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Changes in airport operating procedures and implications for airport strategies post-COVID-19

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ABSTRACT

Covid-19 is demanding a lot of changes in the realm of our daily lives. The aviation industry is also facing unprecedented changes in the management environment. Financial tensions across the sector are rising. This study suggests that the airport strategy's direction focusing on commercial revenue management. After Covid-19, safety and hygiene will be the top priority. As a result, changes in airport operating procedures are inevitable. The most noticeable difference will be the strengthening of the verification process for passengers' health conditions. Dwell time increase can be the by-products. This study identifies a dwell time increase has a more significant impact on increasing the existing purchasers' spending than creating new buyers. Airport operators can introduce a service differentiation perspective, such as a dedicated service, to utilize the current buyers' dwell time more faithfully. Also, the rise of online channels requires airport operators to change sales strategies, reinforcing emotional promotion to stimulate impulse buyers' willingness-to-buy. Before Covid-19, there was little effort to reconcile operation policies and commercial revenue despite the growing importance of revenue management. However, now it is time to change. Pre-Covid-19, passengers were advised of using off-airport processes, such as online check-in and mobile boarding passes. Now, getting passengers to the airport quickly and securing their dwell time can be financially more beneficial. It is necessary to incorporate the commercial revenue perspective into operation policies post-Covid-19 actively. Our finding indicates that even a passenger with solid purchasing power may lose the purchasing intention when assigned to an unfavorable gate or terminal. Airport operators need a better understanding of passenger and flight characteristics when determining operation policy, such as gate allocation or membership services.

1. Introduction

The Covid-19 pandemic that hits the world is causing a tremendous change in our lives. Also, The Covid-19 is causing significant losses to global economies. The aviation industry is one of the most affected sectors, as most countries recognize international and regional aviation connections as a vital epidemic transmission route (Zhang et al., 2020). The damage is expected to top $84 billion in 2020, according to International Air Transport Association (IATA, 2020). This demonstrates that the aviation industry can stop growing at any time.

As low-cost carriers (LCCs) have expanded their market share since the early 2000s, the airline industry has become more sensitive to costs. As competition to attract airlines has intensified (Choi et al., 2019), financial stability is increasingly essential to maintain competitive airport fees (Castillo-Manzano, 2010). However, Covid-19 arouses severe concerns about the financial stability of the aviation industry. Passenger demand has declined sharply, and many airlines are at risk of bankruptcy. Due to Covid-19, each airport lost 50% of connections on average, and network efficiency decreased more (Sun et al., 2020). It is still unknown when the Covid-19 pandemic will be over. Government regulations, such as a lockdown or monetary penalty, may continue because individuals do not internalize the external cost of infection risks they impose on others and the health care system (Oum and Wang, 2020). Thus, it is time for airports to strengthen the revenue management strategy. Airport operation resources are finite. The number of flight slots per hour is a typical example. Therefore, airport operators need to maximize revenue per flight to increase profitability. However, considering the airlines' recent financial difficulties, it seems almost impossible to raise airport fees in the short term. Thus, increasing non-aeronautical revenue per flight, including commercial revenue, is

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key to securing financial stability.[1]

Covid-19 pandemic reinforces airport quarantine procedures. On 1 June, the International Civil Aviation Organization (ICAO) announced a new protocol named 'Guidance for air travel through the Covid-19 public health crisis (ICAO, 2020a). Airport operators are required to equip additional procedures, including strengthening quarantine. Passengers may be recommended to arrive at the airport earlier. However, it is questionable whether a change in airport arrival time leads to a commercial revenue increase. It is also interesting how the change affects passengers' behavior, especially at commercial facilities. According to an annual survey from 919 airports in the 2017 fiscal year by Airport Council International (ACI airport economics report, 2019), non-aeronautical revenue accounted for 40% of surveyed airports' total revenue. Airports in Asia-Pacific and the Middle East, where non-aeronautical activities became a familiar concept for airport operation, reached almost 50% (Asia-Pacific: 47%, Middle East; 49%). Commercial revenue, the largest source of non-aeronautical income, accounts for an average of 14.5% of the world's airport revenue, which is larger than the landing charge's contribution, as shown in Appendix A (ACI, 2020). Therefore, discussing how to increase commercial revenue from airport operation procedure changes can provide significant implications for post-Covid-19 airport strategies.

This paper adopts the Incheon International Airport (ICN) as the subject for an empirical investigation to answer these questions. One of this study's great features is to collect the actual transaction data from ICN duty-free shops. Using the real transaction data helps overcome the potential sample selection bias that might prevail in the survey data. Besides, the transaction data includes the flight characteristics (e.g., airline, departure time, and departure day) of the passenger who made the transaction. It enables us to explore revenue per flight, which the previous studies have hardly approached. Duty-free operation revenue accounts for more than 50% of the airport's commercial revenue (ATRS, 2018). Therefore, looking into the duty-free transaction data is meaningful to understand passenger behaviors at commercial facilities. Also, the implications can be applied to other retail facilities. This study examines passenger spending drivers. The drivers include time factors this study is the most interested in, income factors, and location factors. Based on a deep understanding of the drivers, this study seeks to find implications post-Covid-19 in commercial revenue management. This study adopts a flight-level approach, exploring revenue per flight.

2. Literature review

This study focuses on the two areas of the literature; Covid-19 context and the determining factors of airport's commercial revenue. Next, we provide a detailed review of these two strands of literature.

2.1. Covid-19 context

Since most governments recognized that air travel played an important role in the Covid-19 virus spread, they closed territory borders or restricted traveling (Daon et al., 2020). Since March 2020, the global aviation industry has observed a 70–95% drop in passenger demand (Shepardson et al., 2020; Whittly et al., 2020). The number of scheduled aircraft movements decreased by 47.5% by August 2020 (Khatib et al., 2020). This effect causes difficult economic losses not only for the airport but also for most stakeholders in the sector (ICAO, 2020b; International Finance Corporation, 2020; Sharma and Nicolau, 2020). The airlines have responded to this rapid demand drop from a cost-saving perspective by grounding a large portion of the aircraft and putting employees on leave of absence (Akbar and Kisilowski, 2020; Kao et al., 2020). However, airports' situation seems a little bit different. According to ACI (2019), the fixed costs to maintain and operate infrastructure components account for a considerable portion of the airport cost structure. It means that airports are not as flexible to cost savings as airlines are. Forsyth et al. (2020) point out that the airport must achieve its viability through sufficient liquidity to cover costs in the short term and long term. They suggest that airports need to raise aeronautical charges to finance the capital. However, simultaneously, they indicate that government will direct airports not to raise aeronautical charges as a regulator to keep the whole industry's long-term health. It implies that airports should focus more on other revenue sources, such as commercial revenue, in the post-Covid-19 environment.

2.2. Determining factors of airport's commercial revenue

Activities to increase non-aeronautical revenue have increased considerably since the 1990s (Francis et al., 2003). Mainly, a subsidy from concession to aeronautical operations is positioned as an optimum solution for airport operators. (Zhang and Zhang, 1997). Thus, many researchers have elaborated passenger purchase motivation on this growing importance of non-aeronautical revenue. The purchase motivation is mainly explained in four strands: time factors, income factors, location factors, and environmental factors.

2.2.1. Time factors

Several studies examined the relationship between airport dwell time and passenger spending. Torres et al. (2005) found a positive relationship between dwell time and spending for both vacationers and business travelers. Aza and Valdes (2003) identified the relationship between commercial expenditure (y) and dwell time (x) by using simple regression; $y = 0.17_{(0.015)}x + 2.757_{0.000}$, indicating a positive linear relationship between two variables. D'Alfonso et al. (2013) adopted flight delay's positive impact on passenger spending when simulating airport congestion pricing. Wan et al. (2015) suggested that lengthen dwell time increases their purchasing chance at commercial facilities. Some studies highlighted the importance of retail area design (e.g., easy wayfinding, strategic seating spaces) to provide more time for shopping (Bohl, 2014; Livingstone, 2012). Meanwhile, Wang et al. (2019) indicated that a too-long dwell time reduces passenger's spending intention adversely because of increasing stress.

2.2.2. Income factors

Jiang (2016) compared the expenditure amount at Hong Kong airport (HKG) shops by classifying groups according to income levels. This study showed significant differences in expenditure depending on income levels. Since it is difficult to measure a passenger's income, many studies have focused on flight type comparison. A representative one is a study on LCC flights. Initial studies had suggested that LCC passengers contribute more to the airport's commercial revenue than full-service carrier (FSC) passengers, mainly due to their consumption at F&Bs (McDonald and Gillen, 2003; Francis et al., 2003; Barrett, 2004). However, most studies generally viewed LCC's contribution to non-aeronautical revenue as lower (Papatheodorou and Lei, 2006; Lei and Papatheodorou, 2010; Castillo-Manzano, 2010; Fasone et al., 2016). However, more recent studies showed that certain LCC passenger groups, such as Chinese LCC passengers, are more willing to purchase duty-free goods at overseas airports (Li et al., 2010; Xu and McGehee, 2012; Tsui, 2017). This implies that an understanding of passenger characteristics helps to increase revenue.

2.2.3. Location factors

Fuerst and Gross (2018) used panel data, including airports in 30 countries, to reveal the location of retail space is a significant determinant of passenger purchase. Wu and Chen (2019) also identified the effect of terminal layouts on commercial revenue using an agent-based

[1] ACI Europe also strongly recommends the deregulation of tax-free shopping as a critical element of the airport recovery plan. Retrieved from https://www.aci-europe.org/media-room/280-arrivals-duty-and-tax-free-shopping-at-eu-airports-a-key-element-of-recovery-plan.html (accessed on 23 Nov 2020).

simulation approach. They considered two airport terminal layouts (shop location and terminal size) and suggested that terminal design significantly affects passengers' shopping preferences. Hsu and Chao (2005) showed that commercial revenue could increase by changing stores' location and layout, leading passengers to move through naturally on their path. Del Chiappa et al. (2016) and Forsyth (2004) emphasized that airport operators should actively improve commercial facility layout because location characteristics significantly influence passengers' purchase intention.

2.2.4. Environmental factors

Several studies discussed impulse buying tendency as the main characteristic of airport shoppers. Omar and Kent (2001), Lin and Chen (2013), and Lu (2014) categorized two shopping intentions (i.e., preplanned shopping vs. impulse shopping), showing that airport shoppers are greatly affected by impulse shopping. Thomas (1997) presented a high level of excitement as a driving force behind impulsive buying behavior. Other studies cited the atmosphere and shopping environment as vital impulse purchasing motivation. Because passengers perceive airports as unique environments, experiences escaping out of the routine can become strong shopping motivations at airport shops (Geuens et al., 2004; Lin and Chen, 2013; Han and Hyun, 2018). These studies imply that environmental factors can encourage or discourage impulsive decisions. Thus, an attractive promotion can stimulate passengers' purchasing intentions and create word-of-mouth recommendations (Park et al., 2013). Martin-Cejas (2006) suggested that focusing on fulfilling passengers' expectations by making a joyful environment is more required than increasing facility expansions.

3. Conceptual framework, data, and methodology

3.1. Conceptual framework

This study examines passenger spending determinants at commercial facilities, including time factors, income factors, and location factors, as shown in Eq. (1).

$$Passenger\ Spending = f(time\ factors,\ income\ factors,\ location\ factors) \quad (1)$$

This study considers two variables, including passenger airport arrival time and flight delay, as time factors. Both variables can affect dwell time. We use whether to board an LCC flight and whether to take a transit flight as income factors.[2] Both are supposed to be related to income factors. As the location factors, we consider departure location, including the departure terminal and departure gate. This study does not examine environmental factors because we cannot measure them. Environmental factors depend on each passenger's perception and evaluation of the shopping environment or atmosphere, which cannot be measured in the actual transaction data. In our data set, the number of passengers per flight is 193, and the average number of purchasers is about 30 in the data set. Each passenger may perceive the shopping environment or atmosphere better or worse than the average perception. Because this study applies flight-level research, exploring an impact on commercial revenue per flight, the difference felt by each passenger can be offset. Also, this study employs control variables to control the effect from demographic features and unobserved flight characteristics. Gender and nationality control demographic features. Airline, departure time, and departure day control unobserved flight characteristics.

This study measures passenger spending on a per-flight basis. We estimate revenue per flight by constructing two indicators. The first indicator is the intensive margin, which indicates the sum of passengers' spending onboard the flight. It is to measure the absolute amount of revenue generated by one flight at one slot. The second indicator is the extensive margin, which indicates the percentage of passengers who spent at duty-free shops among total passengers onboard the flight. The extensive margin means the purchase potential. Because airport shoppers have impulse buying tendency, a flight with a higher extensive margin implies a larger possibility of leading passengers to impulse purchases. The concepts of intensive margin and extensive margin are borrowed from trade literature. These two concepts are critical indicators of international trade results and the degree of global trade activation (Kneller, 2013), as shown in Fig. 1. In trade literature, the intensive margin refers to trade volume, and the extensive margin refers to the number of participants in the trade. The increase in the number of participants does not necessarily indicate that the trade volume increases. However, the rise in the number of participants means the potential for trade volume growth in the future. Likewise, a high purchase rate for passengers (extensive margin) does not necessarily imply a large purchase amount (intensive margin). However, the higher purchase rate can lead to more purchase amounts with appropriate sales strategies. Therefore, it is practically helpful to consider the intensive margin and the extensive margin comprehensively.

3.2. Data description

We collected 275,017 transaction data on ICN duty-free shops for this study. The duty-free sector is the most significant component of an airport's commercial revenue, accounting for more than half (ATRS, 2018). Because the ICN rental system and the duty-free shops' Point of Sales (POS) system are connected, ICN maintains a complete transaction database. This study employs a cross-sectional analysis of transaction data. The transaction took place for one week, from 17 November to 23 November2, 019.[3] As per Table 1, our data set includes 3283 flights. Among them, LCC flights[4] account for 33%, with 1087. The transit passenger (TS) proportion, representing the percentage of TS, is 0–0.824. An average is 0.083, and it is not much different from the 0.089 officially announced by ICN in November 2019. The flight departure delay is between −12 min and 59 min, and a negative value indicates an earlier departure than the scheduled time.

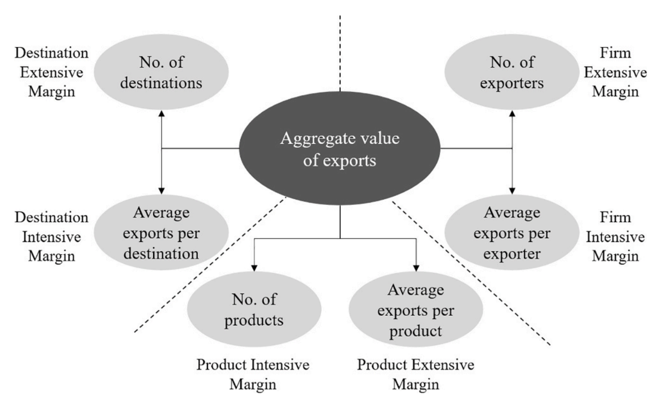


Fig. 1. The margins of trade.

[2] It is a universal view that low-income consumers are more sensitive to prices. (Jones and Mustiful, 1996). Previous studies suggest that fare difference is an essential factor in selecting LCC flights (Pan and Tuong, 2018; Lu, 2017). Considering transit passengers' fare sensitivity, many airlines and airports exempt or discount airport fees for transit passengers (KiM Netherlands Institute, 2011). This study posits that the smaller the income, the more sensitive the fare difference.

[3] This week is representative because it neither coincided with any major holidays or festivals nor encountered any external shocks to cause air traffic volume changes at ICN.

[4] There is no clear standard for LCC definition. This study follows Appendix B applied internally by ICN.

Table 1
Flight profile.

Data	Statistics
Number of Flight	3283
- LCC/FSC	LCC: 1087 FSC: 2196
- Passenger per flight	Max: 496 Min: 19 Average: 193.1 Stdv: 73.1
- Transfer Passenger Proportion	Max: 0.824 Min: 0 Average: 0.083 Stdv: 0.132
- Average dwell time (min)	Max: 159.4 Min: 31.4 Average: 113.2 Stdv: 259.4
- Flight Delay (min)	Max: 59.0 Min: −12.0 Average: 23.5 Stdv: 11.8
- Gate Assignment	Unfavorable gate: 1627 Favorable gate: 1656
- Departure Terminal	Terminal 1(T1), Terminal 2(T2): 2240 Con A: 1043

Passengers have time to shop once they pass the airport departure process. Since ICN measures each passenger's security check passing-time, this study calculates each passenger's dwell time by flight's scheduled departure time minus passenger's security check passing-time. Since the measurement does not include specific personal information, we use the average per flight by calculating the sum of the dwell time per passenger for the flight. The dwell time per flight ranges from 31.4 min to 259.4 min, with an average of 113.2 min. Regarding the location factors, it is necessary to understand ICN's layout. ICN currently has three boarding facilities; Terminal 1 (T1), Terminal 2 (T2), and Concourse A (Con A). Unlike T1 and T2, Con A has no check-in facilities and security checks. As a result, passengers boarding flights at Con A must use separate transportation (a shuttle train) from T1, leading to additional ride and information exploration costs. In our data set, 1043 flights departed from Con A.

As shown in Fig. 2 (a), T1 and Concourse A are long horizontally, and shop density in the central area is high. The T2's commercial facility layout is also similar to that of T1 and Con A, as per Fig. 2 (b). Both ends' departure gates are inconvenient for shopping in terms of distance and store density from the central region. Therefore, it is available to distinguish gates unfavorable and favorable to commercial facilities. Choi et al. (2020a) suggested that the ICN departure gate be divided into an advantageous one and a disadvantageous one, as shown in Table 2. According to Choi et al. (2020a), a gate located in a central area is designated as a favorable gate. A gate that is distant from the central area is assigned as an unfavorable gate, as shown in Fig. 3. In our data set, 1627 flights departed from unfavorable gates.[5]

Meanwhile, we extract 95,389 customer data.[6] Table 3 represents the details.

By using Tables 1 and 3, we calculate the intensive margin and extensive margin per flight, as following Table 4. The intensive margin ranges from 590 USD to 270,695 USD, with an average of 10,900 USD. The extensive margin ranges from 0.4% to 69.9%, with an average of 15.0%.

3.3. Empirical model specification

3.3.1. Regression for the intensive margin

To investigate the intensive margin, we rely on the following regression model,

$$\begin{aligned} Intense_i = {} & \alpha_0 + \alpha_1 Dwell_i + \alpha_2 Delay_i + \alpha_3 Delaysquare_i + \alpha_4 LCC_i \\ & + \alpha_5 TS\_ratio_i + \alpha_6 Gate_i + \alpha_7 Con_i + \alpha_8 Local\_ratio_i \\ & + \alpha_9 Female\_ratio_i + \alpha_{10} flight_i + \alpha_{11} dep\_time_i + \alpha_{12} day_i + \varepsilon_i \end{aligned} \tag{2}$$

where the subscript *i* stands for the flight.

- $Intense_i$: the total amount of duty-free expenditure on flight *i*.
- $Dwell_i$: average passenger dwell time of flight *i*.
- $Delay_i$: the departure delayed time of flight *i*.
- $Delaysquare_i$: the square value of departure delayed time of flight *i*. It is converted to zero when the original value is negative.
- LCC_i : a dummy variable equals one if flight *i* is an LCC.
- TS_ratio_i : transit passenger proportion among total passengers of flight *i*.
- Con_i : a dummy variable equals one if flight *i* departs from Concourse A.
- $Gate_i$: a dummy variable equals one if flight *i* departs from unfavorable gates.
- $Local\_ratio_i$: percentage of Korean nationalities among total passengers of flight *i*.
- $Femail\_ratio_i$: percentage of female among total passengers of flight *i*.
- $flight_i$: airline dummies for flight *i*.
- dep_time_i : departure time of flight *i*.
- day_i : day dummies for flight *i*.
- ε_i: the error term.

The equation captures the impact of time, income, and location factors. α_1 captures the impact of dwell time on the intensive margin. α_2 estimates the impact of the delay. The sign of α_1 and α_2 indicates the direction of the time factors' influence on passengers' purchase amount. $Delaysquare_i$ determines whether the delay has a nonlinear impact on the margin. Researchers include a nonlinear, usually quadratic term to assess the nonlinear relationships in many empirical works. If this term's coefficient has a statistically significant negative value, it implies an inverted U-shape relationship, as shown in Fig. 4 (Jansen et al., 2006; Lind and Mehlum, 2010).

α_4 and α_5 capture the effect of income factors on the intensive margin. This study posits LCC or TS passenger has a smaller disposable income, leading a smaller intensive margin of LCC or a flight with large TS passengers.[7] α_6 and α_7 estimate the impact of location factors on the intensive margin. In this study, a dummy variable representing location factors equals one when a flight is assigned to a disadvantageous location. Thus, if the location affects the passenger's purchase intention, the coefficient's sign should be negative. $Local\_ratio_i$ and $Female\_ratio_i$ control the possible impact of nationality and gender. Flight dummy variable handles the unobserved airline-specific factors. dep_time_i controls departure time affecting congestion. Congestion can affect passenger's purchase intention (Zhang and Zhang, 2010; D'Alfonso et al., 2013). Day dummies are also employed.

3.3.2. Regression for the extensive margin

Analogous to the intensive margin model, we define the regression equations for the extensive margin as the following Eq. (3). The meaning of variables and coefficients are the same as Eq. (2).

$$\begin{aligned} Exntense_i = {} & \beta_0 + \beta_1 Dwell_i + \beta_2 Delay_i + \beta_3 Delaysquare_i + \beta_4 LCC_i \\ & + \beta_5 TS_{ratio\,i} + \beta_6 Gate_i + \beta_7 Con_i + \beta_8 Local_{ratio\,i} \\ & + \beta_9 Female\_ratio_i + \beta_{10} flight_i + \beta_{11} dep\_time_i + \beta_{12} day_i + \varepsilon_i \end{aligned} \tag{3}$$

where the subscript *i* stands for the flight.

[5] Appendix C shows that LCC accounts for 28.5% of flights assigned to unfavorable departure gates. This figure is less than the LCC share in the data set, 33.1%.

[6] This study assumes that transactions having the same flight number, passenger profile, and payment information were made by a single customer.

[7] The LCC and transit ticket prices are lower than FSC and direct ticket prices in the data period (Appendix D).

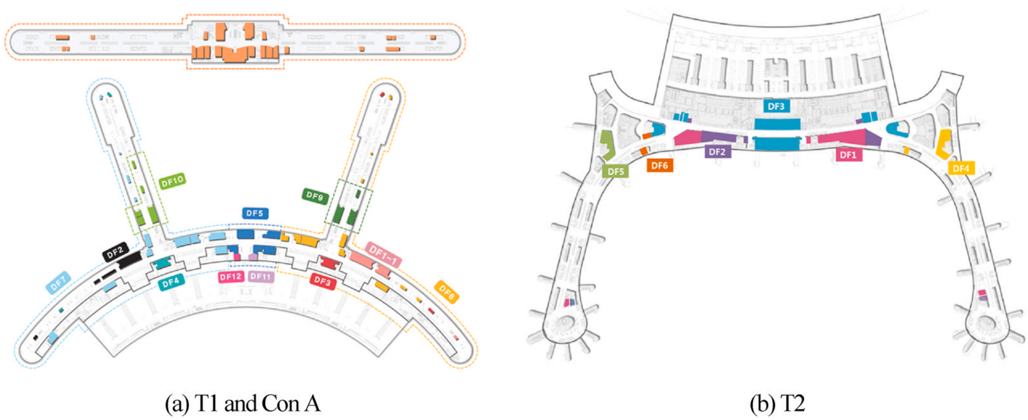


Fig. 2. Terminal layout.

Table 2
Unfavorable gates at ICN.

Terminal	T1(28 Unfavorable gates)	Con A (12 Unfavorable gates)	T2 (16 Unfavorable gates)
Gate No.	6,7,8,9,10,15,16,17,18,19,20, 21,22,23,32,33,34,35,36,37, 38,39,40,46,47,48,49,50	101,102,103,104,105,106, 127,128,129,130,131,132	235,236,237,238,239,240, 241,242,257,258,259,260, 261,262,263,264

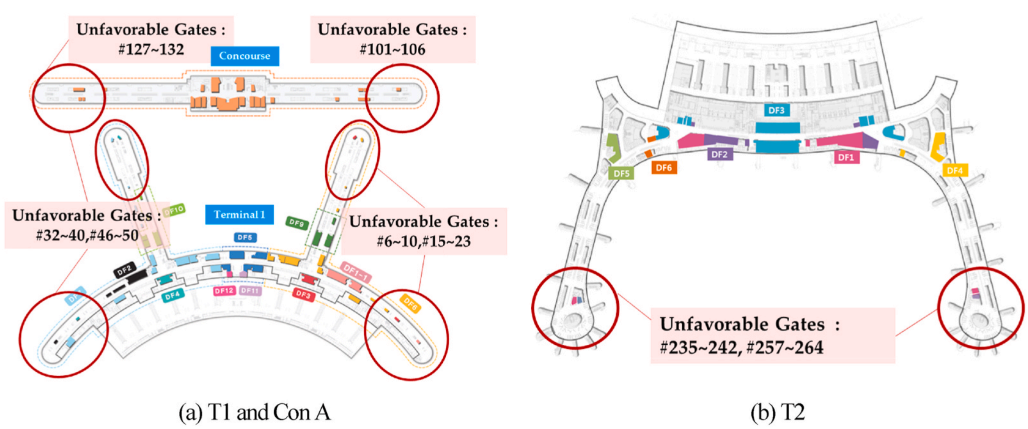


Fig. 3. Unfavorable gates.

Table 3
Customer profile.

Data	Statistics
Number of Customer	95,389
- Gender	Male: 43,507 Female: 51,882
- Nationality	Korea: 69,349 Chinese: 10,618 Japanese: 4292 Others: 11,130
- Spending Amount (USD)	Max: 30,661 Min: 9 Average: 375.1 Stdv: 1236.7

Table 4
Intensive margin and extensive margin.

Data	Statistics
Intensive Margin per flight (USD)	Max: 270,695 Min: 590 Average: 10,900 Stdv: 14,692
Extensive Margin per flight (%)	Max: 69.9 Min: 0.4 Average: 15.0 Stdv: 9.4

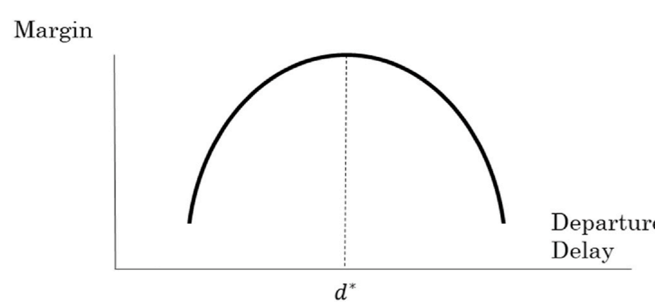


Fig. 4. Inverted U-shape relationship.
* Source: ICAO

4. Estimation results and implications for airport strategies post-covid-19

4.1. Estimation results

We summarize the estimation results of the intensive margin and the extensive margin in Table 5.

The time factors positively affect both the total purchase amount and the purchaser ratio. If passengers enter the duty-free area on average 1 min earlier, the intensive margin per flight increases by 117 USD. The extensive margin increases by 0.07%. A delay also positively affects both the margin. However, an excessive delay can reversely reduce the intensive margin. According to Eq. (2), if the delay exceeds a certain level, i.e., $-\frac{\alpha_2}{2\alpha_3}$, the intensive margin decreases. The estimation suggests that delays exceeding 50.0 min would reduce the intensive margin.[8]

LCC harms both the intensive margin and the extensive margin. Compared to the average, LCC reduces the intensive margin by 3246 USD and the extensive margin by 3.4%. As Choi et al. (2020b) pointed out, ICN's operation policy of assigning LCCs to Con A, which is mainly disadvantageous for shopping, hinders LCC passengers' purchase. With only transit passengers on a flight, both the intensive margin and the extensive margin reduce massively. Regarding the location factors, an unfavorable gate assignment negatively affects the intensive margin. However, the impact on the extensive margin is not statistically significant. On the other hand, Con A allocation harms both margins.

4.2. *Implications for airport strategies post-covid-19*

4.2.1. *Changes in airport operating procedures*

Covid-19 brought about a massive change in airport operations. In ICN, the number of flights between January and December 2020 decreased by 63% year-on-year, and the number of passengers decreased by 83%, as shown in Table 6. Thanks to the airline's business policy transitions, such as converting a passenger aircraft into a cargo plane, ICN could maintain the air cargo volume at the previous year's level. However, ICN recorded a 400 million USD loss in 2020 for the first time in 17 years, from 900 million in2019,[9] mainly because revenue structure is biased toward passengers.

Meanwhile, per-passenger spending at ICN duty-free increased in 2020, as shown in Table 7. Passengers still purchase products at airport shops in traveling during Covid-19. It implies shopping during the trip has already become a part of the journey. It also indicates that commercial revenue may still serve as a valid key to the airport industry's profitability recovery post-Covid-19.

Table 5
Estimation results.

Variable	Intensive Margin		Extensive Margin	
	Est.	Std. Err.	Est.	Std. Err.
Dwell	117.11***	20.71	0.0007***	0.0001
Delay	141.73**	63.97	0.0007*	0.0004
Delay_Square	−1.42***	0.55	−0.000006	0.0000
LCC	−3245.50***	1178.04	−0.0342***	0.0043
TS_Ratio	−9439.09***	3572.65	−0.1711***	0.0131
Gate	−1763.77**	858.00	0.0027	0.0031
Con	−4411.94***	1244.12	−0.0136***	0.0045
Female	−15,848.64***	2726.64	−0.0404***	0.0100
Local	−16,617.62***	1806.98	0.0452***	0.0066

Notes.
1. *, **, *** represents the significant level of 10%, 5% and 1% respectively.
2. The number in the parenthesis is the estimated standard deviation.
3. To save space, the coefficient estimation for the day, flight, and departure time dummies are not reported.
4. The values in column Extensive Margin represent decimal values, not percentages.

Table 6
Airport operation statistics (ICN, Jan to Oct 2020).

	Flight Frequencies		Passenger		Cargo	
	Volume	Year-on-year (%)	Volume	Year-on-year (%)	Volume	Year-on-year (%)
Jan	35,718	4.2	6,309,369	0.9	208,064	−4.3
Fev	26,803	−13.7	3,381,632	−41.5	219,719	20.2
Mar	9861	−71.2	609,516	−89.6	237,106	−4.6
Apr	6659	−79.8	153,514	−97.3	216,711	−4.9
May	7747	−77.4	137,924	−97.6	219,772	−4.0
Jun	7581	−77.5	182,523	−97.0	214,151	−6.2
Jul	8155	−76.9	219,153	−96.5	234,342	1.6
Aug	8452	−76.2	234,958	−96.3	230,244	1.2
Sep	9098	−72.3	196,864	−96.4	249,884	8.4
Oct	9443	−71.7	197,383	−96.6	258,960	4.2
Nov	10,000	−69.0	198,789	−96.4	262,382	3.9
Dec	10,465	−69.7	228,226	−96.3	271,036	12.7
Total	149,982	−62.9	12,049,851	−83.1	2,822,370	2.1

* Source: Incheon Airport Internal Data.

Table 7
Per-passenger spending at ICN duty-free (Mar to Oct 2020).

Year	2019	2020	Difference
Per-passenger spending (USD)	41.8	48.0	+6.2

* Source: Incheon Airport Internal Data.
Notes: Calculated from March when the Covid-19 effect is fully reflected.

In post-Covid-19 operation, the most noticeable difference will be strengthening the verification process for passengers' health conditions. Fig. 5 illustrates the change in airport departure procedures post-Covid-19. The strengthened system comprises three steps; the departure hall, security check, and boarding gate entrance. Airport operators also require passengers to go through a self-examination procedure before check-in.

It is unclear how the changes in operation procedure affect passenger arrival time and dwell time. However, operational statistics can provide a helpful hint to answer the question. It is found that, for the same flight, foreign passengers entered duty-free areas about 10 min earlier than the local passengers on average. Foreign passengers with a relatively small chance of using ICN do not have enough information about the airport. Thus, they need longer dwell time to either plan shopping or familiarize themselves with the airport terminal to avoid missing the flight (Choi et al., 2020a).

Similarly, passengers departing from Con A entered the duty-free area about 14 min earlier than the passengers departing from T1, as shown in Table 8[10]. Passengers must go through an additional procedure of taking a shuttle train when they leave from Con A. It also can increase uncertainty, such as where the shuttle trains board and how often they operate. It means that the uncertainty and the additional procedure can make passengers arrive at the airport earlier and extend their dwell time to avoid potential risks, such as missing flight. It also suggests that the uncertainty makes passengers spend more time than the actual time required for an additional procedure, given that the shuttle train travel time is less than 2 min.

Strengthening quarantine procedures indicates additional steps for passengers. Unexpected problems can happen. Besides, it is difficult for passengers to obtain accurate information on how long the quarantine process will take. Thus, the strengthening of quarantine procedures is similar to Con A allocation in amplifying uncertainty. We have already identified that passengers enter into the duty-free areas earlier than needed due to the uncertainty and lack of information when they take

[8] 105 flights exceed the delayed time of 50.0 min, accounting for 3.3% of the total number of flights in our data set.

[9] Retrieved from http://www.koreaherald.com/view.php?ud=20200831000720&np=1&mp=1 (accessed on 18 Nov 2020).

[10] ICN collected sample data on the passengers' entry time for one week, 20 to 26 October 2019, through PFMS (Passenger Movement Flow System).

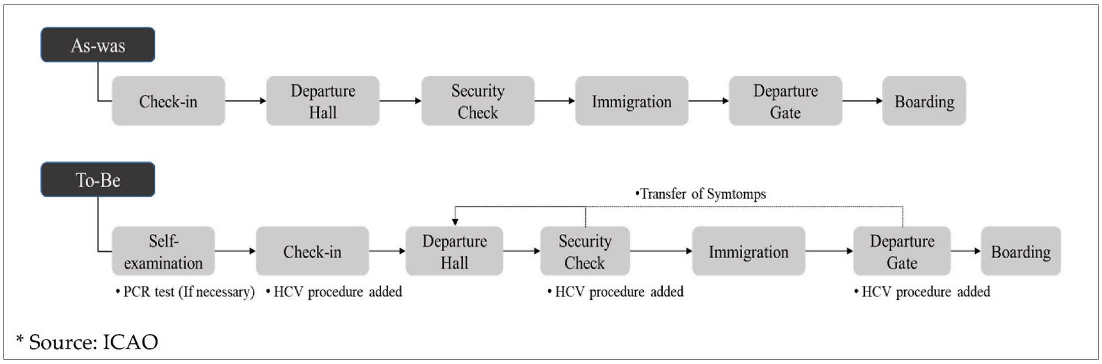


Fig. 5. Change in airport departure procedures post-Covid-19.
* Source: Incheon Airport internal data

Table 8
Passenger entry time (Con A departure vs. T1 departure).

	Con A Departure (A)	Terminal 1 Departure (B)	A-B
Average of "scheduled departure time" – "screen gate passing time"	120.8 min	107.2 min	13.6 min

Note: 20 Oct – 26 Oct 2019, PFMS (Passenger Flow Movement System), ICN.

flights leaving from Con A allocation.

4.2.2. Service differentiation for dwell time management

The increase in dwell time can significantly impact the intensive margin and the extensive margin than expected. If passengers can have 15 min more dwell time, the intensive margin per flight increases by $1,757, approximately 16% of the average. Meanwhile, the extensive margin increases by 1.05%, about 7% of the average. The extensive margin increases much smaller than the intensive margin. It strongly suggests that the dwell time increase affects existing buyers' purchases much more.

Fig. 6 represents a survey result of factors hindering shopping at ICN. The biggest obstacle is the lack of time. Even passengers with solid purchasing power may hesitate shopping due to time constraints, resulting in damaging impulse buying. This is in line with our finding that the dwell time increase has a more significant impact on existing buyers. Thus, airport operators need to be more strategic in managing existing buyers' dwell time.

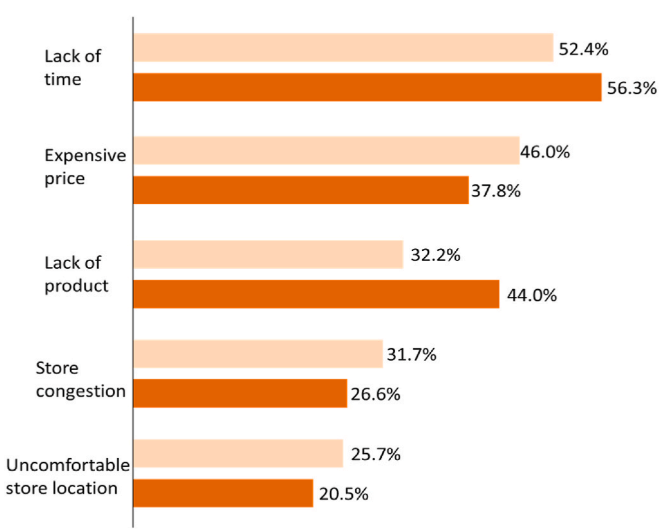


Fig. 6. Survey results: obstacles to purchasing at airports (4237 respondents, multiple responses allowed, May ~ June 2019).

Fig. 7 shows the number of flights, the number of passengers, the purchase amount per passenger, and the number of purchases per passenger on an hourly basis. As per Fig. 7, ICN has two peak schedules a day. The flow of purchase amount per pax and the proportion of purchasers contradict flights and passengers' flow.

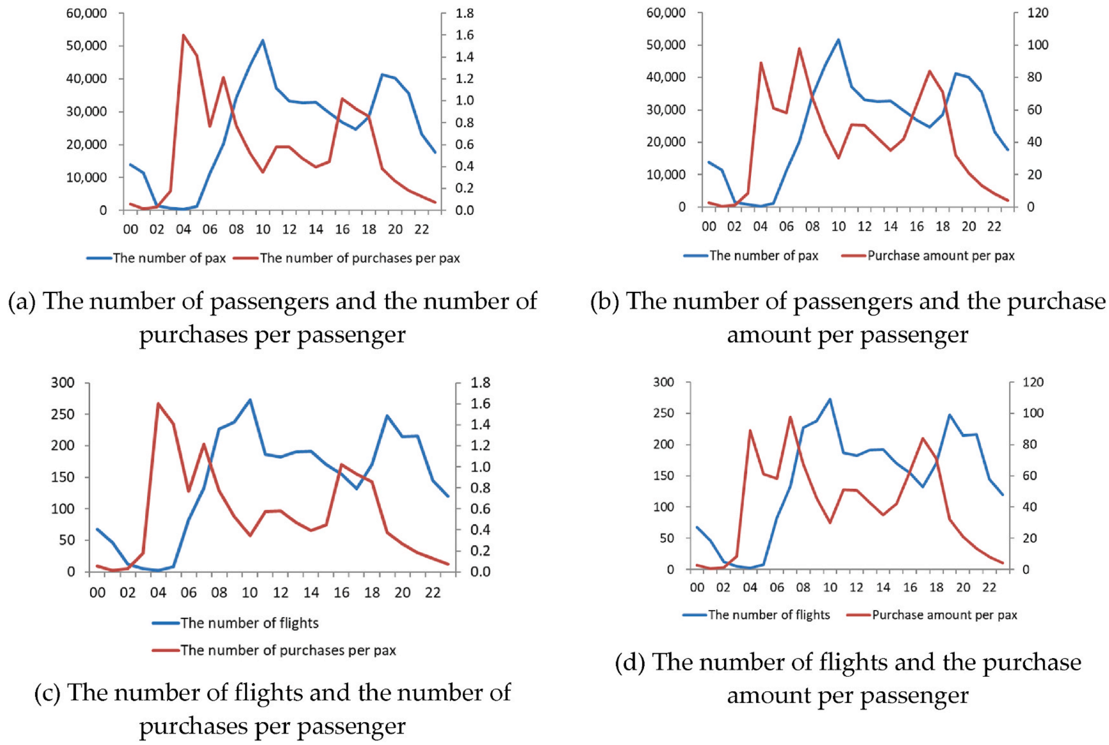
The problem is that the dwell time increase intensifies congestion. Therefore, airport operators need to change a conventional view on passenger service to utilize dwell time increase effectively. Pre-Covid-19, airport operators have focused more on providing uniformly good services to all passengers. For example, more than 900 airports participated in ASQ (Airport Service Quality), evaluating overall service quality. However, introducing a service differentiation can utilize dwell time increase effectively and reinforce duty-free revenue management. Identifying purchasing power based on pre-set criteria such as nationality, flight type (LCC or FSC), etc., can be one possible approach. For example, the Schiphol Airport (AMS), the representative hub in Europe, has hired dedicated marketers for Chinese customers to strengthen commercial facilities' profitability in the consumer marketing department. Also, AMS operates various programs to provide Chinese travelers a smooth shopping experience. To fascinate Chinese customers, AMS has signed a partnership with Unionpay (2015), Alipay (2017), and WeChat pay (2019). AMS has launched a dedicated pre-order service for Chinese passengers, based on the WeChat partnership.[11] In addition, quality services, such as dedicated helpers,[12] can be provided to passengers with strong purchasing power to use dwell time more faithfully. Cutting-edge technologies, such as big data, enable airport operators to implement a service differentiation policy. For instance, ICN is installing 3D sensors inside various retail shops in the terminal, as shown in Fig. 8. With these, ICN can detect passenger flow and collect big data to identify customers with strong purchasing power.

4.2.3. Importance of impulse buying

Online channels are emerging as a powerful alternative to airport duty-free. In South Korea, the online duty-free market size has already surpassed ICN duty-free in 2017, as shown in Fig. 9.[13]

Price and trend-conscious shoppers are moving quickly online. Recently, airports, including Singapore Changi (SIN), Hong Kong (HKG), and London Heathrow (LHR), have also entered the online duty-free business, as shown in Table 9. They provide customers with benefits,

[11] Retrieved from https://www.nextportchina.com/cases/schiphol/(accessed on 11 Mar 2021).
[12] Currently, a small number of airports operate dedicated service systems for VIP customers. For Heathrow Airport, a passenger can book your personal shopping assistant 48 h in advance. Retrieved from https://boutique.heathrow.com/en/personal_shopper_message.html (accessed on 11 Mar 2021).
[13] ICN is South Korea's leading gateway to handle about 80 percent of international air traffic as of 2019. Therefore, it makes sense to discuss the Korean duty-free market size based on ICN duty-free.



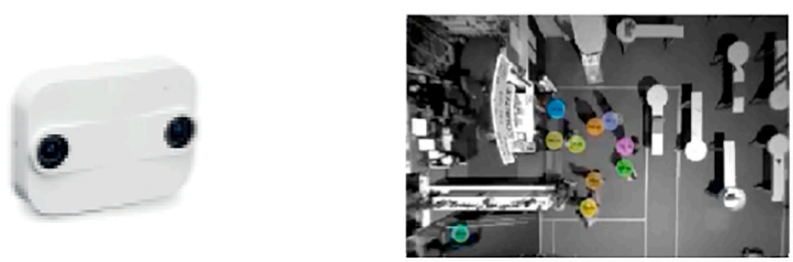
(a) The number of passengers and the number of purchases per passenger

(b) The number of passengers and the purchase amount per passenger

(c) The number of flights and the number of purchases per passenger

(d) The number of flights and the purchase amount per passenger

Fig. 7. Visualization of the number of flights, the number of passengers, the purchase amount per passenger, and the number of purchases per passenger on an hourly basis.
* Source: Incheon Airport internal data



3D sensor image

Passenger movement detection

Fig. 8. An example of collecting passenger flow data (ICN).
* Source: Incheon Airport internal data.

such as pre-order, convenient pick-up at exclusive stores, and domestic shipping.

The main customers of the airport offline duty-free are moving into impulse buyers. Thus, airport operators should pay more attention to inducing impulse buying tendencies. Also, airport operators need to change their main promotion direction for commercial facilities. Traditionally, the main promotion direction has been to provide information on the price or product quality (e.g., 00% cheaper due to the tax exemption). However, to stimulate impulse buyers' willingness-to-purchase, an emotional approach can be more effective. For example, an increasing number of airports are introducing membership to make passengers feel treated and have more loyalty.[14] Besides, airport

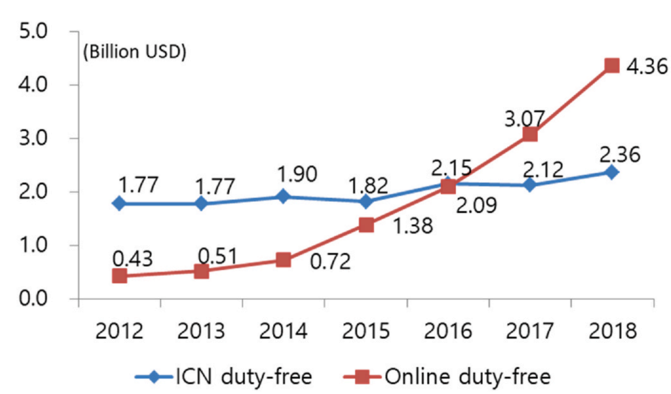


Fig. 9. Sales trend at online and ICN duty-free.
* Source: Incheon Airport internal data

[14] For example, Singapore Changi Airport and Hong Kong Airport operate membership services. Retrieved from https://rewards.changiairport.com/en.html,https://www.hkairportshop.com/?utm_source=AA-website&utm_medium=Fixed&utm_campaign=Awareness2019&utm_content=en_hk_Prospecting_MenuButton, (accessed on 11 Mar 2021).

Table 9
Airport online duty-free.

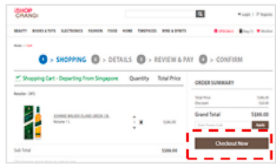
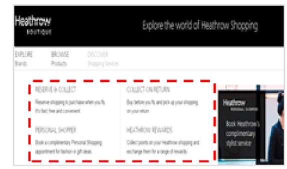
Airport (Brand)	Singapore Changi (iShopChangi)	Hong Kong (HKairportshop)	London Heathrow (Heathrow BOUTIQUE)
Screenshot			
Website	http://ishopchangi.com	http://hkairportshop.com	http://boutique.heathrow.com
Service	Reservation/Payment - Placing orders online - Pick-up in duty-free area - Delivery in Singapore	Reservation/Payment - Placing orders online - Pick-up in duty-free area - Delivery in Hong Kong	Reservation/Payment - Placing orders online - Pick-up in duty-free area - Delivery in UK
Hour of use	18 h before boarding	90 min before boarding	24 h before boarding
Benefit	Membership, Discount (E-coupon)	Discount (5–10%), Chat bot service	Membership, e-coupon

Fig. 10. Appealing shopping atmosphere (ICN).

Fig. 11. Appealing shopping atmosphere (SIN, AMS, BRS).
* Source: Dublin Airport website

operators put more resources in emphasizing the exciting atmosphere of traveling. Recently ICN removed some displays and moving walkways in the central area, as shown in Fig. 10. ICN will install inspirational artworks there because ICN determines that giving inspiration is long-term beneficial rather than delivering information and making moving convenient. A growing number of airports exhibit artworks in the terminal, as shown in Fig. 11. Lamb et al. (2020) suggested that passengers are prone to feel fear and anxiety in post-Covid-19 traveling. The emotional approach may be a practical way to dismiss an anxiety-inducing environment.

4.2.4. *Other operational implications*

This study identifies that disadvantageous locations for shopping can damage commercial revenue. Con A allocation reduces the intensive margin and the extensive margin significantly. In unfavorable gate assignments, total spending significantly decreases even though the purchaser proportion increases by 0.3%, as shown in Table 5. This finding provides some operational implications. The first one is airport charge discrimination. Fig. 12 shows the example of discrimination in Dublin Airport (DUB). DUB applies a different airport fee level depending on location and seasonal characteristics. For instance, it charges a higher fee for a passenger allocated at a more convenient location.

In this study, T1 features a superior location compared to Con A in the shopping convenience perspective. It means that passengers can enjoy better value when they take flights departing from T1 instead of Con A. Thus, it seems that raising the passenger charge at T1 and lowering the charge at Con A is a reasonable policy for ICN. Basically, airlines prefer to depart from T1 because T1 reduces turnaround time and missing passenger possibility. However, although there were vacant

	Dublin Charge Basis	Charges as and from January 2019	Changes coming into effect as and from 29 March 2020	
		(€)		
Runway Movement Charge	Period	Winter	Summer	Winter
Per tonne	Band 1 - 0 to 175 tonnes	4.10	5.50	2.15
	Band 2 - >175 tonnes[i]	3.30	1.50	0.00
Aircraft Parking (Per 15 minutes or part thereof, except "Long Term Remote" which is per day or part thereof)	Wide/Contact	34.90	34.90	34.90
	Narrow/Contact	27.90	27.90	27.90
	Wide/Remote	9.60	9.60	9.60
	Narrow/Remote	7.70	7.70	7.70
	Wide/ Satellite	33.10	33.10	33.10
	Narrow/ Satellite	26.50	26.50	26.50
	Light Aircraft Parking Areas	2.65	2.65	2.65
	Long Term Remote	180.00	180.00	180.00
Airbridge Use	Per 15 minutes or part thereof	7.35	7.35	7.35
Passenger Charge per Departing Passenger	Departure on a Contact Stand	10.69	9.80	7.25
	Departure on a Remote Stand	7.69	5.20	2.65
	Departure on a Satellite Stand (Terminal 1 or 2)	10.19	8.80	6.25
	Transfer Passengers	2.00	2.00	2.00

Fig. 12. Dublin airport charges (as of April 2020).

departure gates at T1 during non-peak hours, ICN did not have an incentive to allocate more flights to T1 in the past. With the airport charge discrimination, ICN has an incentive to accommodate more flights into T1 according to the slot utilization rate, leading to more revenue.

The second one is regarding gate allocation policy. Departure gate allocation is one of the most critical operating procedures because it affects the airlines and passengers' flow. Most airports determine gate allocation according to internal policy. For example, ICN has Airside Safety Manual, including gate allocation criteria.[15] According to the manual, ICN assigns airlines with high on-time operations or flights with the disabled to proximity gate. To increase commercial revenue, airport operators need to allocate a flight with solid purchasing power into a favorable gate for shopping. For example, this study suggests that FSC flight with fewer transit passengers and more male passengers has more substantial purchasing power. Airport operators can include such characteristics associated with purchasing power in the gate allocation criteria.

5. Conclusion

Covid-19 is demanding a lot of changes in the realm of our daily lives. The aviation industry is also facing unprecedented changes in the management environment. Financial tensions across the sector are rising. This study suggests that the airport strategy's direction focusing on commercial revenue management. After Covid-19, safety and hygiene will be the top priority. As a result, changes in airport operating procedures are inevitable. The most noticeable difference will be the strengthening of the verification process for passengers' health conditions. Dwell time increase can be the by-products. This study identifies a dwell time increase has a more significant impact on increasing the existing purchasers' spending than creating new buyers. Airport operators can introduce a service differentiation perspective, such as a dedicated service, to utilize the current buyers' dwell time more faithfully. Also, the rise of online channels requires airport operators to change sales strategies, reinforcing emotional promotion to stimulate impulse buyers' willingness-to-buy.

Before Covid-19, there was little effort to reconcile operation policies and commercial revenue despite the growing importance of revenue management. However, now it is time to change. Pre-Covid-19, passengers were advised of using off-airport processes, such as online check-in and mobile boarding passes. Now, getting passengers to the airport quickly and securing their dwell time can be financially more beneficial. It is necessary to incorporate the commercial revenue perspective into operation policies post-Covid-19 actively. Our finding indicates that even a passenger with solid purchasing power may lose the purchasing intention when assigned to an unfavorable gate or terminal. Airport operators need a better understanding of passenger and flight characteristics when determining operation policy, such as gate allocation or membership services. Hopefully, this study can serve as an opportunity to expand the discussion of various views on airport strategies.

15 Although the definition of a proximity gate is not clear, it seems to mean the location close to the immigration and customs.

Authorship contributions

J.H. Choi: Conception and design of study, acquisition of data, analysis and/or interpretation of data, Drafting the manuscript, revising the manuscript critically for important intellectual content, Approval of the version of the manuscript to be published (the names of all authors must be listed)

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Appendix A. Distribution of revenue (% of total airport revenue, 2018)

	Landing charges	Commercial revenue (Concession, F&B, Ads)
Africa	12.5	10.4
Asia-Pacific	14.0	25.1
Europe	10.5	14.5
Latin America-Caribbean	6.9	10.9
Middle East	8.4	19.6
North America	14.2	6.1
World	12.1	14.5

* Source: ACI Airport Key Performance Index (2020).

Appendix B. List of operating LCCs at ICN

Airline	IATA code	Airline	IATA code
Air Asia	AK	Lion Air	JT
Air Asia-X	D7	Orient Thai	OX
Air Busan	BX	PAL Express	2P
Air Seoul	RS	Peach Air	MM
Bamboo Airways	QH	Philippines Air Asia-X	Z2
Business Air	8B	Scoot Airlines	TZ
Cambodia Ankor Air	K6	Scoot Tiger Airlines	TR
Cebu Pacific Air	5J	Sky Ankor Air	ZA
Estar Air	ZE	Solacid Air	6J
Hong Kong Express	UO	Spring Air	9C
Jeju Air	7C	Thai Air Asia-X	XJ
Jetstar Pacific	BL	T'way airlines	TW
Jin Air	LJ	Viet Jet	VJ

* Source: Incheon Airport internal data.

Appendix C. Gate allocation results at unfavorable gates (ICN, 20 Oct ~ 26 Oct 2019)

Appendix D. Fare differences

(a) Fare differences between LCC and FSC.

Gate Number	The total number of allocated	The number of LCC allocated	The number of FSC allocated	LCC proportion
6	32	0	32	0.0%
7	23	0	23	0.0%
8	33	0	33	0.0%
9	26	0	26	0.0%
10	28	0	28	0.0%
15	41	1	40	2.4%
16	31	0	31	0.0%
17	33	1	32	3.0%
18	33	2	31	6.1%
19	28	0	28	0.0%
20	26	5	21	19.2%
21	33	0	33	0.0%

(continued on next page)

(*continued*)

Gate Number	The total number of allocated	The number of LCC allocated	The number of FSC allocated	LCC proportion
22	32	4	28	12.5%
23	41	3	38	7.3%
32	36	11	25	30.6%
33	43	13	30	30.2%
34	44	30	14	68.2%
35	41	21	20	51.2%
36	44	33	11	75.0%
37	48	30	18	62.5%
38	44	26	18	59.1%
39	18	0	18	0.0%
40	32	0	32	0.0%
46	28	5	23	17.9%
47	35	0	35	0.0%
48	36	0	36	0.0%
49	22	0	22	0.0%
50	39	27	12	69.2%
101	23	23	0	100.0%
102	34	34	0	100.0%
103	36	36	0	100.0%
104	32	15	17	46.9%
105	36	12	24	33.3%
106	39	19	20	48.7%
127	38	31	7	81.6%
128	31	28	3	90.3%
129	26	0	26	0.0%
130	29	27	2	93.1%
131	26	26	0	100.0%
132	24	0	24	0.0%
235	27	0	27	0.0%
236	21	0	21	0.0%
238	19	0	19	0.0%
239	27	0	27	0.0%
241	29	0	29	0.0%
242	26	0	26	0.0%
257	27	0	27	0.0%
258	25	0	25	0.0%
260	23	0	23	0.0%
261	25	0	25	0.0%
263	27	0	27	0.0%
264	27	0	27	0.0%
Total	1627	463	1164	28.5%

* Flights were not assigned to gates 237, 240, 259, and 262.

Average Fare	To China and Japan	To South East Asia
LCC	232.9	331.0
FSC	299.6	462.4
Difference	−66.7	−131.4

* Source: OAG Analysis (as of Nov 2019, based on round-trip full Y class fare, departing from ICN).
** LCC operations to/from ICN are only in North-East Asia and South East Asia as of the end of 2019.

	Transit flight	Direct flight	Differences
Average Fare	419.2	697.1	−277.9

* Source: OAG Analysis (as of Nov 2019, based on round-trip full Y class fare, departing from ICN).

(b) Fare differences between transit and direct flight.

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