539) | (0.845) |
| **transfer_PEK** | -0.132 | 0.145 | 0.130 | 0.311** | 0.375*** | 0.372*** |
| (0.151) | (0.165) | (0.164) | (0.0769) | (0.0895) | (0.114) |
| **transfer.foreign** | 0.212** | 0.0192 | 0.0477* | 0.265*** | 0.0104 | 0.0445** |
| (0.0377) | (0.0193) | (0.0252) | (0.0431) | (0.0391) | (0.0222) |
| **language** | 1.121*** | 0.991*** | 0.962*** | 0.898*** |
| (0.0113) | (0.284) | (0.0142) | (0.265) |
| **HHI_airline.t1** | -1.837*** | -0.892*** | -1.044*** |
| (0.0138) | (0.0815) | (0.118) |
| **lnYield.t1** | -0.0554** | 0.0297 | 0.0451 |
| (0.0166) | (0.0259) | (0.0390) |
| **Constant** | 6.927 | 3.519 | 10.60*** | 5.923* | 3.389 | 7.988*** |
| (3.591) | (3.420) | (3.709) | (1.720) | (2.864) | (2.622) |
| **Obs** | 146 | 146 | 146 | 133 | 133 | 133 |
| **R-squared** | 0.529 | 0.136 | 0.740 | 0.236 |

Note: ***p < 0.01, **p < 0.05, *p < 0.1, the dummy variables representing seasonal factors are not shown in this table.

The index of potential market size is calculated as shown in Eq. (11).8

\[ \text{Potential} = -0.86 \times \ln \text{Dist} + 0.674 \times \ln \text{AirportSize.Foreign} - 0.139 \times \ln \text{AirportHHI.Foreign}. \]

(11)

8 As we need to use the coefficient of flying distance variable, FE estimations cannot be used. RE provides more efficient estimates than OLS, such that RE estimates are used. We have also tried to use the RE estimates including the route HHI and yield variables, and the conclusions are qualitatively consistent.
are ranked very low, although China has strengthened the economic and trade ties with these countries. Beijing does not even open direct flights with some capital cities of B&R countries, such as Bucharest in Romania, Muscat in Oman. Thus, it is even more important to implement supportive policy stipulating airlines to open direct flights to these destinations, such as more favorable airport slots and discounted landing charges. Civil Aviation Administration of China (CAAC) or the Beijing government could also consider subsidizing airlines to initiate direct flights to B&R destinations with high market potential. China should also push forward the liberalization of bilateral ASA with B&R countries through negotiations and even multilateral platforms under the B&R Initiative framework.

4. Conclusions

As China’s economic and political center, Beijing plays a vital role in maintaining the communication between China and foreign countries. The city has also recently aimed to develop into China’s international exchange center and free trade zone. Such national strategies not only provide Beijing with a golden opportunity but also call the city to better develop its international air connectivity. However, there are fewer studies to comprehensively measure and evaluate Beijing’s international air connectivity, this study fills in the research gap by empirically measuring Beijing’s international air connectivity through descriptive statistics and comprehensive indexes. This study found that, although Beijing has a comparable number of foreign destinations with direct flights opened as other counterparts, it still significantly lags behind other counterparts in the international air connectivity due to its inferior connection quality (i.e., flight frequency, number of seats, flying distance) and much underdeveloped transfer function. Beijing even has inferior connectivity and transfer capability index values than Shanghai. Beijing’s poor international air connectivity is mainly attributed to its restrictive aviation policies and airport capacity constraints. Although China has significantly liberalized its bilateral ASAs in recent years, the relatively severe regulations on Beijing’s international air market still exist, which enlarges the gap between Beijing and other major Chinese airports in international connectivity. It can be predicted that once the international aviation market is liberalized, Beijing can thus fully take advantage of the plenty capacity added by new Beijing Daxing Airport to increase international direct flights and to develop the transfer service system.

We also investigated the determinants of Beijing’s route-level direct flight traffic by using a gravity model. It is shown that Beijing has already opened direct flights with most of the candidate airports with great market potential. Thus, it is more important to improve the connectivity quality of existing network by liberalizing restrictions on flight frequency and airfare to improve connection quality. The potential market size of B&R (Belt-and-Road) countries’ airports are ranked very low. Given the growing trade and tightening economic ties between China and B&R countries, Beijing could consider formulating more favorable policies to support opening direct flights with B&R countries.

This study is also subject to some limitations. First, the air connectivity evaluation is based on data before COVID-19 pandemic, such that the policy and managerial implications are examined from a long-term perspective after the global international travel would rebound to the pre-pandemic level. Thus, our analyses and empirical results are not tailored to offer short-term suggestions for Beijing to resume international air connectivity when China is still tightly controlling inbound international flights. Second, this study is mainly on the city-level, while not specifically identifying the distinct functions that can be played by international flights. Second, this study is mainly on the city-level, while not specifically identifying the distinct functions that can be played by international flights. The potential advantage of the plenty capacity added by new Beijing Daxing Airport to improve the connectivity quality of existing network by liberalizing restrictions on flight frequency and airfare to improve connection quality. The potential market size of B&R (Belt-and-Road) countries’ airports are ranked very low. Given the growing trade and tightening economic ties between China and B&R countries, Beijing could consider formulating more favorable policies to support opening direct flights with B&R countries.

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Appendix

Table A1
Index of potential to open direct flight services

| Rank | Airport Code | City     | Country  | Index | Navigation Or not | Top 100 busiest | B&R Country |
|------|--------------|----------|----------|-------|------------------|-----------------|-------------|
| 1    | ICN          | Seoul    | Korea    | 6.73  | Y                | Y               | Y           |
| 2    | HKG          | Hong Kong| China    | 6.61  | Y                | Y               | N           |
| 3    | HND          | Tokyo    | Japan    | 6.02  | Y                | Y               | N           |
| 4    | TPE          | Taipei   | China    | 5.97  | Y                | Y               | N           |
| 5    | GMP          | Seoul    | Korea    | 5.90  | Y                | Y               | N           |
| 6    | NRT          | Tokyo    | Japan    | 5.81  | Y                | Y               | N           |
| 7    | CJU          | Cheju    | Korea    | 5.79  | Y                | Y               | N           |
| 8    | KIX          | Osaka    | Japan    | 5.77  | Y                | Y               | N           |
| 9    | FUK          | Fukuoka  | Japan    | 5.73  | Y                | Y               | N           |
| 10   | BKK          | Bangkok  | Thailand | 5.63  | Y                | Y               | N           |
| 11   | DEL          | Delhi    | India    | 5.47  | Y                | Y               | N           |
| 12   | SIN          | Singapore| Singapore| 5.42  | Y                | Y               | Y           |
| 13   | MNL          | Manila   | Philippines| 5.36 | Y                | Y               | Y           |
| 14   | CGK          | Jakarta  | Indonesia| 5.25  | Y                | Y               | Y           |
| 15   | KUL          | Kuala Lumpur| Malaysia| 5.22  | Y                | Y               | Y           |
| 16   | ORD          | Chicago  | US       | 5.12  | Y                | Y               | N           |
| 17   | LAX          | Los Angeles| US     | 5.12  | Y                | Y               | N           |
| 18   | DXB          | Dubai    | UAE      | 5.10  | Y                | Y               | N           |
| 19   | BOM          | Bombay   | India    | 5.02  | Y                | Y               | N           |
| 20   | HAN          | Hanoi    | Vietnam  | 5.02  | Y                | Y               | N           |
| 21   | SGN          | Ho Chi Minh| Vietnam| 4.94  | Y                | Y               | N           |
| 22   | CDG          | Paris    | France   | 4.93  | Y                | Y               | N           |
| 23   | DOH          | Doha     | Qatar    | 4.91  | Y                | Y               | N           |
| 24   | MAD          | Madrid   | Spain    | 4.89  | Y                | Y               | N           |

(continued on next page)
| Rank | Airport Code | City       | Country         | Index | Navigation Or not | Top 100 busiest | B&R Country |
|------|--------------|------------|-----------------|-------|-------------------|-----------------|-------------|
| 25   | AMS          | Amsterdam  | Netherlands     | 4.86  | Y                 | Y               | N           |
| 26   | LHR          | London     | UK              | 4.84  | Y                 | Y               | N           |
| 27   | DFW          | Dallas     | US              | 4.84  | Y                 | Y               | N           |
| 28   | FRA          | Frankfurt  | Germany         | 4.83  | Y                 | Y               | Y           |
| 29   | SEA          | Seattle    | US              | 4.81  | Y                 | Y               | N           |
| 30   | DTW          | Detroit    | US              | 4.81  | Y                 | Y               | N           |
| 31   | BWI          | Baltimore  | US              | 4.79  | N                 | Y               | N           |
| 32   | IST          | Istanbul   | Turkey          | 4.74  | Y                 | Y               | Y           |
| 33   | SFO          | San Francisco | US         | 4.69  | Y                 | Y               | N           |
| 34   | SVO          | Moscow     | Russia          | 4.69  | Y                 | Y               | Y           |
| 35   | CPH          | Copenhagen | Denmark         | 4.63  | Y                 | Y               | N           |
| 36   | JFK          | New York   | US              | 4.62  | Y                 | Y               | N           |
| 37   | MUC          | Munich     | Germany         | 4.61  | Y                 | Y               | N           |
| 38   | ATL          | Atlanta    | US              | 4.60  | N                 | Y               | N           |
| 39   | YYY          | Toronto    | Canada          | 4.59  | Y                 | Y               | N           |
| 40   | LAS          | Las Vegas  | US              | 4.59  | Y                 | Y               | N           |
| 41   | LGA          | LaGuardiana | New York       | 4.53  | Y                 | Y               | N           |
| 42   | SYD          | Sydney     | Australia       | 4.52  | Y                 | Y               | N           |
| 43   | BOS          | Boston     | US              | 4.52  | Y                 | Y               | N           |
| 44   | FCO          | Rome       | Italy           | 4.50  | Y                 | Y               | Y           |
| 45   | DMK          | Bangkok    | Thailand        | 4.49  | Y                 | Y               | Y           |
| 46   | DME          | Moscow     | Russia          | 4.49  | Y                 | Y               | Y           |
| 47   | YVR          | Vancouver  | Canada          | 4.46  | Y                 | Y               | N           |
| 48   | DEN          | Denver     | US              | 4.43  | N                 | Y               | N           |
| 49   | EWR          | New York   | US              | 4.42  | Y                 | Y               | N           |
| 50   | ARN          | Stockholm  | Sweden          | 4.41  | Y                 | Y               | N           |
| 51   | IAH          | Houston    | US              | 4.40  | Y                 | Y               | N           |
| 52   | BCN          | Barcelona  | Spain           | 4.39  | Y                 | Y               | N           |
| 53   | ZRH          | Zurich     | Switzerland     | 4.35  | Y                 | Y               | N           |
| 54   | VIE          | Vienna     | Austria         | 4.31  | Y                 | Y               | Y           |
| 55   | MEX          | Mexico     | Mexico          | 4.28  | Y                 | Y               | N           |
| 56   | MEL          | Melbourne  | Australia       | 4.28  | Y                 | Y               | N           |
| 57   | RUH          | Riyadh     | Saudi Arabia    | 4.27  | Y                 | Y               | Y           |
| 58   | MIA          | Miami      | US              | 4.27  | Y                 | Y               | N           |
| 59   | JED          | Jeddah     | Saudi Arabia    | 4.27  | Y                 | Y               | N           |
| 60   | MAN          | Manchester | UK              | 4.26  | Y                 | Y               | N           |
| 61   | PNH          | Phnom Penh | Cambodia        | 4.26  | Y                 | Y               | N           |
| 62   | DUS          | Dusseldorf | Germany         | 4.23  | Y                 | Y               | N           |
| 63   | BRU          | Brussels   | Belgium         | 4.22  | Y                 | Y               | N           |
| 64   | PHX          | Phoenix    | US              | 4.20  | N                 | Y               | N           |
| 65   | BNE          | Brisbane   | Australia       | 4.16  | Y                 | Y               | N           |
| 66   | DUB          | Dublin     | Ireland         | 4.14  | Y                 | Y               | N           |
| 67   | MSP          | Minneapolis | US           | 4.14  | N                 | Y               | N           |
| 68   | WAW          | Warsaw     | Poland          | 4.11  | N                 | Y               | N           |
| 69   | RGN          | Rangoon    | Myanmar         | 4.10  | Y                 | Y               | N           |
| 70   | PHL          | Philadelphia | US           | 4.07  | N                 | Y               | N           |
| 71   | PRG          | Prague     | Czech Republic  | 4.02  | Y                 | N               | Y           |
| 72   | DCA          | Washington | US              | 4.02  | N                 | Y               | N           |
| 73   | CLT          | Charlotte  | US              | 4.00  | N                 | Y               | N           |
| 74   | SJC          | San Jose   | Costa Rica      | 4.00  | Y                 | N               | Y           |
| 75   | KWI          | Kuwait     | Kuwait          | 3.99  | N                 | N               | Y           |
| 76   | LIS          | Lisbon     | Portugal        | 3.97  | Y                 | Y               | Y           |
| 77   | KTM          | Kathmandu  | Nepal           | 3.96  | Y                 | N               | Y           |
| 78   | MCO          | Orlando    | US              | 3.94  | N                 | Y               | N           |
| 79   | SLC          | Salt Lake City | US       | 3.94  | N                 | Y               | N           |
| 80   | DAC          | Dhaka      | Dhaka           | 3.92  | Y                 | N               | Y           |
| 81   | CAI          | Dhaka      | Egypt           | 3.87  | N                 | Y               | N           |
| 82   | OSL          | Oslo       | Norway          | 3.85  | N                 | Y               | N           |
| 83   | AUL          | Abu Dhabi  | UAE             | 3.85  | Y                 | Y               | Y           |
| 84   | OTP          | Bucharest  | Romanian        | 3.85  | N                 | N               | N           |
| 85   | FLL          | Fort Lauderdale | US         | 3.81  | N                 | Y               | N           |
| 86   | MCT          | Muscat     | Oman            | 3.81  | N                 | N               | Y           |
| 87   | GRU          | Sao Paulo  | Brazil          | 3.79  | Y                 | Y               | N           |
| 88   | BUD          | Budapest   | Hungary         | 3.75  | N                 | Y               | N           |
| 89   | BAH          | Manama     | Bahrain         | 3.74  | N                 | N               | Y           |
| 90   | CMB          | Colombo    | Sri Lanka       | 3.74  | Y                 | Y               | N           |
| 91   | CUN          | Cancun     | Mexico          | 3.69  | N                 | Y               | N           |
| 92   | KBP          | Kiev       | Ukraine         | 3.61  | N                 | Y               | Y           |
| 93   | BEY          | Beirut     | Lebanon         | 3.55  | N                 | N               | Y           |
| 94   | ISB          | Islamabad  | Pakistan        | 3.52  | Y                 | N               | Y           |
| 95   | JNB          | Pretoria   | South Africa    | 3.52  | Y                 | N               | Y           |
| 96   | BOG          | Bogota     | Colombia        | 3.51  | N                 | Y               | N           |
| 97   | IKA          | Tehran     | Iran            | 3.46  | Y                 | Y               | N           |
| 98   | PMI          | Palma Mallorca | Spain      | 3.44  | N                 | Y               | N           |
| 99   | NBO          | Nevada     | Nevada          | 3.42  | N                 | N               | Y           |

(continued on next page)
Table A1 (continued)

| Rank | Airport Code | City    | Country | Index | Navigation Or not | Top 100 busiest | B&R Country |
|------|--------------|---------|---------|-------|-------------------|-----------------|-------------|
| 100  | AYT          | Antalya | Turkey  | 3.31  | N                 | Y               | Y           |
| 101  | GYD          | Baku    | Azerbaijan | 3.24  | Y                 | N               | Y           |
| 102  | SAW          | Istanbul| Turkey  | 3.23  | N                 | Y               | Y           |
| 103  | MLE          | Male    | Maldives| 3.22  | Y                 | N               | Y           |
| 104  | WLG          | Wellington | New Zealand | 3.19  | N                 | Y               | N           |
| 105  | LIM          | Lima    | Peru    | 3.16  | N                 | Y               | Y           |
| 106  | MSQ          | Minsk   | Belarus | 3.13  | Y                 | N               | Y           |
| 107  | SCL          | Santiago | Chile    | 3.06  | N                 | N               | Y           |
| 108  | LUX          | Luxembourg | Luxembourg | 3.05  | Y                 | N               | Y           |
| 109  | BLR          | Bangalore | India     | 3.05  | N                 | N               | Y           |
| 110  | BWN          | Sribagar Bay | Brunei    | 2.89  | Y                 | N               | Y           |
| 111  | HAV          | Havana  | Cuba    | 2.84  | Y                 | N               | Y           |
| 112  | KRT          | Khartoum | Sudan    | 2.53  | Y                 | N               | Y           |

Note: the airports in bold are those that have not opened direct flights with Beijing as of 2018.

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