MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
Faculty of Transport, Management and Logistics
Air Transportation Management Department

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Head of the Department
____________________ Yun G.M.
“______”________________ 2020

MASTER THESIS
(EXPLANATORY NOTES)

Theme: “Estimation of airports activity efficiency”

Done by: A. Holovniak
Supervisor: Shevchenko Yu.V., PhD in Economic, Associate professor of the air transport management department
Standards Inspector: Shevchenko Yu.V., PhD in Economic, Associate professor of the air transport management department

Kyiv 2020

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Факультет транспорту, менеджменту і логістики
Кафедра організації авіаційних перевезень

ДОПУСТИТИ ДО ЗАХИСТУ
завідувач кафедри
____________________ Юн Г.М.
«______»______________ 2020 р.

ДИПЛОМНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ
«МАГІСТР»

Тема: «Оцінка ефективності діяльності аеропортів»

Виконавець: Головняк Аліна, ОП 202Ма

Керівник: к.е.н., доцент кафедри організації авіаційних перевезень Шевченко Ю.В.

Нормоконтролер: к.е.н., доцент кафедри організації авіаційних перевезень Шевченко Ю.В.

Київ 2020

NATIONAL AVIATION UNIVERSITY

Faculty of Transport, Management and Logistics

Air Transportation Management Department

Major: 275 "Transport Technologies (by transport modes)"

APPROVED BY
Head of the Department
____________________ Yun G.M.
"______"_________________2020

TASK

of completion the master thesis

Alina Holovniak

1. Theme of the master thesis entitled "Estimation of airport efficiency" was approved by a decree of the Rector order № 2401/st. of 17.10.2019.
2. Term performance of thesis: from 14 October 2019 to 29 December 2019 and from 20 January 2020 to 09 February 2020.
3. Initial data required for writing the master thesis: statistical data of the global trends in the aviation industry, passenger traffic changes in Asia Pacific region airports, airport infrastructure in Asia-Pacific region.
4. Content of the explanatory notes: abstract, contents, notation list, introduction, theoretical part (The airport's challenge, efficiency and effectiveness, airport operations management, airport management and airport operations); analytical part (Analysis of the: global trends in the aviation industry; of passenger traffic growth in Asia Pacific region airports; of airport infrastructure in Asia), design part (Operational efficiency of Asia-Pacific airports, research methodology, Data envelopment analysis (DEA), estimation of results, determinants of efficiency), conclusions, references.
5. List of mandatory graphic matters: graphs of the global trends in the aviation industry, graphs of the passenger traffic growth in Asia Pacific region airports

graphical and tabular representation of estimated operational efficiency of Asia-Pacific airports.

6. Planning calendar

№	Assignment	Deadline for completion	Mark on completion
1.	Collection and processing of statistical data	17.10.19 - 31.10.19	done
2.	Writing of the analytical part	01.11.19 - 14.11.19	done
3.	Writing of the design part	15.11.19 - 30.12.19	done
4.	Writing of the introduction and summary	01.12.19 - 20.12.19	done
5.	Execution of the explanatory note, graphic matters and the presentation	21.12.19 - 29.12.19	done

7. Given date of the task: 14.10.19.

Supervisor of the master thesis: Shevchenko Yu.V., Phd in Economic, Associated Professor of the air transport management department

Task was accepted for completion: A. Holovniak

REPORT

Explanatory note to the diploma project “Estimation of airport efficiency”: 92 pages, 24 figures, 3 tables, 5 equations and 47 references.

Keywords: OPERATIONAL EFFICIENCY, FIRST-STAGE DATA ENVELOPMENT ANALYSIS, SECOND-STAGE REGRESSION ANALYSIS.

The research is devoted to operational efficiency assessment of 21 airports in Asia-Pacific region between 2009 and 2018.

The object of research. Airports in Asia-Pacific region.

The subject of research. Operational efficiency assessment of airports in Asia-Pacific region.

The aims and objectives of the research. The aim is to investigate airport efficiency in Asia-Pacific region using Data Envelopment Analysis (DEA) research method.

To achieve the aim during performing, it is necessary to perform a number of tasks:

– analyze theoretical information about airport operations management and the efficiency and effectiveness;

– collect and analyze information about newest global trends in the in the aviation industry and in Asia-Pacific region ;

– assessment of operational efficiency of Asia-Pacific airports using Data envelopment analysis (DEA) and The SimareWilson bootstrapping regression analysis.

The technique presented in this research (data envelopment analysis) can be easily implemented for efficiency estimation for any operating airport worldwide.

CONTENTS

NOTATION LIST

ESRA – Eurocontrol Statistical Reference Area

FAA – Federal Aviation Administration

US – United States

MRO – maintenance and repair organisation

FBO – fixed-based operators

IATA – International Air Transport Association

LOS – level of service

SQA – service quality agreement

TSA – Transportation Security Administration

CCTV – Closed Circuit Television

ICAO – International Civil Aviation Organization

INTRODUCTION

Air Transportation Management Department				NAU 20.02.96.000 EN					
Researcher	Holovniak A. A.			INTRODUCTION	Letter			Sheet	Sheets
Supervisor	Shevchenko Yu. V.						D	8	2
Normative Supervisor	Shevchenko Yu. V.				**FML 275ОП-.202Ma**				
Head of the Department	Yun G. M.								

The increasing demand for air transport in conjunction with technical, physical and political constraints on providing capacity has resulted in a serious mismatch between demand and capacity. According to Eurocontrol, the planned capacity at the 138 Eurocontrol Statistical Reference Area (ESRA) airports is expected to increase by 41% in total by 2030, while the corresponding demand is foreseen to exceed airport capacity by as many as 2.3 million flights (or 11% of demand) in the most-likely growth forecast scenario for 2030 (Eurocontrol, 2016). Similarly, the FAA expects a quick resumption of US traffic growth, with traffic reaching 2013 levels by 2020, and growing by an additional 32% by 2025 (FAA, 2018).

The anticipated traffic volumes have to be accommodated by a system of airports with limited capacity, which in many cases has already been exceeded. Airports, as the terminal nodes of the air transport network, are the locations where delays generated and propagated throughout the network become most evident. At the same time, airports are also the most important ‘triggers’ of delay events, as a result of their often-reduced capacity due to poor weather or other problems. Direct consequences of airport congestion and delays include large external costs, poor level of service to the travelling public, inefficiency in airport operations, and negative impacts on the quality of the surrounding environment and the safety of the entire air transport system. Even during the current economic crisis, unconstrained demand (i.e. demand in the absence of slot controls) at several of the busiest European airports would have exceeded capacity for most of the day or, in a few cases, throughout the day. The percentage of departures delayed reached 37% (36% for arrivals), with an average delay per delayed flight for departures reaching 28 min (29 min for arrivals) in 2011 (Eurocontrol, 2012). The economic costs of these delays, operational inefficiencies and bottlenecks have been staggering. Ball et al. (2010) have estimated that the total economic impact of air transportation delays on the US economy amounted to $28.9 billion in 2007. Unavoidably, there has been increasing political pressure for improvements in airport performance through better and sustainable management of existing airport resources. But in order to improve performance, one should first be able to assess it. This has stimulated vigorous research efforts aimed at modelling all aspects of airport operations and evaluating quantitatively their impacts on delays and congestion, safety, the environment and the economy at large.

The assessment of airport performance is a complex task that requires a thorough understanding of the numerous aspects of airport operations and processes. By definition, a large variety of performance measures (e.g. capacity, delays, level of service, safety, security, emissions, noise, economic costs and benefits) should be considered along with their interdependencies and trade-offs. The airport decision making process is further complicated by the diversity of entities processed (passengers, baggage, cargo and aircraft) and the range of strategic, tactical, and operational considerations that need to be addressed throughout the airport, from ground access to the terminal airspace. Most importantly, these decisions should account for the often-conflicting needs and interests of the multiple stakeholders involved (civil aviation authorities, airlines, airport operators, passengers and shippers, airport neighbours, other government agencies). In such a multifaceted and complex environment, airport decision makers and planners must be supported by advanced airport modelling capabilities complemented by policies and strategies aimed at minimizing congestion and the externalities of airport operations.

The object of research. Airports in Asia-Pacific region.

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The aims and objectives of the research. The aim is to investigate airport efficiency in Asia-Pacific region using Data Envelopment Analysis (DEA) research method.

1. THEORETICAL PART

Air Transportation Management Department				*NAU 20.02.96.100 EN*				
Researcher	*Holovniak A. A.*			*1. THEORETICAL PART*	*Letter*		*Sheet*	*Sheets*
Supervisor	*Shevchenko Yu. V.*					*D*	*11*	*26*
Normative Supervisor	*Shevchenko Yu. V.*				***FML 275 ОП-202Ма***			
Head of the Department	*Yun G. M.*							

1.1. The airport's challenge

This part of research reviews trends that in the past characterised change in airport operations and considers newer developments. The way these will impinge on airports is analyzed under viability, compliancy, efficiency and effectiveness headings. The implications of requirements that can be perceived to be imposed by other elements within the air transport system are considered and the ability of airports to respond to change from these sources is postulated.

There are few airport managers who, having taken a break, come back and find things as recognizable as they might expect. Change in the airport scene has been more piecemeal than in other parts of the air transport system, but with the cumulative effect of many changes coalescing to create periods of rapid change. Fascinatingly, the rate at which matters continue to change shows no signs of respite. The preceding chapters have shown that the characteristics of aircraft and the services that airlines might plan to operate, will continue to introduce change. Additionally, and unfortunately, there is one further significant change overall that has affected virtually all airports worldwide, and that is airport security.

Security procedures at airports are reactions to the threats that arise from tensions – social, economic, political or even religious – that affect communities. They involve aviation because of the perceived vulnerability of aircraft to terrorist action, and the airport is where the threat is most imminent or most detectable. There is nothing that civil aviation can do inter alia to solve these problems. It has to conduct its business in such a way that threats are understood, and counter-measures are put in place that will have an acceptably high probability of success to counter, or deter, life-threatening actions. This is an example of where the full scope of the interaction of the system has to be taken into account by all civil aviation stakeholders.

The airport is therefore often a servant to the service provider, but an airline, having found a potential and desirable service, cannot necessarily expect the airports they choose to use always to welcome them. Airports have capacity issues to address, perhaps refusing to accommodate a service or forcing the service proposal to operate at less favorable times. All these are strictly air transport issues, but there are also political issues that need to be addressed. Within the air transport legislation arena this can mean accepting the circumstances imposed by bilateral agreements and freedoms of the air, and deeper into the political arena there may be other national and even international political agreements (or disagreements) to take on board.

These are factors that all impinge, eventually, on the way that airports are managed and that make them all so different, which in turn makes airports often the most varied, and most interesting, of all the elements in the system. Even so, the managers themselves are held to the same rulings as the management teams in other elements, and it is through the four windows of viability, compliance, efficiency and effectiveness that change is now addressed.

Financial viability

The question of how much viability can be differentiated from profit becomes very clear when the financial accounts of many airport are investigated. At airports throughout the world where traffic is stable, but perhaps unimpressive in terms of volume, the revenue raised from charges will often more than offset the operating cost, assuring the owner(s) that they are in charge of a profitable airport. However, the cost of investment in infrastructure, from runways through buildings and even vehicles (fire appliances that are capable of meeting the requirements of protecting commercial operations rarely come with less than a $500 000 price tag) can overwhelm the annual operating cost. The belief has always been that large international airports were proverbial examples of ‘a license to print money’.

This can be close to a true remark wherever there is a well-established and well-used airport. It is less true as one slides down the scale through regional airports to small local airfields.

In the latter case, where the land value and its semi-rural use to provide occasional batches of silage to local farmers offsets substantially enough the fees that can be teased from a local flying club and based on visiting private aircraft owners, a situation is reached that does not compare readily with the situation regarding airports with commercial operations.

All aerodromes that handle public scheduled services need to offer facilities that meet recognized operations standards that often stretch costs. As well as meeting the cost of a set of fire appliances there is a need to recruit trained (or to accept the cost of training) competent fire-fighting staff, who can be rostered on shifts that provide full coverage throughout extensive operating hours.

The navigation aids and aerodrome lighting systems will be expensive and carry operating costs for maintenance and refurbishment or renewal. There will be air traffic staff services (again with equipment and staff costs involved) and of course the costs involved with the terminal, its apron, the car parks and even access facilities need to be considered.

In the mid-1980s, there was a political desire in the UK to take all airports into private ownership. British airports were like many other airports worldwide in that they had started out as municipal airstrips and had aggregated capabilities step-by-step over several decades, becoming important travel hubs to their communities, but at the same time a draw on municipal funds. Very few were purpose-built civil airports, some having started as military aerodromes, but the common denominator in all cases was that their running costs were absorbed, in essence subsidized, by local public-ownership enterprises. The local authorities, in turn, could dress these as travel utilities and pass the cost of infrastructure development on to central government.

The local councils pocketed the financial reward from successful operations, but subsidized the businesses through funding requests. The processes of central government decided these were not costs that should be borne by the taxpayer. They wanted the enterprises themselves to become private entities and to be free to compete for money on the financial markets. Thus airport ‘privatization’ (not unknown before the mid-1980s, but it was rare to find examples) became a phrase that defined a watershed in airport history. The UK model was applied by wholly or partially privatizing airport operating companies throughout the nation, even selling off the major state-owned airport company, and it has since been widely recognized as having merit in many nations worldwide.

The traditional management board of an airport had been a group of local business leaders, and a number of the individuals might have brought the benefits of some aeronautical knowledge, but this was not always essential.

The ‘privatization’ initiative required airports to evaluate their assets, draw up their business case and to offer the business for sale on a shareholding basis. In many cases, municipal owners would offer only 49% of shares, thus retaining a controlling interest.

This has been maintained at some airports, although many local communities that took this route have since sold even their shares, often with considerable profit, and have therefore shown to have contributed directly to local prosperity through the local realignment of airport ownership. Major airports throughout the world are still often owned by multi-national, fund-based or industrial enterprises.

One aspect of privatization has been a realignment of viability criteria. In order to raise cash, surrounding land has often been sold or leased for development to generate single payment or rental income that will supplement the traditional aeronautical revenue stream.

The importance in modern airport accounts of ‘non-aeronautical’ revenue generation is unmistakable. Some airports that have had large land banks on which they had planned expansion have chosen to squeeze what they can out of existing facilities, through capacity enhancement programs, and to release the land for the creation of enterprise zones.

In some cases an aeronautical edge has been retained, with – where local political circumstances would permit – ‘duty-free zones’ (sometimes called ‘freeports’) established.

These can attract international businesses that need to import and export materials and products, and they benefit from tax incentives. These developments boost local employment and can inflate national import and export statistics. Where a direct airport-related development has been possible airports have attracted aircraft maintenance and repair organizations (MROs) and fixed-based operators (FBOs). However, these are often the least lucrative of the diversification options.

The more attractive aeronautical-related opportunities arise when a parcel or mail-service operator chooses to use the airport as a distribution center, with international overnight parcel operations provided by aircraft.

This can generate revenue from movements in hours of operation where the impact on passenger services are small (between 2200 and 0600 hours overnight), but the dichotomy is that the local area will be subject to night-time jet aircraft operations, so the cost of noise-abatement procedures and noise-protection programs have to be factored into business plans.

The certainty is that not all local residents will feel they are best served by such policies. Of all the options, the least risky for a management team is to use land to accommodate businesses that can benefit from the location. The site can boast good air links worldwide, and often has good local surface infrastructure links.

The downside of such development is that the land would not be available, and perhaps indefinitely, for aeronautical use. This begs the question of what functions an airport is expected to fulfil in a community. If it is seen as just aviation's equivalence of a bus or railway station, it will not necessarily be able to make ends meet financially.

If it performs other functions that allow it to prosper as a business and that simultaneously provide employment and prosperity, then surely it is a better integrated part of a community? The corollary to this argument is that bus and railway stations can be developed according to similar principles, albeit they tend to be more city-center located.

An aspect of this common thread of interest is that well-established surface transport companies have often been the enterprises that have bought into airports. Notably, very few airlines have chosen to buy their own airports.

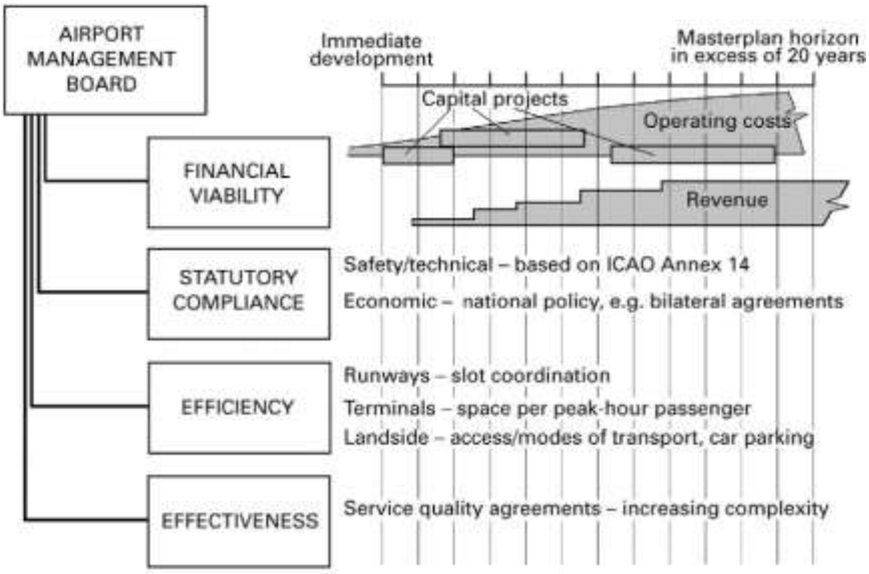

Fig. 1.1. An airport management board has to balance the same parameters as an airline, but their development horizon is often over 20 years in the future. Assumptions are based on traffic forecasts and many other time-dependent variables, adding to the levels of technical and commercial risk.

Statutory compliance

Some statutory compliance issues have been mentioned already, as they impinge directly on operational facility infrastructure and staffing requirements. To be awarded a license to serve as a commercial airport, each location has to conform to ICAO Annex 14 requirements or national standards that are based on this document.

The requirements place a responsibility on the license holder to set out technical compliances, referring to airport configuration, physical characteristics, and so on. This requires the approval of an aerodrome manual that expresses specific procedures, including a comprehensive safety management system (SMS) statement.

An airport must be managed by a board (see Fig. 1.1), and whether privatised or in public ownership its financial and decision-making processes will need to be approved by the national regulatory authority. The national regulator will look for safeguards against malpractice and risk-mitigation procedures, and if an airport borrows from commercial sources it will need to do so under strict guidelines.

Increasingly airports are coming under scrutiny with regard to environ-mental impact and will be expected, where commercial operations are sizeable, to conduct studies that show the expected extent of air and ground pollution, and airport noise. The procedures to mitigate circumstances where the statutory criteria might be jeopardized must be clearly stated, costed and approved for expansion to take place. In the event of a sizeable physical development, such as a runway, apron or facilities including terminals or even aircraft maintenance, the planning permission might hinge on a public inquiry, which can take considerable time and cost. In all cases, airports have to be developed within permitted planning regulations.

As has already been described, security aspects have become central to many aspects of airport operations, and their implementation has become enshrined in its own legislation. Until relatively recent times, security was treated largely as an adjunct of safety; initially hijacking was seen as the major threat, but then terrorism aimed at the airport itself, as well as aircraft and their occupants, has emerged as an equally important security issue that must be addressed.

Initially, airport perimeters were fenced to keep people and animals outside the boundaries, so that they were not put at peril by aircraft operations. Nowadays the requirements for all public-use civil airports is to have a fence line that is very definite, of specific minimum height, with relatively deep penetration in the ground and a durable form of construction. It has to be maintained, and the cost of installation, inspection and general repair of this one item can be a considerable expenditure on any airport’s budget. In some cases there may also need to be sophisticated monitoring, using lighting and infra-red and CCTV cameras perhaps.

Intriguingly, the perimeter length of airports, whether they handle a few tens of thousands or several million passengers per year, can be about the same. This adds to fixed operation costs, and exemplifies one element of operating cost that makes the operation of small airports less commercially attractive.

Security concerns increasingly focus on the establishment of procedures that address unlawful interference with air transport activities. It is essential to ensure adequate detection of unlawful intent and as covertly as possible.

The covertness of security in the passenger-handling areas of airports has become an almost obsessive governmental requirement as terrorism has increased in scope and sophistication.

Even so, there is also direct security. Nowadays all passengers are aware of the security process and are wise to give themselves extra time to pass through the numerous stages of inspection.

The official list of unlawful actions that should be prevented, according to ICAO Annex 17, are:

- unlawful seizure of aircraft in flight
- unlawful seizure of aircraft on the ground
- hostage-taking on board aircraft or aerodromes
- forcible intrusion on board aircraft, at an airport or on the premises of an aeronautical facility
- communication of false information such as to jeopardize the safety of an aircraft in flight or on the ground, of passengers, crew, ground personnel or the general public, at an airport or on the premises of a civil aviation facility.

The list shows that the concerns are not just about what might happen on a flight, but what might be happening, which should be detectable, before a flight.

The security-restricted zone that is required to meet ICAO regulator needs is expressed as a risk area where there shall be access and other security controls. It is recommended to include ‘aviation passenger departure areas between the screening checkpoint and the aircraft, the ramp, baggage make-up area, including those where aircraft are being brought into service and screened baggage and cargo are present, cargo sheds, mail centers, airside catering and aircraft cleaning premises.

It seems inevitable that security, which did not even feature in airport terminal designs in the 1960s, will be a major part of the design of terminals forever.

1.2. Efficiency and effectiveness

Efficiency

Given that no two airports are alike (even if some can be highly comparable in terms of layout or operations), finding efficiency criteria is not easy. Consider size, for example. Small airports need a decent length of runway, but by the time that necessary safeguarding has been applied, it will often be similar in area to a much busier airport with a similar, or perhaps slightly longer, runway. Measuring airport area and trying to correlate that to productivity through annual traffic data is not a safe criterion for evaluating efficiency. It is what an airport does that defines how efficient it is.

Certainly some measure of throughput and the linking of that to the available infrastructure is desired. The best that an airport can do, in aeronautical revenue terms, is to utilize that capacity as well as possible. An airport that starts small is often a single runway with minimal taxiways, apron and terminal. As traffic demand rises, because it is often driven by the diurnal habits of travelers, movements tend to bunch into peak hours and there are often peak days (especially at tourist destinations, where the demand is geared to serving nearby hotels). This can lead to a need to invest in new taxiways, designed to minimize runway occupancy time, so that the peak hour movements can be handled with as little delay as possible. Some extra apron space and terminal passenger facilitation area will also be required, and an adroit manager will phase these in stages.

Often the link between them is so close that a few sizeable phases are better than a series of smaller ones, so efficiency and financial viability coalesce in such decision-making. The efficiency of an airport can therefore be measured in terms of such parameters as movements/hour per runway, average movements per apron stand and peak-hour passengers per square meter of terminal area. These are relatively easily determined characteristics and are often used to rank airports in terms of traffic handling efficiency. Where a measurement shows ‘low’ efficiency, the positive way of addressing this information is to regard the airport as one with development potential. Certainly, the lower the measurements in such cases, the more likely it is that, without some degree of diversification into non-aeronautical revenue generating areas, the airport will be financially at risk.

The interpretation of any ranking processes is never as straightforward as looking at the relative scale of a few simple statistics, however. In particular, the nuances that will have molded the shape of the passenger demand need to be understood. An airport that handles mainly scheduled passengers typically will offer more terminal space than one that handles mainly low-cost passengers. This seeps into the details, with fewer check-in desks, security and immigration channels and baggage reclaim belts apparent in airports biased towards low-cost operations.

As an airport expands, the annual growth of traffic statistics forces a realization that there is a point where operational concepts might need to change. It is typical, for example, to expect an airport that starts with a small single-floor terminal to set its sights on a two- or three-floor terminal at an approximate annual passenger throughput level. When scheduled service operations did not include low-cost carriers this was often an accepted need when around 3–4 million passengers per year were being handled, but with low-cost terminal facilities being regarded as needing to be nothing more than a single canopy in which walls can be moved and extensions bolted on in successive seasons, there are examples of single-floor terminals that handle many more passengers per year. Leisure destinations are similar, and they have been examples that have set this trend.

A 10-million passenger per annum terminal can require up to 45 000 m^2 of facilities space. If this is not to be unnecessarily deep – often a design requirement based on the space available between the apron and landside facilities – the terminal is always being stretched. At 45 m deep, the single-floor terminal is 1000 m long. Clearly, if there are two floors the length reduces to 500 m or so. These are dimensions that create passenger-handling headaches, as a passenger arriving at the 'wrong end' will have a considerable journey before they can even use facilities; if the internal processes take them back along a parallel route, a total processing path of over a kilometre for some passengers is soon a frequent occurrence. Some terminal designers have set the limit at 10–15 million passengers per terminal, and would state that is a break-point in the development. Above this level, there would need to be a second terminal and that then begs the question of where this will be located relative to the first terminal and the rest of the airport infrastructure. Some terminals have struggled to meet the criteria quoted above and some have exceeded it handsomely. At Atlanta's Hartford Airport, designed in the 1970s, the design target was already 60 million passengers in a single terminal. With tens of thousands of passengers to accommodate in the peak hour alone, this was a formidable design target, but the way to do it was derived from understanding the passenger flows. Atlanta is perhaps the best example of an airline network hub in the USA, and with passengers arriving, transferring flights and departing, there was no need for a 60-million passenger per annum check-in or baggage reclaim facility. As most of the transfer demand was domestic, the terminal designer looked at airline requirements, and designed the airport as a main terminal – in which the passenger originating from or arriving for Atlanta and its surrounding areas were handled – and a set of parallel terminals, called satellites, that were almost 'piers' (although sizeable scaled) around which the incoming and departing schedules for individual airlines could congregate. If one flies in/out of Atlanta using the same carrier (or a carrier with a code-share) the terminal design is flexible enough to accommodate the majority of such connections on one satellite. The transfer passenger walking distance is thus greatly minimized. This exemplifies innovative thinking and taking a systems-wide approach to design, in that the airlines were consulted and used to evaluate options before the terminal was built. Atlanta was the first such airport, but it has often since been copied, wholesale or in part.

Runways are strips of paving that cannot be physically reconfigured. Their use is a function of taxiway access and egress configuration, and the way they are supported by approach and runway lighting, navigation aids and air traffic service provisions, which have the capability to handle the demand at the capacity that the runway can provide. The aircraft movement rate that a single runway can handle is finite, around 195 000 to 240 000 movements per year. This assumes it has very comprehensive taxiway, lighting, navaid and ATC support. Assuming that this operational status is achievable, it is necessary for an expanding airport to start thinking about a second runway long before the 150 000 movements per year mark is reached. If by then the margin between demand and capacity is only 45 000 annual movements, at a 5% annual growth rate the new runway provision is required in barely five years.

When circumstances are favorable – meaning that the land is available and the necessary planning approvals for expansion are granted – the design can be completed, contracts let and the runway constructed in such a timescale.

This is one example of the commercial risk involved in airport management. The cost of such a development will be sufficient to absorb a large slice of investment, and the likelihood of it being used at a book value of better than 50% efficiency for several years is dependent on traffic growth following a course that has been predicted from several years – a substantial proportion of a decade – beforehand.

The frustration of many an airport manager, fueled by the desire to serve the community diligently and chastised for running an overcrowded and inefficient airport, and yet having to endure protracted and expensive public inquiries, is not hard to find.

As these notes were in preparation the UK government hinted that it would mollify the planning procedures at airports where the national interest is served by expansion.

There are traffic targets for most of the major and regional airports outlined in a White Paper, which sought to look 30 years ahead (from year 2000), but despite this initiative and these good words, thus far the experience is that public concerns about the overexpansion of airports will continue to result in a protracted development process. The UK experience is similar to that of many other European countries, where airport capacity expansion is being challenged almost routinely. In the USA there is less public concern, which is probably borne of the wide acceptance of air travel as the best mode of transport to use between major cities, and the fact that land is more readily available.

The only way to accommodate demand at an airport where the traffic capacity limit is being reached is to allocate movements to 'slots'. The airport tends to want to state how many slots it will allocate in each period. (Usually an hourly arrival and departure rate is defined, with room to shift the emphasis from one to the other in various hours.) Airlines vie for slots, and IATA is the facilitator at the twice-annual slot coordination conventions that are vital operational planning forums for airlines and airports.

Airports that are involved in such a process are said to be 'slot-allocated' (sometimes also said to be 'capacity-capped'). For any airport it is a dubious kind of premier league in which to have your name quoted. A prime consideration in the convention is to 'coordinate' to the extent that each operation is associated with departure and arrival slots at realistic times. This is vital to ensure that slot allocation is done realistically, but the process is essential to ensure that airports are faced with loads that are not beyond their capacity. Slot coordination evolved in the late 1960s in the USA and was adopted by a few major airports in Europe in the 1970s. It has since become an integral part of the summer and winter season planning cycle for all the slot coordinated airports.

A slot-allocation process, because it is invariably in place to protect service quality when capacity is only just adequate to meet demand, does suggest that an airport will score good points in any 'efficiency' survey, but the equilibrium between efficiency and good customer satisfaction is a delicate balancing act.

Slot allocation will re-emerge in the next chapter, when the allocations made by en route flow-controller operations in airspace issues are considered. These are developed in conjunction with the airport slot coordination process.

Effectiveness

Still with one eye on efficiency, attention is now directed to effectiveness, as the relationship between the two has become part and parcel of discussion already, while the debate has been concerned almost wholly with the runway. The change of orientation will also be associated with a change in the components of the airport in which these characteristics are discussed, as the same dichotomy that affects runways plagues the development of the airport terminal. The way in which airports are affected as a result of changes in the way that airlines develop their seat-sales strategies has little significance at the runway – they are all movements, irrespective of the carrier's commercial justification for luring passengers to use its service – but in the terminal, the airline's service quality criteria can have an enormous impact.

Left to their own free will, an airport operator can choose to provide a service capability that will range from superb to the bare minimum. Superb service implies spacious facilities and a high probability of prompt service at any function offered within the terminal handling processes.

Bare minimum service is clearly one where space is at a premium and service is far from prompt, but setting limits that describe what is good, acceptable, poor and so on is often difficult. Table 7.5 has presented a sample set of IATA level of service (LOS) criteria that illustrate one way of quantifying these distinctions. These can be applied generally, taking account of all the facilities at an airport, or by considering subsets of the complete facilities, thus assessing service quality or effectiveness with regard to the operation of a particular airline. The latter course is essential to collect information that will support the justification of service quality criteria promised to a particular client.

The essential agreement between airlines and airports in this regard is the service quality agreement (SQA). This is a jointly drafted document, which, in some cases, might be simple and non-binding, but regarded as a statement of intent. In many cases, however, the detail is considerable, and the SQA is effectively a binding contract between the two parties.

Wherever possible, means of measuring and thus of monitoring service attributes that are defined in the SQA will be available or implemented, and the agreement will express remedial actions and timescales if service standards do not meet requirements. There will be penalties, and in a sensible agreement incentives too, applicable in respect of airline and airport operator contributions to the agreement.

The ICAO Airport Economics Manual offers a checklist for the contents of an SQA. The elements proposed are:

Service elements:

. a description of the facilities and services to be provided

. the conditions of service availability

. the service standard

. the cost versus the benefit of providing that service standard

. service escalation or de-escalation procedures from the current service standard.

Management elements:

. a description of how service effectiveness will be tracked

. a description of how service effectiveness will be reported and addressed

. a description of how service-related disagreements will be resolved and

. a description of how the agreement will be reviewed and revised.

The source states that success depends on critical factors, such as close consultation, joint agreement of service standards and the careful selection of criteria that reflect performance in essential areas. They categorise the range of SQAs under four headings:

'One-way', reflecting commitments by an airport;

'Two-way', reflecting mutual agreements by both the airport and the airline(s);

'Non-financially incentivized' and 'financially incentivized', whereby in the first case voluntary commitment is encouraged, without detail of implementation, or in the latter case commercial incentives and penalties are associated with each SQA parameter.

Every SQA, while following a principle format, will differ in detail. The detailing of airside, terminal and landside facility service standards will probably be evident in all examples, but at some airports there will be a stress on, say, transfer passenger service standards, while at other airports these may go unmentioned.

An example of the way that change is occurring, through technological impacts on society, which leads to the two parties having to incentivize one another in ensuring that change is accommodated in a manner that will suit users, is in the question of check-in performance. Check-in, a few years ago, was a simple matter. The airport agreed to offer a given number of desks for a given period, per flight, and if they had responsibility for an agent who handled the check-in process, agreed the maximum queue length and average passenger wait time in the queue that would be anticipated. The system would then record as part of the monitoring process. (This could often be achieved cost-effectively by 'sampling' security CCTV camera recordings.)

However, airlines will now often determine attributes of interaction at check-in by offering traditional and self-service and remote (including internet) check-in. Associated with these developments is the concept of the bag-drop desk, which will usually occupy a conventional check-in desk location. This means that the airport is less able to address service quality issues and the SQA becomes a more fluid agreement, which requires the resolution of issues through joint actions.

Combine the service situation with the issues that arise, from the airlines' perspective, from the banding of passengers into high-, medium- and low-yield categories, and the potential complexity of agreements becomes apparent.

The SQA for each category might be subtly, or even drastically, different. An airline will want their high-yield passengers to get priority check-in, perhaps priority security access and certainly will provide (and pay for) a lounge, where the passengers can conduct pre-flight business or rest without being in a busy public area. Their low-yield passengers will get little priority in any of the sectors mentioned. Even so, the airline will not expect them to be herded. They want them 'streamed'. Providing the capacity to meet such demanding objectives is often too onerous to consider as worthy of a simple quality indicator, and it is not uncommon for the airport to agree a service standard that is expressed in terms of minimum and maximum values, or attainment targets that are valid if achieved on, say, 90 or 95% of occasions. The airline can choose to use discretion if the 'tail' of the distribution that this kind of expression represents seems to them to deserve some action.

Some airports have already begun to be proactive in terms of SQA, and will meet potential or new customers with statistical evidence of provision and performance, and ask that these form the basis of an SQA.

The range of data offered is sometimes bewildering, including such data as ratio of passengers/flight information displays, based on a statistical average day or hour. This can mean little, given that there can be a need for many small displays or a few large displays and the choice will be governed by terminal configuration.

The ratio of passengers/toilets is perhaps more akin to what the customer would prefer to see, and here they might also want details, such as the distribution of toilets in a terminal, so that they can determine that there are such facilities available throughout the passenger-handling processes.

Overall, airports are complex and often overlooked. The users (airlines) tend to measure their value first and foremost in terms of volumes of passenger access, second in terms of equipment compatibility and only latterly in terms of how efficiently and effectively they can fulfil their expectations.

Often, the latter are operationally constraining factors, and the resolution of airport operation dilemmas is best viewed jointly, perhaps through a regular committee on which major users have a representative and where the trade-off across the four management perspectives cited can be reconciled in terms of impact on the airport and the users alike.

This is a noble view of the aims at this point, as any such committee nowadays tends to be one where the airport has to justify its actions and the airlines are their judge. The biggest change in airport management will occur when airlines begin to accept that the airport, while it is a facility they pay to use, is just as important to them for passenger satisfaction reasons as any part of the airline inventory.

1.3. Airport operations management

As described above, Airport Operations (or "Ops") and emergency management are primarily responsible for managing the airport to sustain the safe, effective, and efficient flow of passengers and cargo. Airport Ops is charged with keeping the airport functional during all hours of operation and under greatly varying conditions. Managers of Airport Operations and emergency response must routinely plan, schedule, direct, control, and evaluate airport personnel and other resources in an environment of high stress and high risk. Airport Operations is concerned with managing the stress of and risk to a populace similar to a small city, within tightly controlled boundaries and under highly regulated procedures.

Airport Operations is commonly referred to as "Ops" in the domain of airport management. Ops is used interchangeably with Operations, as is experienced in the profession.

The breadth and depth of an Airport Operations division can vary greatly among airports. However, while there are more than 5,000 public-use airports in the United States, including more than 450 commercial service airports of all sizes, the mission of Airport Operations stays essentially the same. Large airports usually have operational departments or divisions consisting of hundreds of personnel. In contrast, operations management at small general aviation (GA) airports may be assigned to an individual with other responsibilities, such as maintenance or overall airport management.

Depending on the size of the airport, Ops personnel may also fulfill the roles of firefighter, paramedic, police officer, ambassador to passengers, and customer service agent, and in nearly all cases act as a representative of the airport authority. As a department, Airport Operations is often structured around areas of functional responsibility, such as (a) airfield Ops, (b) terminal Ops, landside or Ground Transportation Ops, (d) police, fire, emergency, and medical services Ops, and (e) communication Ops. Although staffing, functional areas, and organizational structures of Airport Operations vary greatly among airports, the types of concerns routinely addressed by operations and emergency response personnel remain the same at many airports. For example, common concerns and responses include:

Is it snowing: Make sure the snow is removed from all operational areas and that surfaces meet operational and regulatory requirements. Notify pilots of the condition of the runway.

A passenger slipped and fell in the terminal: Ensure paramedics are responding and immediately begin to address airport liability issues.

A suspicious item was found on an airplane: Begin working with federal, state, and local agencies to mitigate risk and resulting effects on Airport Operations.

Construction is being conducted onsite: Ensure contractors are not driving on operational runways and taxiways without proper authorization.

An aircraft accident or incident has occurred: Above all, focus on saving lives, stabilizing the scene, and protecting property and the environment. Notify all relevant stakeholders, coordinate response to inquiries, manage the media, and return the airport back to routine operations as soon as possible.

An automobile has stalled on an entrance road within the airport's landside area: Ensure that the vehicle is attended to and is not a safety or security hazard. Rapidly develop a course of action to ensure the vehicle does not impede the flow of passengers to and from the airport.

Managing an airport safely, effectively, and efficiently requires attention to numerous functional areas. For example, when airport planners, engineers, and architects design and build new facilities or renovate existing facilities, airport Ops personnel provide extensive feedback to the design team.

Ops also assists in overseeing the construction as a way to ensure safety and compliance with regulatory concerns.

During construction, operational personnel also handle rerouting of aircraft for air-field projects, passenger movement for terminal projects, or vehicle movement for landside projects. Airport Operations may also enforce leases for concessions or tenants. Ops personnel routinely audit and inspect tenants to make sure they are in compliance with provisions in the lease and airport rules, regulations, and business standards.

Airport Operations helps to ensure that airline boarding and arrival gates are managed in accordance with FAA and Transportation Security Administration (TSA) policies and regulations. This duty also includes monitoring use agreements established between the airport authority and the airline. At various airports, Ops personnel may also conduct ramp control of aircraft movements and related revenue collection functions, such as the logging of aircraft registration ("N-number" or "tail numbers") so that landing fees can be tracked and assessed.

Operations throughout the airport layout

Even though there are some differences between commercial service and GA airports, all airports have three major areas requiring operations management: (a) landside, (b) terminal, and (c) airside (Figure 1.1). Each area has unique characteristics in terms of operational and emergency response requirements.

Landside areas represent the initial arrival or terminus of the passenger's air travel and interaction with the airport. Landside operations include parking lots, Ground Transportation (private and commercial), and intermodal connections, such as subway, light rail, or roadways.

Commercial vehicle fees from taxis, limos, and other forms of Ground Transportation generate significant revenue for the airport. Safe, effective, and efficient landside services can increase the benefits to travelers of the airport as a desired node for travel. Therefore, providing operational support to landside infrastructure and entities operating in those areas is vital.

The terminal area is where passenger check-in and security screening take place. Even at small airports, the terminal area can generate significant revenue to the airport through the leasing of space and commissions on concession sales. Therefore, terminal operations management is concerned with handling resources and personnel such that passengers receive at least satisfactory customer service within a healthy, safe, and secure facility.

Fig. 1.2 Operations, safety, and emergency management are core functions of aviation management within the airport or aerotropolis environment.

Upon arriving from landside, passengers check-in with their airlines, process through the Security Screening Checkpoint, and proceed to the boarding gates. When they land at the airport, they return through the terminal, including the concourses, to be reunited with their luggage, and then proceed back out to landside and on to other destinations.

Airside is a heavily regulated portion of the airport where aircraft takeoff, land, receive service, and conduct other forms of flight-related operations. Airside operations address:

(a) the airfield environment,

(b) core elements of Airport Operations, including weather, communications, security systems, and personnel, and

(c) integration and management of air carriers, vendors, tenants, con-tractors, and other affiliates.

1.4. Airport management and airport operations

Airport Operations is comprised of regulations, policies, procedures, resources, and personnel that provide the infrastructure and organization integrated within and across four primary concerns of airport management: (a) airport safety, (b) Airport Operations, (c) airport emergency management and response, and (d) airport planning. These areas are explored in-depth within this textbook, and are introduced below (Fig. 1.3).

Fig. 1.3. Primary topics as related to Airport operations, safety, and emergency management

Part 1: Airport Operations and the Airport Environment

Essentially all entities within the airport environment rely on a well-functioning Airport Operations department. This section of the textbook addresses the overall organization and assignment of duties and the role Ops plays in each of those factors within the airport environment. Airport Operations is commonly subdivided into structures focused on landside, terminal, and airside functions.

Regardless of the size or level of service, all public airports have operational functions or requirements. For many small GA airports this may require that operations be conducted by one or two individuals.

As airports grow, they typically first add maintenance and other administrative personnel to their operational staff. Maintenance personnel are usually cross-trained in operational duties and perform such until the airport sponsor can justify the creation of an independent Ops department. Part 1 addresses the “how-to” of planning and organizing an Airport Operations department.

Part 2: Airport Operations and Safety and Emergency Management

This section addresses overall Airport Operations with an emphasis on safety and emergency management processes. Special topics such as Safety Management Systems (SMS) and Title 14 CFR Part 139 are featured. SMS is the formal, top-down business approach to managing safety risk, which includes a systemic approach such as necessary organizational structures, accountabilities, policies, and procedures. The four elements of SMS described in this section of the textbook are: (a) safety policy, (b) safety risk management, (c) safety assurance, and (d) safety promotion.

Title 14 Aeronautics and Space, Chapter I Federal Aviation Administration, Department of Transportation Subchapter G Air Carriers and Operators for Compensation or Hire: Certification and Operations, Part 139 Certification of Airports (typically referred to as “Part 139”), addresses the safety and certain operational requirements of commercial service airports. Part 139 focuses on three areas: (a) safety self-inspection, (b) safety programs, and (c) maintenance programs. The safety self-inspection requires that Airport Operations personnel ensure that FAA standards are maintained on a daily basis.

Federal regulators certify the airport for operation and make periodic inspections; however, it is the duty of Airport Operations to inspect areas where aircraft operate and to ensure that elements such as pavement, navigational aids, signs, markings, and lighting systems are in proper working order. Examples of routine Airport Operations maintenance include ensuring fencing and jet blast deflectors are in place, pavement repair, navigational aid care, and airport snow and ice control.

Other safety programs supported by Airport Operations include, (a) the Airport Emergency Plan (AEP), (b) the Wildlife Hazard Management Plan (WHMP) program, (c) the Notices to Airmen (NOTAM) program (pilot advisory service of, e.g., hazardous or nonstandard conditions), the Construction Safety and Phasing Plan (CSPP), (e) various ground vehicle operations and regulations, and (f) Aircraft Rescue and Firefighting (ARFF) requirements.

Many Aircraft Accidents take place during the takeoff or landing phase, often on or adjacent to airport property. Airport Operations must have an FAA-approved AEP that follows federal regulations and guidance for emergency management and response.

At larger airports, Airport Operations personnel often coordinate the response of first responders, police, and fire assets. At small, commercial service and GA airports, Airport Operations personnel are often cross-trained in the areas of firefighting, emergency medical, and, in some cases, law enforcement and security. This section also focuses on the development and implementation of the emergency response plan contained in the AEP.

Included in the emergency response plan are regulations, policies, strategies, and tactics for operational emergency response personnel to address related core functions, such as: (a) command-and-control, (b) communications, (c) alert and warning, (d) emergency public notification, (e) Protective Actions, (f) law enforcement and security, (g) firefighting rescue, (h) health and medical, (i) overall resource management, and (j) Airport Operations and maintenance. Specific hazards are also addressed, including Aircraft Accidents, natural disasters, security incidents, and hazardous material incidents.

This section also describes airport requirements to utilize and integrate with the National Incident Management System (NIMS) and related Incident Command System.

Part 3: Future Airport Operational Challenges

Airport operators are now embracing new challenges as research and development into the civilian and commercial use of UAVs and spaceport operations brings these concepts to reality. Integration of the Next Generation Air Transportation System (NextGen) ATC system will also bring new challenges to the industry.

The development and integration of UAVs for personal use by citizens and commercial industries is now a global demand. UAVs have a wide range of civilian applications, including agriculture, Search and Rescue, law enforcement, surveillance, power line patrol, and wildfire spotting, among many other applications. Regulations are currently being proposed and evaluated by the FAA for the operation of UAVs in the civilian and commercial sectors. Civilian UAVs currently require line-of-sight operations by the pilot of the vehicle, but are nonetheless flown from a remote location. This aspect alone will require new ways of managing operations at airports that may eventually integrate UAV activity within their airspace or ground movement areas. Launch and recovery operations will have to be integrated into the airside environment of the airport. UAV operations will also require special runway use considerations, pavement maintenance standards, and other issues, such as emergency recovery operations.

The advent of the horizontal takeoff to low Earth orbit (LEO) space vehicle operations has created a viable commercial spaceflight industry. Several U.S. airports have already submitted applications to be certificated as commercial spaceports (or commercial space facilities) by the FAA under 14 CFR Part 413.5.16 The licensing an FAA 14 CFR Part 139 airport uses for space operations must be coordinated with the FAA's Office of Commercial Space Transportation (AST). Spaceport designation results in new security and safety issues for airport operators. There will be new aircraft rescue and firefighting equipment and new maintenance and personnel training requirements for handling a craft that has departed to, or arrived from, LEO. Other operational concerns being developed and evaluated include medical facilities onsite to handle new types of physiological problems that may develop in passengers visiting the space environment, airside transportation to areas where commercial space operations are conducted, and overall emergency response requirements unique to space vehicles and travel.

Another future challenge to Airport Operations is the extensive FAA transition of the ATC system from a land-based to a satellite-based system. This effort is referred to as the FAA's NextGen17 program, and it significantly enhances the flow of aircraft into the traffic area of an air-port and throughout the NAS. NextGen also uses onboard weather and traffic avoidance technologies, further enhancing the ability of aircraft to fly more efficiently in the NAS. With increased effectiveness and efficiencies in ATC resulting from NextGen, airports will likely have to increase their ground operations services and incorporate many new and related procedures and technologies to safely, effectively, and efficiently deal with an increase in arrivals, departures, and passenger flow.

2. ANALYTICAL PART

Air Transportation Management Department				*NAU 20.02.96.200 EN*					
Researcher	*Holovniak A. A.*			*2. ANALYTICAL PART*	*Letter*			*Sheet*	*Sheets*
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Normative Supervisor	*Shevchenko Yu. V.*				***FML 275 ОП-202Ма***				
Head of the Department	*Yun G. M.*								

2.1. Analysis of the global trends in the aviation industry

Air transport connected more cities at lowered cost. In 2018, airlines continued to increase the number of city-pair routes globally. Almost 22,000 city pairs are now regularly serviced by airlines. This is an increase of 1,300 over the number of city-pair connections in 2017.

Strong improvements in connectivity and in costs over the past two decades—the real, inflation-adjusted cost of air transport has halved in the past 20 years and declined further in 2018—help to ensure that aviation, the "business of freedom," continues to distribute its array of benefits to consumers, suppliers, and economies globally (fig. 2.1).

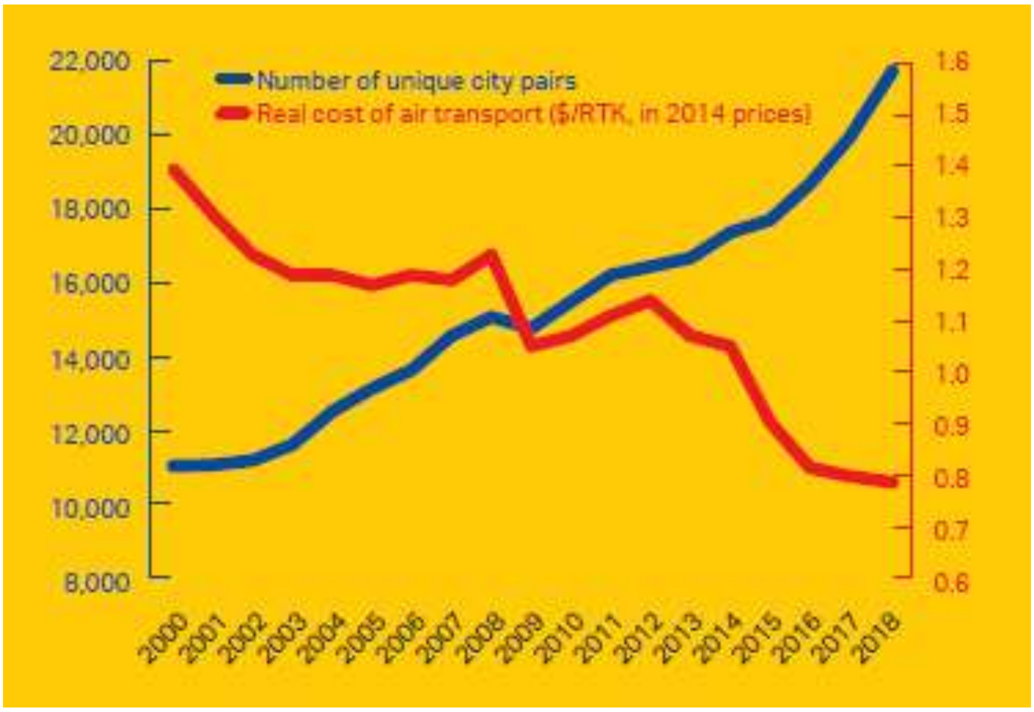

Fig. 2.1. Unique city pairs and real transport costs

Air transport supported economic growth and prosperity through tourism and trade.

Air transport is central to world tourism and trade. Tourists traveling internationally by air are estimated to have spent about $850 billion in 2018, an increase of more than 10% over 2017. The additional number of city-pair connections and the lower cost of air transport also boosts trade in goods and services and heightens foreign direct investment and other important economic flows.

Air transport accounts for only a small, less than 1%, proportion of world trade by volume but for a much larger share by value, of about 33%. In 2018, the value of goods carried by air is estimated to have been $6.7 trillion (fig. 2.2).

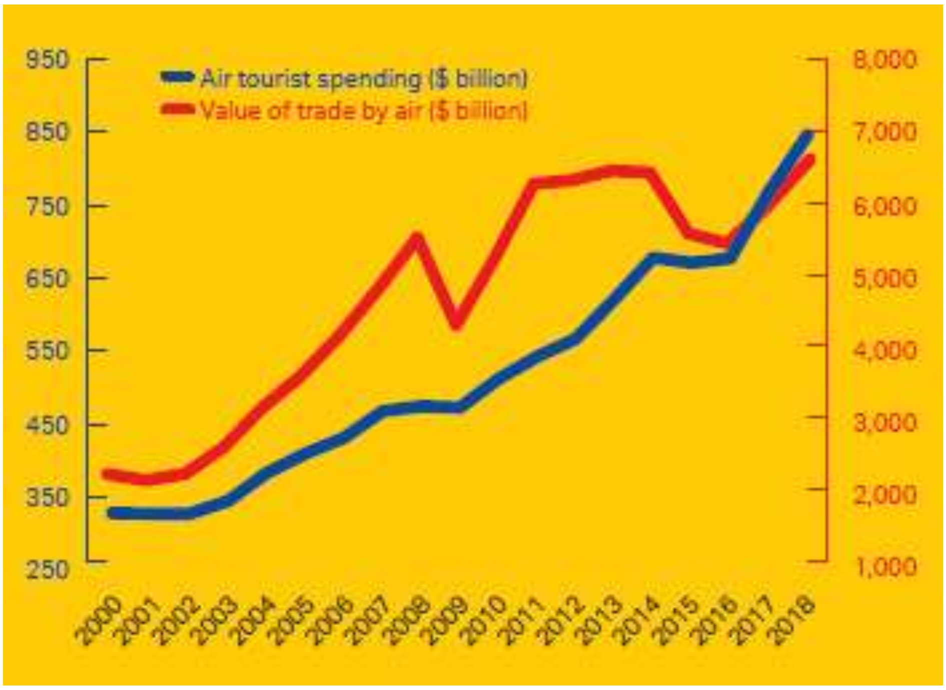

Fig. 2.2. Air tourist spending and value of trade carried by air

Air travel was more accessible for more people.

Worldwide air passenger numbers continued to rise, exceeding 4.3 billion journeys in 2018. Connecting cities directly cuts the cost of air transport by saving time for shippers and travelers.

Combined with cheaper fares, this enables more people to fly more often. In 2000, the average citizen flew just once every 44 months. In 2018, the time between trips had halved, to just 21 months (fig. 2.3).

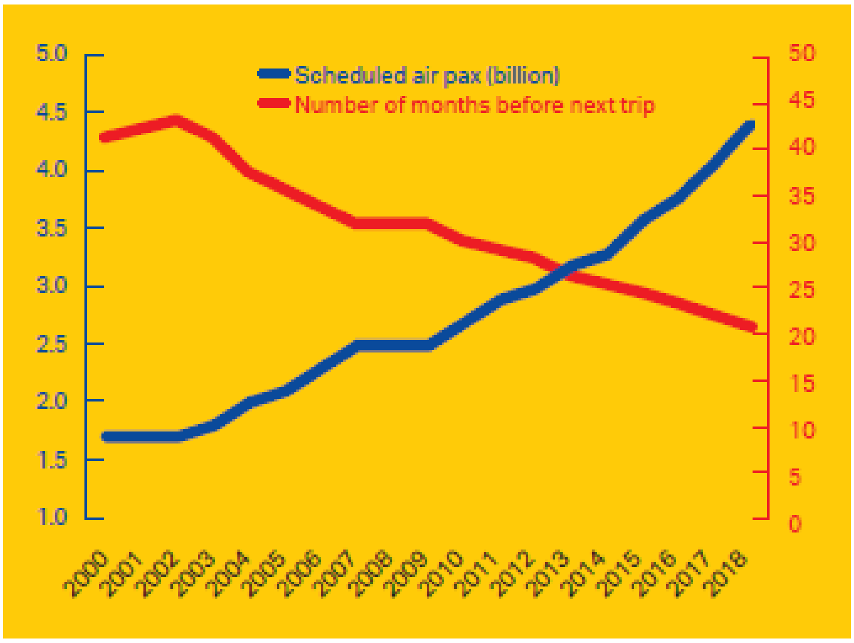

Fig. 2.3. Accessibility of air travel

Passenger demand was again robust.

Air passenger demand was underpinned by a generally solid global economic backdrop, especially earlier in the year, which, in turn, supports jobs, incomes, and business activity, and by fierce competition in the industry, which helps to ensure airfares remain affordable to travelers (fig. 2.4).

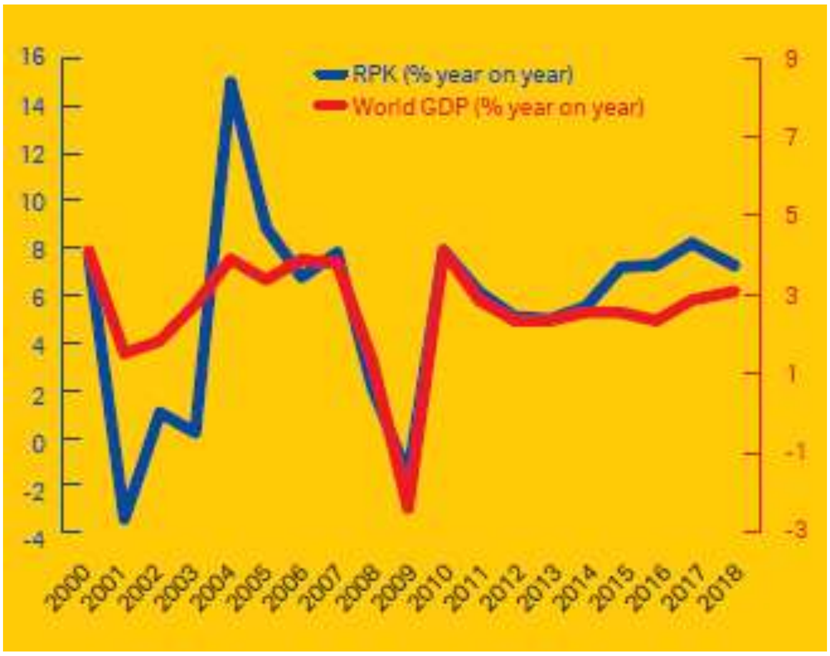

Fig. 2.4. RPK versus world GDP growth

Demand for air passenger services remained strong in 2018, with industry-wide revenue passenger kilometers (RPK) increasing 7.4%. This represented a slowdown from the decade-high pace recorded in 2017, of about 8%, but still exceeded the long-run industry average growth rate by around 2 percentage points.

China added the most passenger journeys.

There were close to 4 billion origin-destination (O-D) passenger journeys worldwide in 2018. Among them, domestic routes within China again provided the largest incremental increase in passenger trips, adding just under 50 million journeys.

The domestic markets of the United States and India once more ranked second and third, with around 30 million and 18 million more passenger journeys, respectively. Of the main markets that IATA regularly tracks, India's domestic market showed the fastest growth in passenger numbers, which increased 18.5% in 2018. That India recorded its 50th consecutive month of double-digit, year-on-year growth in RPK in October highlights the consistently strong performance of its market (fig. 2.5).

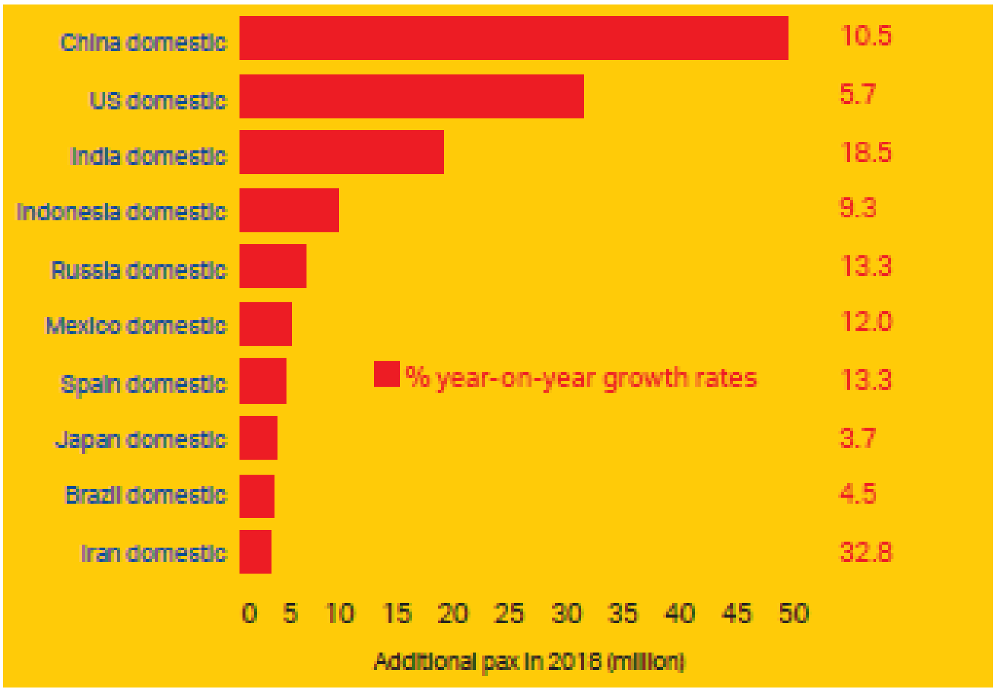

Fig. 2.5. Top 10 increasing O-D markets

The US O-D passenger market remained the world's largest.

Although China's domestic market added the most passenger journeys in 2018, the US domestic market—where almost 590 million passenger journeys were undertaken in 2018—continues to be the world's largest single O-D market. China comes second, with 515 million, followed by India some distance back, at 116 million. Unsurprisingly, domestic markets dominated the rankings. The top 12 markets accounted for almost half of the total number of O-D passenger journeys in 2018 (fig. 2.6).

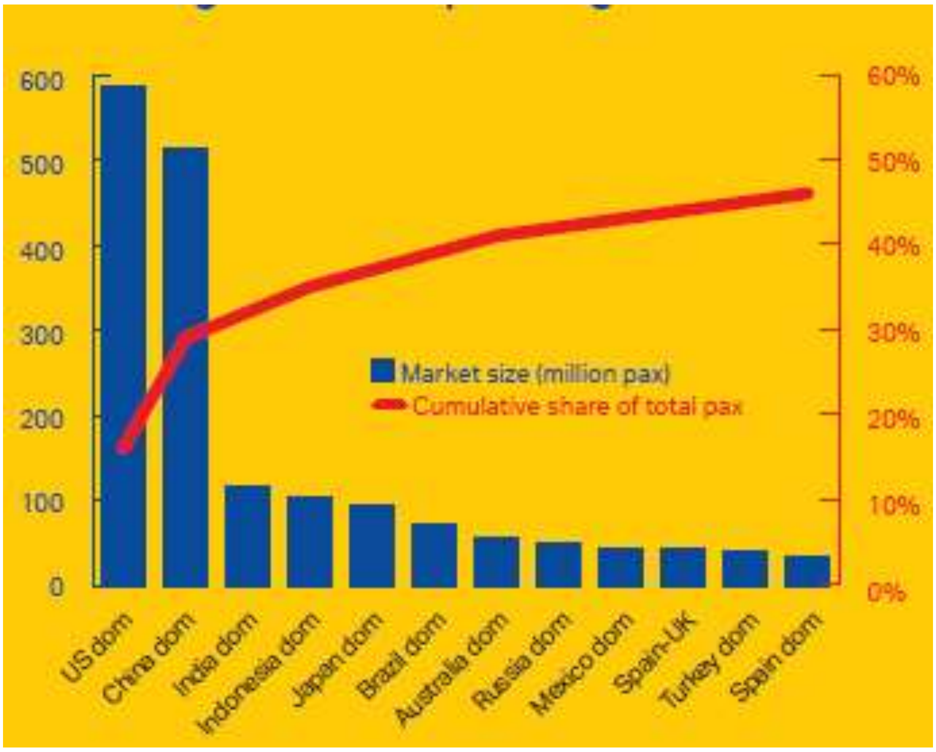

Fig 2.6. Largest O-D air passenger markets

Air freight demand growth eased.

Air freight grew slightly in 2018 compared with 2017. Buoyed by the global inventory restocking cycle, industry-wide freight tonne kilometers (FTK) increased 9.7% in 2017. In 2018, FTK likewise grew, but a mere 3.4%. This was in line with global trade volumes, which trended broadly sideways in the first part of 2018 and contracted in the year's fourth quarter. The lesser increase for air freight also reflected the typical slowdown following an inventory rebuild.

The second half of the year also saw the industry face a number of headwinds. There was a moderation in world trade—a result in part of the heightened trade tensions between the United States and China—and a deterioration in some leading indicators, such as the new export orders component of the global Purchasing Managers Index. Having said that, not all air freight sectors were equally affected. E-commerce and pharmaceuticals continued to perform strongly (fig. 2.7).

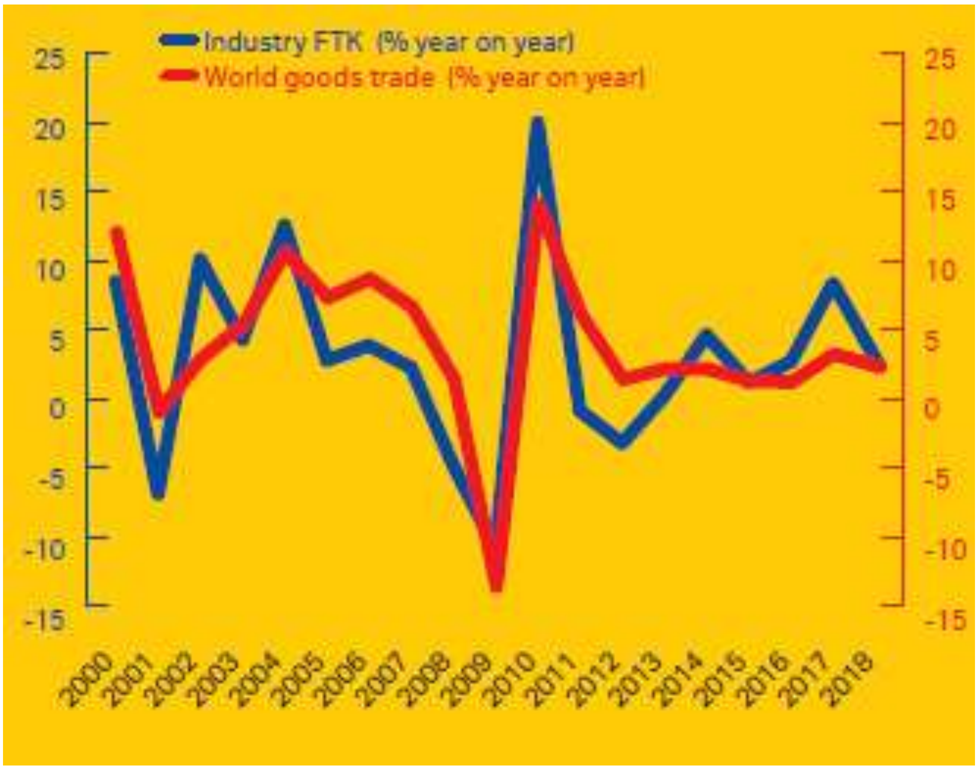

Fig. 2.7. Air freight versus global goods trade growth

Regional outcomes for passenger and freight demand were mixed.

Regions saw varied performance in passenger and freight demand in 2018. Airlines from Asia-Pacific led the way in passenger growth, which increased 9.5% in that region, followed by airlines in Europe and in Latin America.

For freight, it was the Latin American carriers that outperformed, followed by carriers in North America. Freight volumes for African airlines were broadly stable in 2018, but this should be viewed in the context of their robust 24% growth in volume in 2017 (fig. 2.8).

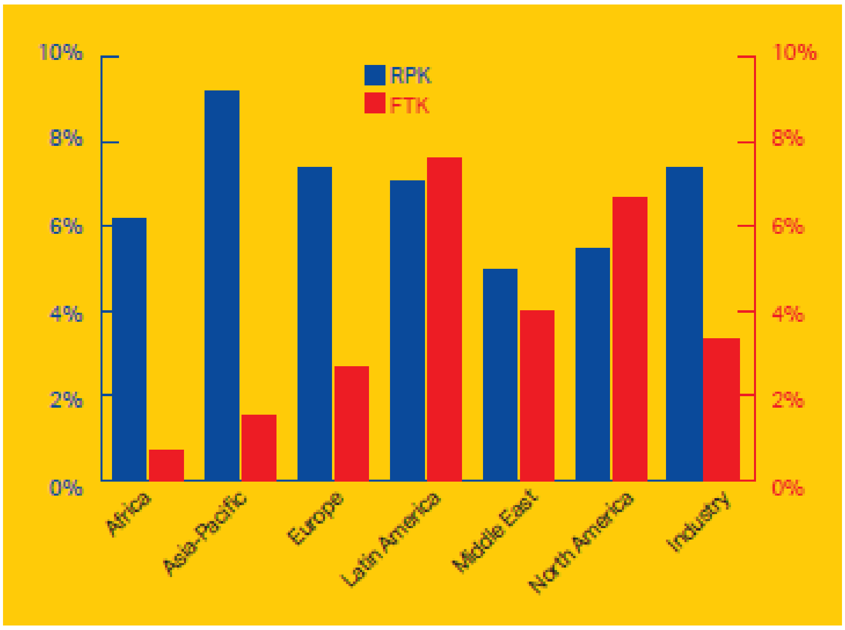

Fig. 2.8. Regional passenger and freight demand outcomes

Passenger load factor achieved a record as demand growth exceeded capacity

Available freight tonne kilometers (AFTK), meanwhile, grew 4.5% year on year, easily outpacing the 3.4% growth in FTK. The freight load factor, therefore, fell about 1 percentage point in 2018, partly unwinding 2017's gain (fig. 2.9).

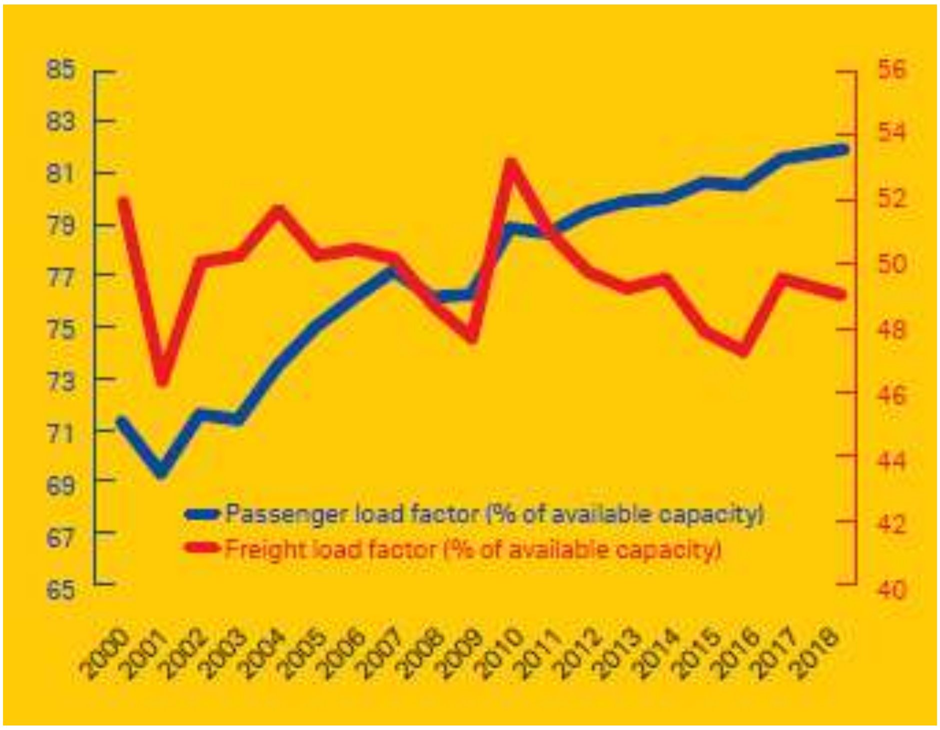

Fig. 2.9. Industry passenger and freight load factors

Available seat kilometers (ASK) increased 6.9% globally in 2018 compared with 2017, slightly lower than the 7.4% RPK increase in passenger demand. As a result, the passenger load factor (PLF) ticked up slightly to a record 81.9%. The PLF has risen more than 10 percentage points over the past 15 years. And this increase is behind the improved industry financial performance of recent years.

Oil prices had a bumpy ride

The jet fuel price opened the year under review about $80 a barrel and was initially stable. At the end of the year's first quarter, though, the fuel price began to track upward, increasing more than 20%, to peak at $96 per barrel in October 2018. In November and December, however, market sentiment turned sharply down amid signs of a deteriorating global economy and strong supply from US tight oil producers. The price quickly tumbled, falling more than 25% to end the year averaging about $72 in December. The price of jet fuel has subsequently begun to rise in the early months of 2019. But the sharp and unanticipated nature of the decline at year-end means that many airlines that hedge their fuel exposure are unlikely to have seen much benefit from the price adjustment so far (fig. 2.10).

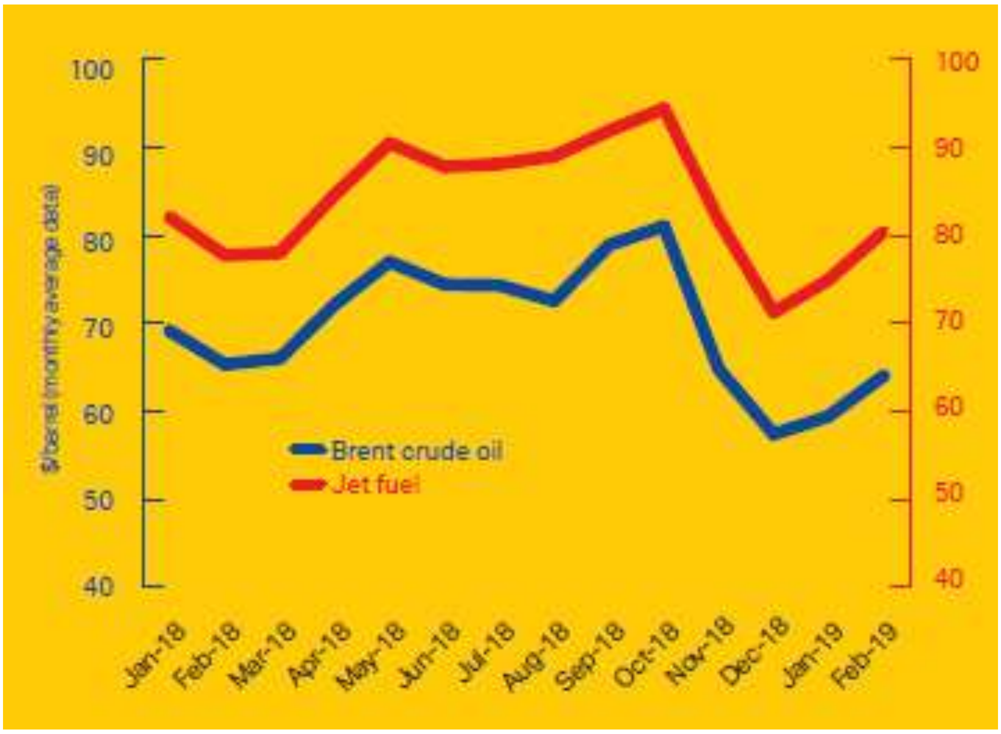

Fig. 2.10. World oil and jet fuel prices

Airlines raised their achieved load factor and maintained a gap above the breakeven level

With oil prices, interest rates, and such other key costs as labor rising further in 2018, the estimate for the industry-wide breakeven load factor increased to 65.9%.

Aided, however, by the record PLF cited previously, the combined achieved load factor also rose, enabling airlines to maintain a solid gap above the level required for financial breakeven. The gap between the breakeven and achieved load factors is driving profitability and returns and was again a critical contributor to the industry's financial performance in 2018 (fig. 2.11).

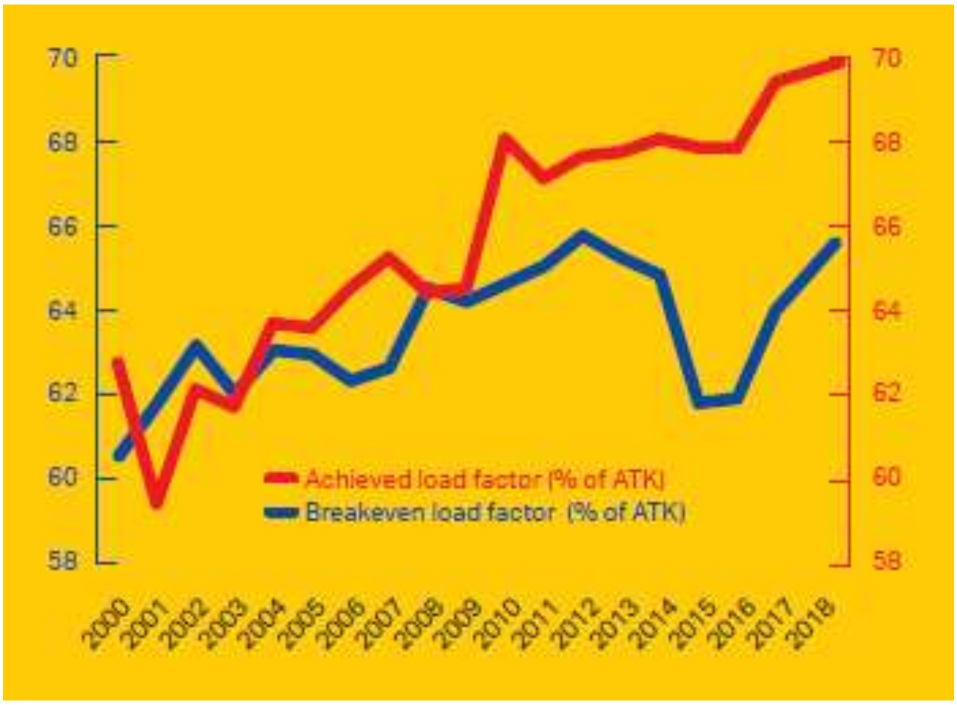

Fig. 2.11. Breakeven and achieved load factors

Another solid financial performance generated an above cost of capital return for the fourth consecutive year.

The global airline industry experienced another year of robust financial outcomes in 2018. IATA estimates that airlines generated a net posttax profit of $30 billion on an operating (EBIT) margin of 5.8%. These outcomes are modestly lower than for 2017 and, as such, reflect 2018's more challenging business environment and particularly its rising cost pressures.

Despite a moderation in industry-wide returns, to 8.0%, the air transport's return on capital exceeded its average cost of capital, which increased to 7.3%, for the fourth consecutive year. Creating value for investors on a more sustainable basis than the industry has managed to do historically will be an increasingly crucial element in attracting the capital necessary to fund fleet renewal and replacement in the years ahead (fig. 2.12).

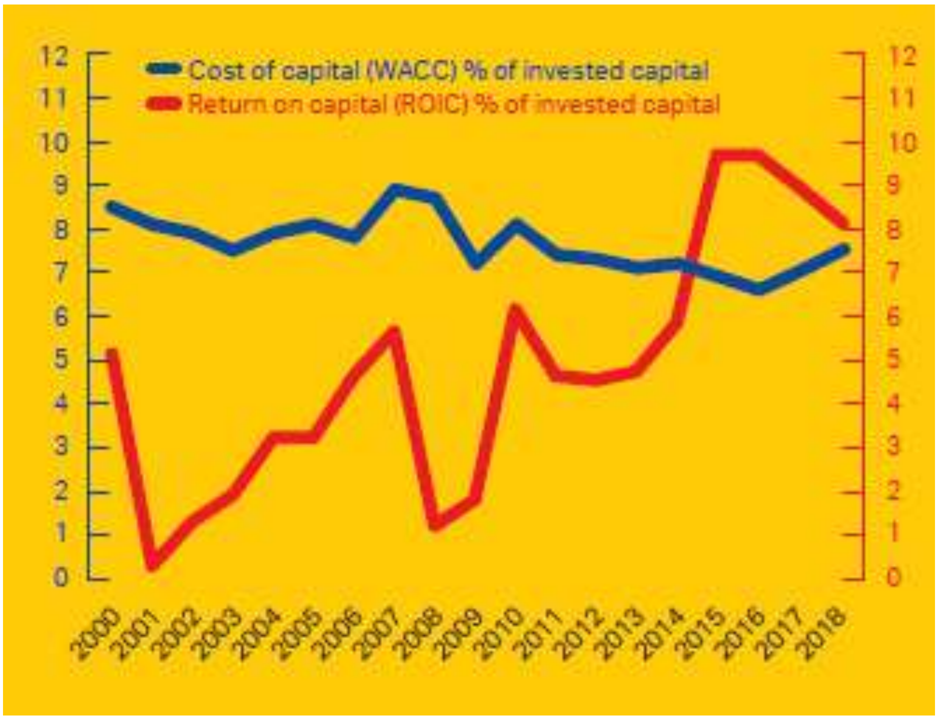

Fig. 2.12. Industry return on investment and the cost of capital

Regional financial performance was again mixed

Regionally, the industry's financial performance remained considerably varied. The financial performance of the North American airlines continued to lead the way, delivering an operating (EBIT) margin of 9.1% in 2018. Airlines in Europe, Asia-Pacific, and Latin America also yielded solid profitability, while carriers in the Middle East and in Africa faced especially challenging operating environments (fig. 2.13).

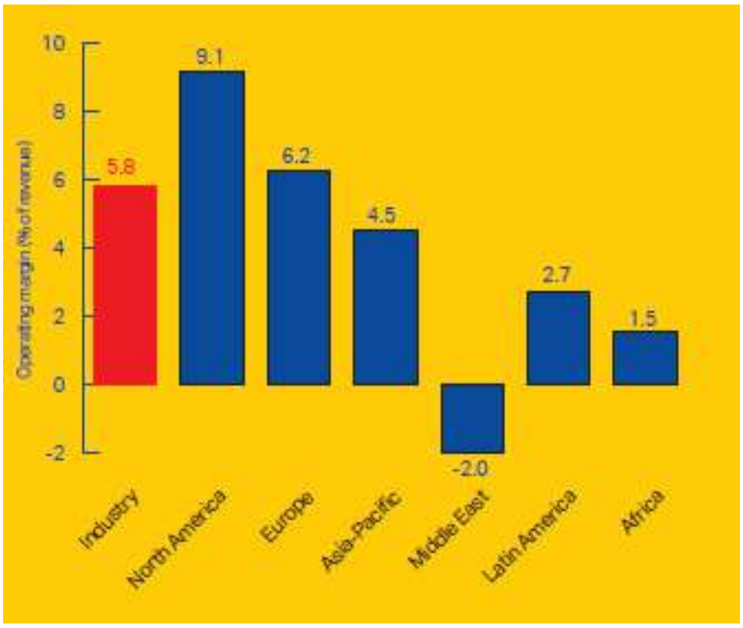

Fig. 2.13. Regional profit performance

On a per passenger basis, the airline industry is a high-volume, low-margin industry. Considering net profits on a per passenger basis highlights this and presents an alternative perspective on regional airline profitability. By this measure, the industry generated a modest $6.85 per passenger in 2018. Regionally, the North American carriers were the best performers, earning $14.66 per passenger (fig. 2.14).

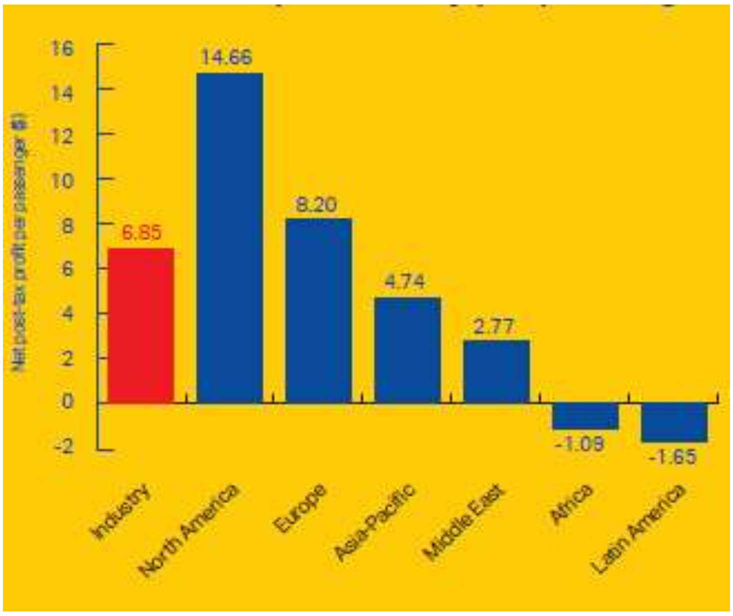

Fig. 2.14. Airline profitability per passenger

2.2. Analysis of the passenger traffic growth in Asia Pacific region airports

• Air passenger traffic in Asia is projected to nearly triple to 3.5bn pax in the next two decades but most of Asia's major airports are already congested.

• At least US$500bn in airport investments would be needed in the next 2 decades to meet demand, with private capital expected to play an increasing larger role, especially in emerging markets like Indonesia, Philippines, China, India and even Japan

• Price weakness for airports on upcoming expansion capex presents an opportunity for investors to accumulate on the cheap airports with growth potential, with throughput growth proving to be a critical share price driver in the long term.

Bigger, better and more airports needed in Asia. Most of Asia's major airports are already congested and expanding rapidly to meet burgeoning demand. It is estimated that at least US$500bn in airport investments are needed over the next 2 decades and there are increasing opportunities for private capital to be involved to lighten the financial burden on governments, especially in the emerging markets.

Asia's billion-dollar airports. The region is home to many listed airports with a market capitalization of above US$2b while there are several unlisted airport groups that are also highly valuable. Names such as Hong Kong International Airport, Seoul Incheon International Airport and Changi Airport Group are likely worth tens of billions as listed companies while Indonesia's Angkasa Pura I & II would also be worth billions.

Look beyond capex spending and focus on throughput growth for share price performance. Observing listed airports under our coverage, the impact of expansion capital expenditure (capex) on near term profits have generally been punished by the market, despite the potential of higher passenger throughput driving revenue and higher earnings in the longer term.

Beijing Capital Airport (BCIA) offers deep value while Airports of Thailand (AOT) still has room to grow. BCIA is the cheapest major airport stock globally, as the market is too pessimistic on the impact of Beijing Daxing International Airport's expected opening in late 2019 on BCIA's earnings, and we continue to like BCIA's fundamentals. AOT may face some capacity constraints in the short term, but a planned expansion, new duty free/commercial concessions and other projects should underpin its long term earnings growth as ASEAN's premier tourism play.

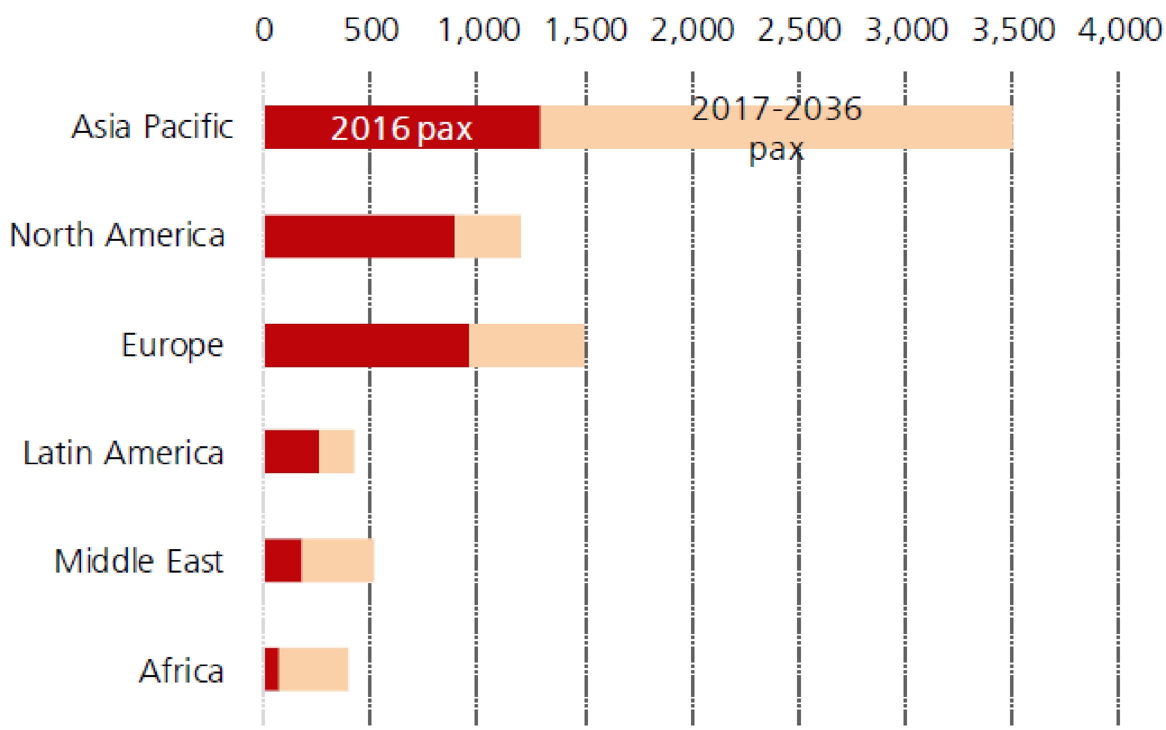

Fig. 2.15. Growth in air passenger traffic in the Asia Pacific (m)

Rising air travel leads to urgent need for more airport infrastructure. A growing middle class, rising propensity to travel and broadly improving global connectivity are setting the stage for air passenger volume in Asia to rise significantly over the coming decades. Besides the impending expansion of airline fleet (evidenced by burgeoning Boeing & Airbus order books), the other critical component necessary to facilitate this growth is the expansion of key Asian airports. Urgency is a mounting factor as the majority of Asia's busiest airports are already operating at above built-for capacity. Where possible, airport operators are aiming to enhance and enlarge their available infrastructure, in addition to furnishing them with cutting-edge technology and systems. Space constraints are also a common feature, leading to both public and private efforts to find and develop new hub locations.

Urgent need for more airport capacity. The International Air Transportation Association (IATA) is forecasting passenger traffic in the Asia Pacific to grow at a 20-yr compound annual growth rate (CAGR) of 5.1% from 2016, higher than the global rate of 3.8%, and to reach around 3,500m passengers (pax) in 2036. By 2036, the Asia Pacific market will add 2.2bn more passengers, accounting for 45% of global traffic. On average, that works out to be more than 100m more passengers per year for the next two decades – requiring an increase in passenger throughput capacity of 200m pax per annum.

12 of the top 20 airports in Asia were operating at or above capacity in 2017 while a further 4 airports were operating at 90% or more. While most of the region's airports have expansions or a new airport planned, many of these airports will still be operating above or near capacity by the time the expansions are complete, highlighting the need for continuous expansion and investment.

Bigger, better and more airports. Capital expenditure for airport construction has been rising, in particular for those aspiring to become hub airports, as best-in-class facilities will help draw airline and air passenger customers to use them as connecting points. The potential to build 'aerotropolises' (airport cities), especially around newer and larger airport expansions, implies large potential investment inflows for the respective geographical areas and leverage to procure government support. Taking the weighted average cost per pax for proposed airports in Asia of US$129.1 per pax multiplied by the c. 4bn passenger handling capacity needed in Asia in the next 2 decades, we derive an estimated total value of US$516bn that will be needed for investment in Asia's airports. Given rising land acquisition and construction costs over time, there is likely to be upside risk to this estimated figure of US$516bn.

A growing role for private capital. While investment in airports in Asia were traditionally thought to be the domain of the public sector, the large investment required, as well as the allure of steady returns and commercial revenue opportunities are attracting more private capital into the sector. The staggering investment needed to build airport infrastructure is strong motivation for governments to turn to private capital as a supplementary, or even primary, means of funding such projects. Generally, there are three airport privatisation models, 1) full private ownership, 2) partial privatisation, and 3) long term concessions. There are more privatization opportunities in markets like Japan, China, India, Indonesia, and the Philippines.

Fund raising lessons from Asia's listed airports. Two of ASEAN's largest airport groups – Malaysia Airports Holdings Berhad and Airports of Thailand - were among the earliest in Asia to tap the equity markets to fund their expansion plans and both are now in a strong financial position to finance their own growth. Meanwhile, much smaller airports like Samui Airport also managed to raise money from the equity markets with a well-structured sale of concession to a listed fund, showing the way for other small airports to do the same.

The home of billion-dollar airports. The Asia Pacific region is home to some of the most valuable airports in the world. In fact, the largest pure play airport company in the world is Airports of Thailand, with a market capitalization of nearly US$28bn. Names such as Hong Kong International Airport, Seoul Incheon International Airport and Changi Airport Group which are among three of the most profitable airports in Asia, are likely worth tens of billions of dollars as listed companies, while Indonesia's Angkasa Pura I & II groups would also be worth billions, when we apply the average PE of listed peer companies to their respective earnings.

The Asia Pacific is the largest air transportation market in the world. According to the International Civil Aviation Organization (ICAO), air passenger traffic in the Asia Pacific region reached 1,485m pax in 2017, accounting for c.36.5% of overall passengers globally, growing by 10.8% y-o-y compared to 5.3% growth for the rest of the world in 2017. Asia Pacific's share of air passengers has risen from 27.7% in 2010 to 36.5% in 2017 and more than half the growth in passenger traffic in 2017 was from Asia Pacific.

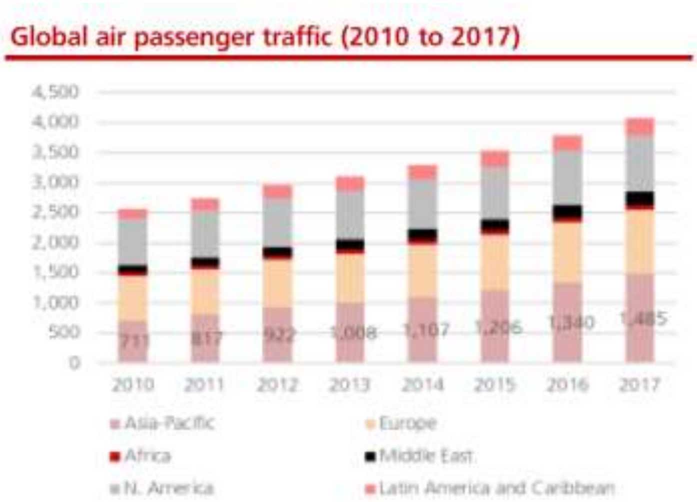

Fig. 2.16. Global air passenger traffic (2010 to 2017)

In terms of absolute numbers, an average of nearly 100m passengers were added in each year between 2011 and 2015 while nearly 140m passengers on average were added each year in 2016 and 2017.

Fig. 2.17. Growth of air passenger traffic in Asia Pacific (m)

The Asia Pacific will see 2.2bn more air passengers by 2026. IATA is forecasting passenger traffic in Asia Pacific to grow at a 20-yr CAGR of 5.1% from 2016, higher than the global rate of 3.8%, and reach around 3,500m pax in 2036. By 2036, the Asia Pacific market will add 2.2bn more passengers, accounting for 45% of global traffic.

On average, that works out to be more than 100m more passengers per year for the next two decades – requiring an increase in passenger throughput capacity of 200m pax per annum. This forecast may be pessimistic given that the year-to-date Revenue Passenger Kilometres (RPK) growth (August 2018) in the Asia Pacific was 9.5% while passenger growth in 2017 was 10.8%.

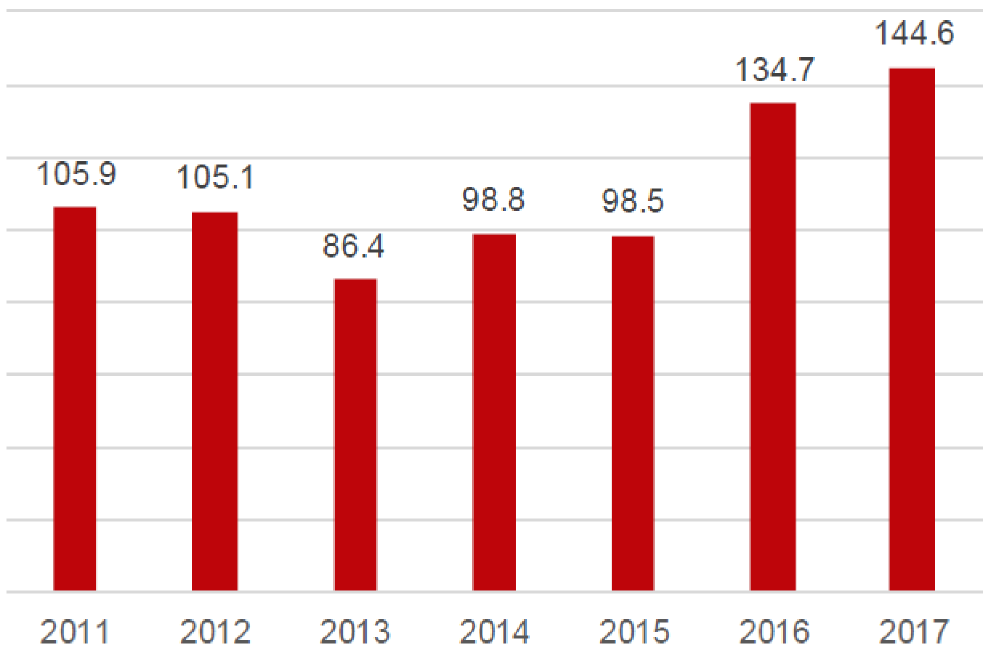

Fig. 2.18. Growth of air passenger traffic in Asia Pacific (m)

2.3. Analysis of airport infrastructure in Asia

Asia's rapid growth in the commercial aviation sector in recent decades has positioned the region as the largest and fastest growing in the world. The growth in Asia is expected to remain resilient, forecast to continue as the world's highest growth region well beyond 2020. However, aviation infrastructure is not keeping pace with this growth.

Many of the Asian hubs are already operating above their planned capacity, resulting in a rapid escalation of delays since 2010. Current plans for constructing mega-hub airports are not effective from a cost perspective and will fail to keep up with demand. Instead, governments should plan larger numbers of medium-sized airports to keep costs manageable, gain maximum operational efficiency, and build a wider aviation network, allowing Asian commercial aviation to continue in its role as a key enabler of economic growth.

Airport operators and governments in Asia are competing to build the world's biggest airport, with capacities well in excess of 100 million passengers per annum. However, our experience is that owing to exponentially increasing complexity, airports suffer from significant diseconomies of scale above around 50 million passengers per annum, both for the airport operator (Capex and Opex) and for the airlines and passengers using them (time to move around the airport). At the same time, the network benefits of these very large airports do not increase as fast as their size. Therefore, Asian airport planners and operators will need to acquire capabilities in multi-airport systems – or radically change how airports operate to overcome the inherent scale diseconomies of mega-hubs.

Asia as a high-growth region

In recent decades, Asia has emerged as the leading region in aviation traffic, currently accounting for 30% of the world's revenue passenger kilometers, up from 24% in 2004. As the world's fastest growing region, Asia should see its growth remain resilient at over 6% per annum over the next two decades1. In contrast, established regions such as Europe and North America are expected to experience relatively slower growth, with opportunities scarce due to market maturity, environmental concerns, and increasing availability of substitutes such as high-speed rail.

The growth in Asia is expected to remain resilient, forecast to continue as the world's highest growth region well beyond 2020.

Asia's surge in demand for airport infrastructure is explained by three factors: liberalisation of the Asian markets, growth in wealth and size of the Asian middle class, and a lack of alternative modes of transport.

Since the 1980s, the opening of formerly closed countries in Asia to global trade has massively stimulated the movement of both goods and people in the region. Free trade agreements (FTAs) have driven the convergence and integration of economies within Asia, stimulating intra-regional trade. Concurrently, Asian countries have liberalized visa requirements and air travel agreements. For example, the ongoing programme of ASEAN air services liberalization has already resulted in significant increases in flights between capital cities, and should enable the opening up of many secondary airports to intra-ASEAN flights in 2015.

In combination, the liberalization of Asian economies and travel restrictions has opened travel opportunities to new population segments, many of which were previously unable to travel by air.

Asia already has the largest share of the world's urban population in its cities; this is unleashing a massive wave of new travel. The reasons are simple: people migrate to centers where they can earn higher wages; they can then travel owing due to the availability of airport infrastructure in proximity to such cities. They also have the motivation to do so, in many cases for visits to their home towns but also for tourism. Asia is rapidly becoming a higher income region, and is already home to 41% of the world's middle class. This percentage is predicted to rise to 68% of the world's middle class in 2033, owing to an expected four-fold increase in absolute numbers of Asia's current middle-class population.

Empirical evidence shows that the propensity to travel increases with the economic well-being of the country. (See Figure 1.) However, upon further inspection, the trend points toward an even more compelling case for the growth of air travel in Asia. At similar levels of economic well-being, Asians take more trips than the Europeans and North Americans who adopted mass air transport far earlier than Asians.

One reason for this is the lack of alternative modes of transport. Unlike in Europe and North America, where large contiguous landmasses allow intercity highways and railways, large parts of Asia can be reached only by air. Geographical barriers include mountainous regions, the island nature of much of Southeast Asia (the Philippines, Indonesia, Malaysia, Brunei, and Singapore), and sheer distances between major Asian cities. Although high-speed rail is now well developed in parts of North Asia, for much of the continent, air travel will remain the best option from a cost and time perspective for the foreseeable future.

To fully respond to this demand, Asia's current aircraft fleet has to grow rapidly. This equates to an estimated 13,000 new aircraft deliveries in the next 20 years, more than doubling the size of the current fleet. So, the question remains: How can a region set to lead the world in terms of aviation traffic and size of fleet accommodate its growth?

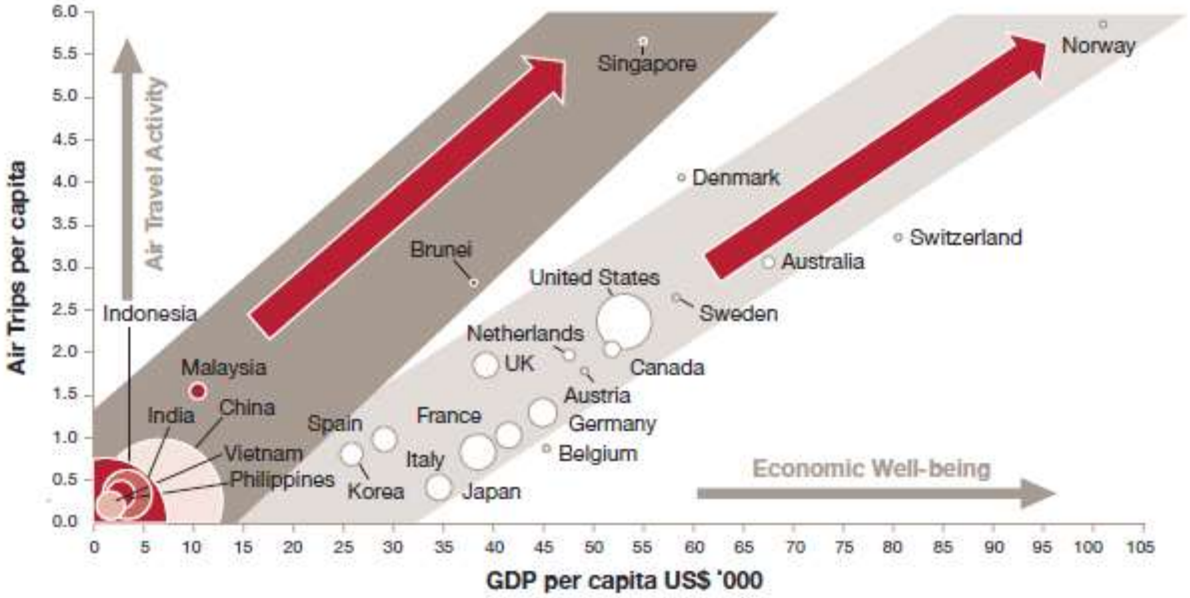

Fig. 2.19. Air-travel activity versus economic well-being

Current observations in Asia

Development of Asia's airport infrastructure has lagged behind travel growth. Traffic at most major Asian hubs is already exceeding planned capacity whilst even secondary hubs are starting to experience capacity strains. (See fig. 2.20)

Since the large surge in Asian airport developments in the 1990s, infrastructure has rarely been built ahead of demand. This is a cause for concern, owing to Asia's predicted high rate of growth and given that runway and terminal projects typically require 5-10 years from need recognition to implementation. As a consequence, congestion-related delays are rapidly increasing at most Asian hubs. Passengers experience increasingly common flight delays, long queues for take-off, and circling of aircraft in stacks prior to landing.

Availability of suitable landing and take-off slots is suddenly becoming scarce, leaving airports unable to cope with any further growth, and leaving airlines with nowhere to operate their newly delivered aircraft. Therefore, it is not surprising that in 2013, only 57% of departures from Asian airports were on time. This number is considerably lower than for airports in North America and Europe, which boast 79% and 73% of departures on time, respectively.

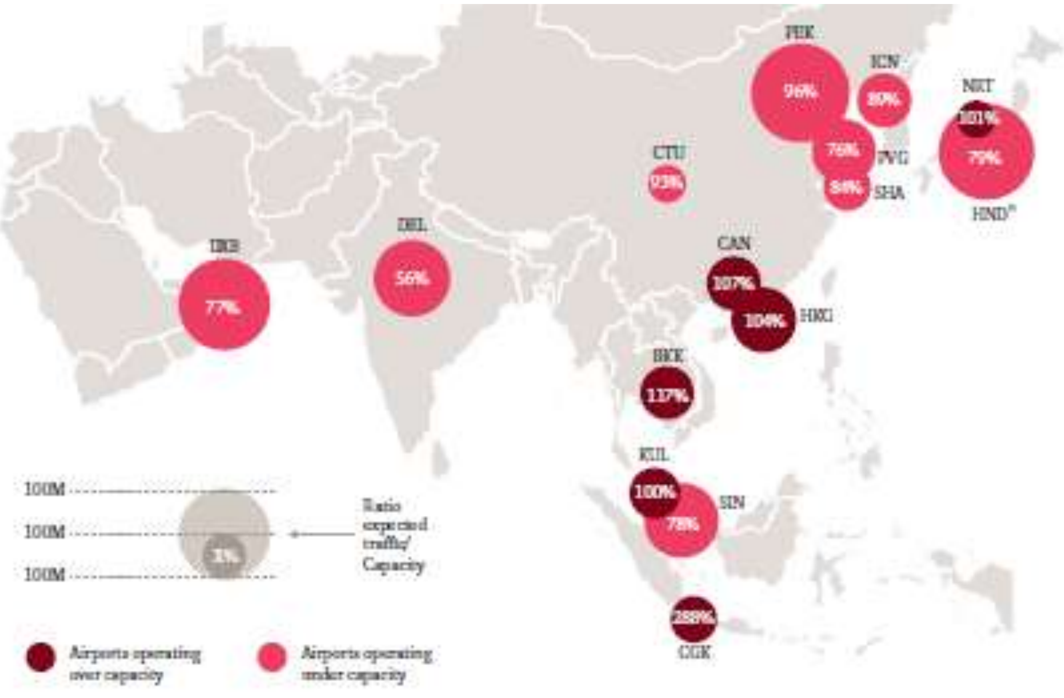

Fig. 2.20. Passenger capacity of Asian hubs in 2012

Specifically, in 2013, less than one third of the flights from China's three largest airports departed on time. And even Changi International Airport and

Incheon International Airport, both award-winning and highly rated, were not able to match North America's average percentage of on-time departures.

When we look more closely at the demand patterns, we see some major issues that have exacerbated the problem:

1. Liberalization and the growth of LCCs has led to smaller aircraft being deployed: Historically, Asian airlines operated large aircraft with relatively low frequency between capital cities. Most of the growth in the past decade has been in narrow-body flights, reducing the ratio of passengers per runway slot.

2. Rates of commercial aviation growth have been higher than forecast: Despite various set backs such as SARS, the 2008 GFC, and political issues in some countries, aviation in Asia has grown faster than forecasters of the 1980s and 1990s expected.

However, looking beyond the demand for flights to the supply of infrastructure, we can see that Asia has developed its airports in a very different way from the rest of the world.

As a region, Asia has just 0.22 airports per million inhabitants; the least of any region in the world. However, these airports serve an average of 1.75 million passengers, well above the mature aviation markets of North America and Europe.

Bearing in mind that Asia's main hubs are already under capacity despite being among the largest in the world, it's clear that Asia has too few airports, and the inefficiencies of larger-sized airports is leading to increasingly frequent delays.

Moving to a better travel world

Building mega-hubs

Several mega-hub projects have been announced and are set to come into service in the next decade. Such projects include the Al Maktoum International Airport, Beijing Daxing International Airport, Hong Kong International Airport's Three-Runway System, and finished, each of these is planned to have a capacity of more than 100 million passengers per annum.

When we study growth trends amongst airports globally, we find that the largest airports have experienced slow rates of growth, appearing to hit a growth wall at the 80-100 million passenger level, while the second tier of large airports continues to grow rapidly in terms of passengers served. Given the current inability to manage large Asian hubs efficiently, and the evidence from other regions that airports typically do not grow indefinitely, constructing even larger airports may not be the best approach moving forward.

Optimizing airport size

An alternative approach involves the construction of a larger number of optimally sized airports, sufficient as a whole to handle the growth in demand – despite being smaller than mega-hubs. The rationale behind this approach rests on three pillars:

• Delivering airport infrastructure that is cost-effective and efficient, potentially introducing competition for the provision of airport infrastructure

• Providing airport accessibility to a larger percentage of the population, as more airports inevitably means a larger population lives within easy surface-travel distance

• Improving the quality of travel and reducing congestion and delays, during normal service and by delivering redundancy in the event of unplanned incidents

This approach is not entirely new; more than 70 cities globally (including London, Paris, New York, Chicago, and Sao Paulo) are already being served by more than one airport, with just 15 such cities in Asia (such as Kuala Lumpur, Bangkok, and Manila). Regardless of the reasons for multi-airport cities, the benefits appear clear. Operating several smaller airports is very different from operating a mega-hub with capacities exceeding 100 million passengers per annum, both in magnitude of costs and ease of achieving operational efficiency.

Managing multiple airports

The notion of having multiple airports serving a city, raises several concerns:

• In some cases (such as Singapore and Hong Kong), it is extremely hard to find space in the city for more than one airport. In these situations, airports in neighbouring territories can provide an alternative (for example, Johor Bahru for Singapore, and Shenzhen, Macao, and Zhuhai for Hong Kong).

• To avoid transfer passengers having to move between airports in a multi-airport city, airports should be planned so that a single airline or alliance can be accommodated in a single airport; transfers between non-alliance airlines are rare.

• Private airport operators may not wish to see a competing airport in the city. It is therefore essential that prior to privatization, clear policies on multi-airport development are laid out so that the operator has certainty when making the privatisation investment.

Our recommendation is that government policy makers and planners in Asia consider moving beyond simply considering the provision of capacity to meet demand, and instead think through the options for providing a cost-effective travel experience for passengers. Such options should take into account surface travel distance to the airport, time spent navigating the airport (kerbside to aircraft), and operating efficiencies that airlines gain with shorter taxi distances from runway to gate as well as slots that are available to suit passenger and airline schedules. Our expectation is that airports with terminal capacities of 20-25 million passengers and runway capacity of around 50 million passengers (twin independent parallel runways) will give the optimal combination of scale economy whilst allowing the majority of passengers to travel on point-to-point flights. As such, governments should plan to construct more optimally sized airports with capacities of 20-50 million passengers per annum, rather than mega-hubs exceeding 100 million passengers. In this way, they will stand a better chance of meeting Asia's growing demand in a way that enhances air connectivity and improves the quality of travel.

3. DESIGN PART

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3.1. Operational efficiency of Asia-Pacific airports

Airports are important drivers of economic development and thus under tremendous pressure from emerging competitors. However, few studies have analyzed the operational efficiency of Asia-Pacific airports. This study therefore evaluated the operational efficiency of 21 Asia Pacific airports between 2009 and 2018. A two-stage method was used: Data Envelopment Analysis (DEA) to assess airport efficiency, followed by the second-stage regression analysis to identify the key determinants of airport efficiency. The first-stage DEA results indicated that Adelaide, Beijing, Brisbane, Hong Kong, Melbourne, and Shenzhen are the efficient airports. The second-stage regression analysis suggested that percentage of international passengers handled by an airport, airport hinterland population size, dominant airline(s) of an airport when entering global airline strategic alliance, and an increase in GDP per capita are significant in explaining variations in airport efficiency.

Several factors have stimulated the growth in air transport demand and airport development, such as rapid economic development, privatization of the airport industry, and the liberalization of aviation policy in the Asia-Pacific region (e.g. Oum and Yu, 2000; Park, 2003; Williams, 2006; Yang et al., 2008; Zhang, 2003). The growth is reflected by the increasing air traffic volumes handled by Asia-Pacific airports. The Airport Council International (ACI) re-ported that several major Asia-Pacific airports have been frequently ranked inside the world's top 30 busiest airports between 2002 and 2011 (ACI, 2002e2011). Moreover, ACI also projects that the announced growth rates for air cargo volumes and aircraft movements in the Asia-Pacific region will reach 6.3% and 4.5%, respectively, by 2025 (ACI, 2007). The International Civil Aviation Organization (ICAO) also estimates that the Asia-Pacific region will become the busiest and fastest growing air transportation market for international passenger traffic by 2025 (ICAO, 2008). Governments in the Asia-Pacific region have therefore invested heavily and constructed airport infrastructure and facilities to meet projected future air transport demand (O'Connor, 1995). However, airports are also under pressure from emerging competitors competing for air traffic demand. To respond to this pressure, airport efficiency has been identified as a critical issue facing airport management (Chin and Siong, 2001; Forsyth, 2003, Talley, 1983).

To investigate airport efficiency, Data Envelopment Analysis (DEA) has become the recognized method for efficiency evaluation due to its simplicity in constructing an efficiency frontier for identifying efficient or inefficient airports (Gillen and Lall, 1997). Also, the DEA model requires no assumptions for specifying production functions between airport inputs and outputs. The DEA model can also compute multiple airport inputs and outputs within a single analysis without any difficulties of aggregation, and can assess an airport's relative efficiency in a single period or in a sequence of periods as well as requiring less information for analysis (e.g. Cooper et al., 2006; Pels et al., 2001, 2003). Therefore, we first applied the DEA model to assess the operational efficiencies of Asia-Pacific airports, and then the SimareWilson bootstrapping regression analysis to identify which factors significantly explain variations in airport efficiency. There are three primary reasons why this study is meaningful: (i) airports operating in the Asia-Pacific region seem to be less researched compared with their counterparts in the US, Europe, and South America; (ii) this study contributes to the existing literature by analyzing the efficiency of a large group of Asia-Pacific airports (21 airports) the size of sampled airports in this study is a good reflection and representation of the airport industry in the Asia-Pacific region due to their roles as the international or regional hub airports in their countries; and (iii) this study extends the work of Ha et al. (2010), Lam et al. (2009), and Yang (2010a,b) in assessing the operational efficiency of Asia-Pacific airports and seeking to identify the causes of variations in airport efficiency.

The format of this study is structured as follows. Section 3.2 presents the literature review with regard to airport efficiency evaluations. Section 3.3 outlines the DEA methodology and the SimareWilson bootstrapping regression analysis. Section 3.4 presents the dataset of sampled airports, and airport input and output variables for the DEA analysis as well as the key determinants for the second-stage regression analysis. Section 3.5 presents the results and discussion of the first-stage DEA analysis and the second-stage regression analysis. Section 3.6 concludes what are the key findings of this study.

3.2. Literature review

DEA has become a popular method of investigating airport efficiency. Prior DEA studies showed considerable differences in the airport input and output variables used for the efficiency analysis. Three specific forms of DEA analysis were identified from the literature: (i) DEA analysis with operational variables; (ii) DEA analysis with financial variables; and (iii) DEA analysis with second-stage analysis.

Airport efficiency studies that have used DEA analysis with operational variables include Fernandes and Pacheco (2002), Fung et al. (2008), Ha et al. (2010), Lam et al. (2009), Lin and Hong (2006), Lozano and Gutierrez (2009), Roghanian and Foroughi (2010), and Yoshida and Fujimoto (2004). The reasons why DEA studies employ operational variables for benchmarking airport efficiency but then do not incorporate any financial variables are complicated and an in depth explanation is beyond the scope of the current study. However, one of the reasons may be lack of available financial data related to airport operations or because it is extremely difficult to gather relevant financial data for each airport analysed.

Most airports are currently operated as commercial organizations to maximize the profitability from aeronautical and non-aeronautical activities (Graham, 2008). Therefore the financial variables or indicators have been used in the prior studies as airport input and/or output variables in DEA analyses in order to achieve a fair evaluation of airport efficiency. DEA analysis with financial variables has been applied in such studies such as Barros and Dieke (2007), Martin and Roman

(2001), Murillo-Melchor (1999), Pacheco and Fernandes (2003), Parker (1999), Sarkis (2000), Sarkis and Talluri (2004), and Yang (2010a,b).

One potential problem is that the key determinants causing variations in airport efficiency may not be clearly understood using the operational and/or financial variables in the DEA analysis, although DEA studies of airport efficiency evaluations showed the ability to evaluate airport efficiency (Gillen and Lall, 1997). A clear understanding of which factors affect airport efficiency would provide insight to airport managers and policy makers for improving airport efficiency through benchmarking; that is, it would help to compare an airport's performance with its peers in the same region and improve its operations. The approach combining a first-stage DEA analysis and a second-stage Tobit model has become a popular method to identify those significant determinants. A number of studies have used this two-stage approach to investigate airports, for example, Abbott and Wu (2002), Barros and Sampaio (2004), Gillen and Lall (1997), Malighetti et al. (2007), Pathomsiri et al. (2006), Pels et al. (2001, 2003), Perelman and Serebrisky (2010), and Yuen and Zhang (2009).

Although adopting Tobit models in the second-stage analysis has been popular, it is considered as an invalid approach to deter-mine the factors for explaining variations in airport efficiency, due to the presence of inherent dependence among the DEA efficiency indexes from the first-stage DEA analysis (Casu and Molyneux, 2003; Xue and Harker, 1999). Importantly, one basic assumption of regression analysis is violated e the independence within the sample. To solve this problem, Simar and Wilson (2007, 2008) introduced the bootstrapping methodology to solve this problem.

Recently, studies have begun to apply the SimareWilson boot-strapping approach for estimating the significant determinants of airport efficiency. For example, Barros and Dieke (2008) used the truncated bootstrapped regression to estimate the efficiency and identify the determinants of 31 Italian airports between 2001 and 2003. They found that the method to bootstrap the DEA efficiency scores with a truncated regression analysis can better explain DEA efficiency levels.

Similarly, Barros (2008) employed the truncated bootstrapped regression analysis to analyze the efficiency of Argentinian airports during the period of intense economic crisis. Curi et al. (2011) also used the bootstrapping methodology to investigate 18 Italian airports. During the same year, Tsekeris (2011) used the truncated bootstrapped regression to assess the relative technical efficiency of Greek airports and investigate factors that determine airport efficiency. Merkert and Mangia (2012) also applied the bootstrapping two-stage DEA model to analyse 46 Norwegian airports' efficiency. Merkert et al. (2012) employed the input-oriented DEA model and the SimareWilson bootstrapping approach to analyse the efficiency of regional airports worldwide, and suggested that the more sophisticated two-stage model can deliver powerful insights into the performance of regional airports. Tsui et al. (2014b) also utilised the slack-based measure (SBM) model, the Malmquist Productivity Index (MPI), and the SimareWilson bootstrapping methods to investigate the efficiency and productivity changes of 11 New Zealand airports for the period of 2010-2012.

3.3. Methodology

3.3.1. Data envelopment analysis (DEA)

The DEA methodology evaluates the relative efficiency of a decision making unit (DMU) by building a ratio which consists of the maximum weighted outputs to maximum weighted inputs for each DMU subject to a set of conditions (Charnes et al., 1978). Considering a group of airports, where y_{rk} and x_{ik} are the known airport outputs and inputs of airport k. The DEA efficiency index of an airport is denoted as B_o, which represents the inputs $x_{io}(i=1,2,3,\ldots,n)$ that produce the outputs $y_{ro}(r=1,2,3,\ldots,m)$; u_r and v_i are the weights of aggregation (virtual multipliers), that are non-negative which are chosen to maximise the value of B_o.

Thus, the fractional programming model is written as shown in Eq. (3.1):

$$B_o = \max_{u_r, v_i} \frac{\sum_{r=1}^{m} u_r y_{ro}}{\sum_{i=1}^{n} v_i x_{io}}$$

subject to:

$$\frac{\sum_{r=1}^{m} u_r y_{rk}}{\sum_{i=1}^{n} v_i x_{ik}} \leq 1, \quad k = 1,2,3,\ldots,l$$

$$u_r, v_i \geq 0; \quad r = 1,2,3,..m; \quad i = 1,2,3,\ldots,n \qquad (3.1)$$

Later, Banker et al. (1984) developed the DEA-BCC model, which allows airports operating with lower airport inputs to have an increasing return to scale under the principle of Variable Return to Scale (VRS), and those operating with higher airport inputs to have a decreasing return to scale. The DEA-BCC model is written as shown in Eq. (3.2):

$$\theta = \max \varphi + \varepsilon \left[\sum_{r=1}^{m} s_{ro}^{+} + \sum_{i=1}^{n} s_{io}^{-} \right]$$

subject to

$$\sum_{r=1}^{m} y_{rk} \lambda_k - s_{ro}^{+} = \varphi y_{ro} \quad r = 1,2,3,\ldots,m;$$

$$\sum_{r=1}^{n} x_{ik} \lambda_k + s_{io}^{-} = x_{io} \quad i = 1,2,3,\ldots,n;$$

$$\sum_{r=1}^{m} \lambda_k = 1, \ \lambda_k \geq 0; \quad k = 1,2,3,\ldots,l. \qquad (3.2)$$

where θ – airport efficiency index; ε – a constant (greater than 0); s_{ro}^{+} and s_{io}^{-} – airport output and input slacks; λ_k – the dual variable or the scalar vector associated with each airport. An airport is considered as a BCC-efficient airport when θ is equivalent to 1 and has zero output and input slacks and $s_{ro}^{+} = 0, s_{io}^{-} = 0$. Otherwise, the airport is called a BCC-inefficient airport (Cooper et al., 2006).

3.3.2. The SimareWilson bootstrapping regression analysis

The DEA efficiency indexes obtained from the first-stage DEA analysis will be used to regress on the factors (e.g. the specific operating characteristics, management/ownerships, and regional locations) related to the sampled Asia-Pacific airports and identify the significant factors to explain variations in airport efficiency using the second-stage SimareWilson bootstrapping regression analysis5 (see Simar and Wilson, 2007).

The initial estimation specification can be written as shown in Eq. (3.3):

$$\theta_k = \alpha + z_k\beta + \varepsilon_k \quad k = 1,2,3,\ldots,n \tag{3.3}$$

Eq. (3.3) is the first-order approximation of the unknown true relationship. Where θ_k is the DEA efficiency index of airport *k*. α is the constant, z_k is a vector of observation-specific variables that is expected to associate with airport *k*'s DEA efficiency index, β is a vector of parameters, and ε_k is the error term.

Applying the Simare-Wilson bootstrapping approach, the distribution of ε_k is limited to the condition $\varepsilon_k = 1 - \alpha - z_k\beta$. Thus, the distribution of ε_k becomes $\varepsilon_k \sim iidN(0, \sigma_\varepsilon^2)$. Moreover, the true and unobserved dependent variable θ_k in Eq. (3.3) to be replaced by θ_k^* (the DEA efficiency index of airport *k* after applying the SimareWilson bootstrapping approach), and the model specification can be written as shown in Eq. (3.4):

$$\theta_k^* = \alpha + z_k\beta + \varepsilon_k \quad k = 1,2,3,\ldots,n \quad \varepsilon_k \sim iidN(0, \sigma_\varepsilon^2) \tag{3.4}$$

Table 3.1

List of Asia-Pacific airports

Airport code	Airports	Country, city	Airport status
ADL	Adelaide Airport	Australia, Adelaide	Regional hub
AKL	Auckland International Airport	New Zealand, Auckland	International hub

Continuation of the Table 3.1

PEK	Beijing Capital International Airport	China, Beijing	International hub
BNE	Brisbane Airport	Australia, Brisbane	Regional hub
CHC	Christchurch International Airport	New Zealand, Christchurch	Regional hub
GMP	Gimpo International Airport	South Korea, Seoul	Regional hub
CAN	Guangzhou Baiyun International Airport	China, Guangzhou	International hub
HKG	Hong Kong International Airport	China, Hong Kong	International hub
ICN	Incheon International Airport	South Korea, Seoul	International hub
KIX	Kansai International Airport	Japan, Osaka	Regional hub
KUL	Kuala Lumpur International Airport	Malaysia, Kuala Lumpur	International hub
MEL	Melbourne Airport	Australia, Melbourne	International hub
NRT	Narita International Airport	Japan, Tokyo	International hub
MNL	Ninoy Aquino International Airport	Philippines, Manila	International hub
PER	Perth Airport	Australia, Perth	Regional hub
SXZ	Shenzhen Bao'an International Airport	China, Shenzhen	Regional hub
SIN	Singapore Changi Airport	Singapore	International hub

Continuation of the Table 3.1

CGK	Soekarno-Hatta International Airport	Indonesia, Jakarta	International hub
BKK	Suvarnabhumi Airport	Thailand, Bangkok	International hub
SYD	Sydney (Kingsford Smith) Airport	Australia, Sydney	International hub
TPE	Taiwan Taoyuan International Airport	Taiwan, Taipei	International hub

Remarks: The classification of an airport's status is based on the airport's strategic role and flight connectivity network. For example, an international hub airport connects to at least 25 international destinations; a regional hub or non-hub airport flies to no more than 25 international destinations (Matthiessen, 2004).

3.4. Data description

3.4.1. The dataset

A rigid DEA convention was followed to determine the total number of airport observations in association with the total number of airport input and output variables; the minimum number of airports observed should be greater than or equal to three times the sum of airport input and output variables to ensure that satisfactory discriminating power is possible (Banker et al., 1989; Cooper et al., 2006; Raab and Lichty, 2002). The current study achieved this requirement with a sample size of 21 Asia-Pacific airports, and a total of seven airport input and output variables for the first-stage DEA analysis. Table 3.1 shows the list of 21 major Asia-Pacific airports for analysis between 2009 and 2018

The data was collected from the following sources: International Civil Aviation Organisation (ICAO), Airport Council International (ACI), Air Transport Research Society (ATRS)-Airport Benchmarking Reports, civil aviation authority of the respective countries, airports' annual reports and websites. Individual airports were also contacted to obtain additional information.

3.4.2. Airport input and output variables for the first-stage DEA analysis

To select airport input and output variables for the first-stage analysis, we considered data availability, referred to extant literature (e.g. Doganis, 1992), and sought the professional opinion from airport managers. At a result, we selected four airport input variables (i.e. number of employees, number of runaways, total runway length, and passenger terminal area) and three airport output variables (i.e. air passenger numbers, air cargo volumes, and aircraft movements) for the first-stage DEA analysis.

3.4.3. Key determinants for the second-stage regression analysis

Three tasks were performed in this study to identify the key determinants in explaining variations in airport efficiency. First, the airport input and output variables used in the first-stage DEA analysis will not be reused as the explanatory variables in the second-stage regression analysis, avoiding the problem of double-counting and possibly obtaining misleading or biased results (Lin, 2008). Second, prior studies relating to airport efficiency were examined to identify the potential explanatory variables for the second-stage regression analysis. Lastly, an attempt was made to look at other principles applying the two-stage regression analysis that may assist in devel-oping other relevant explanatory variables for this study (e.g. Boame, 2004; Fethi et al., 2000; Oum and Yu, 1994; Zheng et al., 1998).

Taking the literature and data availability into account, seven explanatory variables were developed for the second-stage regression analysis, which represents Asia-Pacific airports' operating characteristics, management/ownerships, and regional locations (see Table 3.3). Data related to the selected explanatory variables was obtained from National Yearbooks, National Statistical Departments, World Bank Data, United Nation Data, and airports' annual reports and websites.

3.5. Estimation of results

3.5.1. DEA analysis

The DEA Output-Oriented and VRS framework was selected for the first-stage DEA analysis. Table 3.2 shows the DEA estimation results categorising in three groups of airports with reference to changes in airport efficiency including the DEA efficiency indexes for each airport over the years and the percentage of efficient airports during each study year.

Table 3.2 shows that at least 52% of Asia-Pacific airports are considered as ‘efficient’ between 2009 and 2018. Six airports were found to be best performers over the entire study periods having consistently full DEA efficiency indexes (i.e. Adelaide, Beijing, Brisbane, Hong Kong, Melbourne, and Shenzhen). Of these, three were international hub airports (i.e. Beijing, Hong Kong, and Melbourne). This might be consistent with the concept that the inter-national hub or gateway airports are able to attract and handle more air transport demand than the regional or non-hub airports, leading to higher efficiency. Also, their strategic roles and extensive flight connectivity networks reflect their ability to attract more international and domestic passenger traffic (i.e. origin-destination traffic and connecting traffic). The full efficiency of Beijing and Hong Kong for all ten years may be explained by their respective air traffic volumes being consistently ranked inside the world's top 30 busiest passenger airports for the period of 2009-2018. The full efficiency levels of Brisbane throughout the study period may be due to its prime location for holiday travel to the principal Australian tourist attraction the Gold Coast. For Shenzhen, its remarkable record may have been largely due to the rapid economic growth of the Pearl River Delta (PRD) region in Mainland China (particularly experiencing 103.4-187.8% growth for three airport outputs between 2009 and 2018).

Twelve airports were considered to be moderate performers since they were efficient in at least one of the ten years during the study periods. Overall, these airports either showed improvements (eight airports) or deteriorations (four airports) in their efficiency levels across the analysis periods, although there was no regular trend with respect to their respective efficiency levels. For the improving airports, in particular, Guangzhou deserves to be explored why its efficiency improved and it became efficient after 2014. Its rapid expansion improved the airport's flight connectivity network, covering more than 200 routes, which translated into an increase in airport traffic. In addition, Sydney was ranked as one of the world's top 30 busiest passenger airports in 2010, and its growth after 2010 could be attributable to its strategic role served as the main international gateway hub airport to and from Australasia and Oceania. In addition, Gimpo's inefficiency before 2017 was likely due to the opening of Incheon in 2009, which adversely affected its operations by attracting away international passenger and cargo traffic. However, its three airport outputs achieved a 5.4-15.0% increase between 2017 and 2018, leading to its full efficiency level in 2018. Likewise, the decline in Jakarta's efficiency was likely related to the Bali bombings that occurred in 2009 and 2012 these disruptive events had significant negative impacts on international visitors visiting Indonesia (Hitchcock and Putra, 2005). In particular, Jakarta's positive air traffic growth after 2016 led to its full efficiency levels, with an average annual growth of air passenger numbers (10.6%), air cargo volumes (20.5%), and aircraft movements (8.9%), respectively.

The airports never achieved full efficiency levels (i.e. DEA efficiency index = 1) during the study periods (i.e. Incheon, Kuala Lumpur, and Singapore). Interestingly, these three major international hub and gateway airports were considered to be the worst performers. One explanation might be largely related to the con-sequences of underutilization or over-investment in airport resources or high capacity airports handling lower amounts of air traffic. Indeed, further investigation revealed that Incheon and Kuala Lumpur's inefficiencies across the years did not result from recent expansions but from ongoing overcapacity. Likewise, part of the explanation of Singapore's under-utilisation is the result of its passenger terminal expansion in 2014, while its international passenger traffic only increased by less than 3% between 2013 and 2014 as well as between 2016 and 2017, respectively, leaving Singapore with significant excess capacity.

Regarding the deteriorating airports, Bangkok's inefficiency after 2015 was primarily the consequence of Thailand's political unrest, which triggered negative airport traffic growth (Yin and Walsh, 2011). Moreover, Kansai became inefficient after 2013 as an additional runway came into operation in 2014, but its air traffic volumes did not respond with a significant increase accordingly. Passenger terminal expansion might contribute to the deteriorations in efficiency of Manila.

Table 3.2

DEA efficiency indexes of Asia-Pacific airports (2009 - 2018)

	Airports	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average
Best performers[a]	Adelaide	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
	Beijing	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
	Brisbane	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
	Hong Kong	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
	Melbourne	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
	Shenzhen	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Moderate performers (improvement) [b]	Auckland	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.965	**1.000**	0.996
	Gimpo	0.948	0.907	0.679	0.766	0.749	0.659	0.678	0.654	0.795	**1.000**	0.783
	Guangzhou	0.699	0.639	0.672	0.763	0.735	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.851
	Jakarta	0.503	0.895	0.918	0.908	0.864	**1.000**	0.976	**1.000**	**1.000**	**1.000**	0.906
	Manila	0.679	0.682	0.810	0.787	0.945	**1.000**	0.682	0.800	0.934	0.959	0.828
	Perth	0.614	0.914	0.558	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.963	**1.000**	0.905
	Sydney	0.978	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.998
	Taipei	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.834	**1.000**	**1.000**	0.983
Moderate performers (deterioration)[c]	Bangkok	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.919	0.902	0.878	0.919	0.962
	Christchurch	0.956	**1.000**	0.952	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.753	0.966
	Kansai	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.806	0.844	0.615	0.701	0.677	0.864
	Narita	**1.000**	**1.000**	**1.000**	0.983	0.958	**1.000**	**1.000**	**1.000**	0.907	0.887	0.973
Worst performers[d]	Incheon	0.821	0.817	0.844	0.765	0.950	0.859	0.799	0.789	0.806	0.788	0.824
	Kuala Lumpur	0.660	0.734	0.677	0.591	0.502	0.677	0.707	0.784	0.779	0.779	0.689
	Singapore	0.855	0.859	0.815	0.804	0.764	0.823	0.788	0.866	0897	0.901	0.837
	Efficient airports (%)	52	62	57	62	62	76	62	62	52	62	60.9

Remarks: Bold typefaces indicate the efficient airports.

a Indicates an airport achieved consistently full efficiency levels.

b Indicates an airport showed an improvement in efficiency levels.

c Indicates an airport showed a deterioration in efficiency levels.

d Indicates an airport never achieved full efficiency levels.

Furthermore, Narita became inefficient between 2012 and 2013 as annual air passenger numbers and annual aircraft movements increased by less than 3%, and also annual air cargo volumes experienced negative growth in 2005 and 2006. Narita's inefficiency in 2010 and 2011 resulted from negative growth of aircraft movements. In addition, Christchurch was efficient between 2005 and 2010 due to its role as one of two key international airports in New Zealand serving a significant amount of domestic and international traffic to and from South Island (New Zealand). The Christchurch Earthquake in 2011 caused significant drops in airport traffic volumes and adversely affected airport operations.

It should be noted that the DEA efficiency indexes of Asia-Pacific airports reported above were generally consistent with those reported in the extant literature. In particular, Hong Kong was claimed to be the most efficient airport during the study periods, and Incheon was also claimed to have the worst efficiency (Ha et al., 2010; Lam et al., 2009). Kuala Lumpur and Singapore were also identified as inefficient airports (Yang, 2010b), which was largely due to on-going overcapacity and the poor scale efficiency. Overall, the dissimilarity of DEA efficiency indexes (or efficiency ranking) of Asia-Pacific airports can be also seen in prior literature as the DEA efficiency indexes computed by the DEA methodology are highly dependent upon the sample size of airports and number of airport input and output variables used during the efficiency evaluation.

3.5.2. Average DEA efficiency index

The average performance of Asia-Pacific airports during one particular year compared to other years is very important, as this would indicate whether any year was the best performing year with respect to overall airport efficiency. This is in line with the study of Sengupta (1995), which stated that industrial competitiveness or efficiency can be evaluated through the analysis of average efficiencies.

Fig. 3.1 shows average DEA efficiency indexes and the number of efficient airports for the sampled Asia-Pacific airports. Over the study periods, variations in the average DEA efficiency indexes were found among Asia-Pacific airports. In general, they showed an upward trend from 2002 to 2007, except for 2004, followed by falls in 2008 and 2009, and lastly rebounds in 2010 and 2011. The lowest and highest average DEA efficiency indexes were in 2002 (0.891) and 2007 (0.944). This situation indicated that the majority of Asia-Pacific airports did not achieve their maximum output levels throughout the study periods. It also corresponds to the fact that the smallest and largest number of efficient airports appeared during 2002 and 2007, respectively. Furthermore, the smallest average DEA efficiency index (in 2002) can be interpreted as, on average, Asia-Pacific airports were only 89.1% efficient in that year, or, on average, the airports could almost increase by an additional 10.9% of outputs to attain their maximum outputs using the same amount of inputs.

Fewer efficient airports were found during 2009, 2011, and 2017, which could largely be attributable to the impact of the September 11 terrorist attacks in 2001, and high aviation fuel prices. These unfavourable incidents for the global aviation industry may have led to the relatively poor performance of Asia-Pacific airports, handling fewer air passenger traffic and air cargo volumes during these periods. That said, air cargo traffic was not as seriously affected as air passenger traffic during the SARS outbreak. The average airport efficiency seemed to remain stable for the periods of 2012-2013 and 2017-2018. It could be said that Asia-Pacific airports enjoyed a more favorable operating environment in these four years. More importantly, the best performing year was 2014, when the airport industry in the Asia-Pacific region seemed to benefit from a more favorable economic atmosphere for their operations. The declines in average airport efficiency that appeared in 2015 and 2016 might largely be due to aviation fuel price surges alongside the global economic downturn. These unfavorable economic factors had negative impacts for the worldwide air transport industry and, as a consequence, led to the slump in air passenger travelling and air cargo volumes across the Asia-Pacific region.

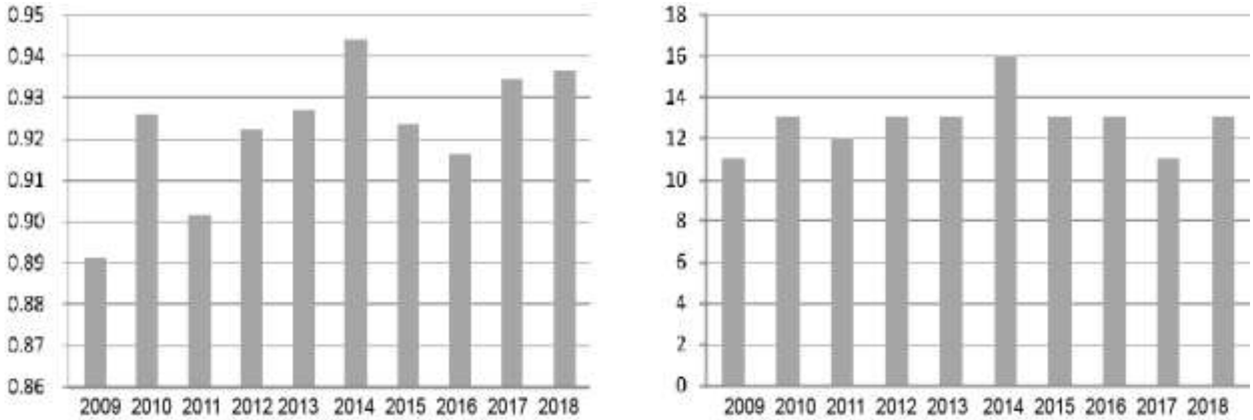

Fig. 3.1. Average DEA efficiency index and number of efficient airports (2009-2018).

Table 3.3

Second-stage estimation results.

Explanatory variables	Truncated regression with Bootstrapping		Random effect Tobit Model	
	Coefficient	t-Value	Coefficient	t-Value
Constant	0.868***	3.08	0.276	0.84
Trend	0.005	1.06	0.001	0.50
ln GDP per capita	0.009	0.45	0.043*	1.84
Percentage of international passengers	0.001**	2.17	0.001**	2.13
Airport hub status	0.076	1.49	0.059	1.02
Airport management	0.003	0.09	0.038	0.96
Airport operating hours	0.002	0.31	0.008	1.08

Airport hinterland population	0.126***	2.75	0.004	0.08
Alliance membership of dominant airline	0.080*	1.85	0.078**	2.32
Log-likelihood	188.710	-	214.018	-
Observations	210	-	210	-

Remarks: *, **, and *** indicate that the explanatory variable is significant at the 0.10, 0.05, and 0.01 significance level, respectively. The truncated regression analysis with bootstrapping (Simar and Wilson, 2007) results above was derived from 5000 bootstrapped iterations.

3.5.3. Determinants of efficiency

To evaluate the determinants of efficiency of Asia-Pacific air-ports, we adopted the approach of Simar and Wilson (2007). After obtaining the DEA efficiency indexes in the first-stage, we calculated the following (truncated) regression equation through the bootstrapped procedure in the second stage (with DEA efficiency indexes bounded at both ends of the 0e1 distribution). For further details, see Simar and Wilson, 2007).

$$\begin{aligned}\theta_{i,t} = \beta_0 + \beta_1 \text{Trend}_{i,t} + \beta_2 \text{GDP}_{i,t} + \beta_3 \text{PIP}_{i,t} + \beta_4 \text{Hub}_{i,t} + \beta_5 \text{Man}_{i,t} + \\ + \beta_6 \text{OH}_{i,t} + \beta_7 \text{Pop}_{i,t} + \beta_8 \text{Alliance}_{i,t} + \varepsilon_{i,t}\end{aligned} \quad (3.5)$$

where θ represents the estimated DEA efficiency score in the first-stage. ‘Trend’ is a yearly trend. ‘GDP’ represents the logarithm of GDP per capita of the country or city in which an airport is located (in logarithm). ‘PIP’ represents the percentage of international passengers handled by an airport. The dummy value of airport hub status denoted by ‘Hub’ is 1 if an airport is an international hub airport, 0 otherwise. The dummy value of airport management denoted by ‘Man’ is 1 if an airport is government-controlled or owned, 0 otherwise. ‘OH’ represents airport’s daily operating hours. ‘Pop’ represents the dummy variable which takes 1 if an airport's hinterland population is more than 4 million people, 0 otherwise. ‘Alliance’ represents alliance membership of dominant airline, and it is a dummy variable which takes the value 1 if the dominant airline of an airport becomes a member of a major global airline strategic alliance, 0 otherwise.

First, Im et al.'s (2003) panel unit root test was employed to check the problem of unit roots of all relevant variables. The second-stage estimation results showed the factors for explaining airport efficiency were reported in Table 3.1. Four explanatory variables were found to be significant factors for explaining variations in airport efficiency: percentage of international passengers; airport's hinterland population; alliance membership of dominant airline; and the logarithm of GDP per capita.

For ‘percentage of international passengers’ the coefficient was negative; for every percentage increase in international passengers handled by an airport, its efficiency reduced by 0.001 units. Importantly, this finding appears to be consistent with Pathomsiri et al. (2006), who claimed that the handling of international passenger traffic has a negative impact on an airport's efficiency as larger airport infra-structure and facilities (e.g. check-in counters and baggage handling areas) need to be built to serve international travelers comparing with domestic passengers.

We expected the sign of the coefficient estimation for the variable of ‘airport hinterland population’ to be positive, as a larger hinterland population may generate more airport demand, thus leading to higher airport efficiency. Surprisingly, this variable had a negative impact on airport efficiency.

This may suggest that an airport that serves a larger hinterland population is less efficient than an airport that serves a smaller hinterland population; it also suggests that larger airport infrastructure or capacity need to be constructed to accommodate a larger hinterland population and the forecasted growth of air traffic demand across the Asia-Pacific region.

However, air transport demand and airport operations were inevitably affected by unwanted adverse incidents or difficult operating conditions that led to lower airport efficiency (Grais et al., 2003; Kozak et al., 2007; Siu and Wong, 2004). Also, it should be acknowledged that it is extremely difficult to define the exact size of an airport's hinterland size due to improvements in aircraft technology that allow longer distance to be flown, the formation of strategic alliances between airlines, the establishment of hub-and-spoke networks by many airlines, and airport overlap or congestion in multi-airport region (MAR) in which an airport competes air traffic volumes with its neighbouring airports.12 (e.g. Graham, 1999; Graham and Guyer, 2000; Williams, 2006). The coefficient suggests that if an airport serves a larger hinterland population, its efficiency would drop by 0.126 units.

‘Alliance membership of dominant airline’ variable was also reported as significant in both estimations, and suggests that if an airport's dominant airline enters a global airline strategic alliance, this might positively influence its home-based airport's efficiency; when the dominant airline(s) of an airport enters a global airline strategic alliance, the airport's efficiency will increase by 0.080 units as allied airlines could share airport facilities to handle more connecting traffic.

More importantly, this finding provides evidence to support the argument of Gillen and Lall (1997), who claimed that common use of airport facilities can improve efficiency by allocating passenger terminal facilities for airlines of a particular alliance so they have exclusive use of the passenger terminals. This gives airlines an incentive to use the designated passenger terminals more efficiently.

Also, the current situation shows that an increasing number of large or legacy airlines have joined or intend to enter three major global airline strategic alliances (i.e. oneworld, Star Alliance, and SkyTeam) or formed their own partnerships (e.g. Qantas Airways and Emirates Airline). Importantly, allied activities between partner airlines are seen to affect airport operations in different ways such as a specific passenger terminal (e.g. Narita's Terminal One) being designated for a group of airlines associated with a particular alliance (in Narita's case, Star Alliance) (Cento, 2009).

As expected, “ln GDP per capita” has a positive and significant impact on airport efficiency when we used the Random Effect Tobit regression. This implies that there is a positive relationship between GDP per capita of a country or city with an airport’s traffic demand (Abed et al., 2001; Tsui et al., 2014a), and an airport's efficiency would be improved.

The remaining variables were not statistically significant. For example, ‘airport hub status’ has no significant impact on the efficiency of an airport but its coefficient may imply that if an airport that serves as an international hub airport could be more efficient than those serve as regional airports or non-hub airports in the Asia-Pacific region.

Prior studies (e.g. Fung et al., 2008; Gillen and Lall, 1997; Lin and Hong, 2006; Perelman and Serebrisky, 2010; Tsui et al., 2014b) also claimed that international hub airports possess size and location advantages for transporting more airport traffic and, as a consequence, improve airport efficiency.

Also, the insignificant variable of ‘airport management’ might imply that government-controlled/owned airports might perform better than privately-controlled/owned airports among the sampled Asia-Pacific airports. It is worthwhile to note that this finding is not consistent with the literature relating to the effect of airport management/ownership upon airport efficiency (e.g. Barros and Dieke, 2007; Muller et al., 2009; Oum et al., 2006, 2008).

As many key Asian international hub airports (e.g. Beijing, Hong Kong, and Singapore) are still under government ownership and control, since the governments consider an airport to be the strategic asset and/or an engine to contribute economic development of the country and city (Doganis, 1992). Indeed, these airports now tend to operate on a more commercial basis, rather than being guided by non-economic political objectives while facing the growth in air transport demand and other emerging competitors in the region (Hooper, 2002).

Moreover, many Asia-Pacific airports have been fully or partially privatised as the benefits of airport efficiency improvement and finance support for future development (Oum et al., 2006).

In addition, the insignificant positive coefficient of 'airport operating hours' might imply that longer operating hours of an airport might positively influence its operations and increase efficiency. This finding is in line with the perspective argued by Humphreys and Francis (2000), and demonstrates that the duration of airport operating hours is a significant factor that positively affects airport operations and efficiency. However, this presumably cannot apply to Adelaide, Narita, and Sydney due to their curfew policies.

CONCLUSIONS

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The main purpose of our research was to investigate the operational efficiency of 21 major airports in the Asia-Pacific region, and identify the key factors to explain variations in airport efficiency. The empirical results suggested that six airports (i.e. Adelaide, Beijing, Brisbane, Hong Kong, Melbourne, and Shenzhen) are the 'efficient' airports which operated at the efficiency frontier during the period of this study. In addition, the average DEA efficiency indexes of Asia-Pacific airports suggested a varying trend throughout the study periods, and that most airports operated below their optimal output levels.

Four significant factors were found to account for the identified variations in airport efficiency among Asia-Pacific airports: (i) more international passengers handled by an airport that may reduce its efficiency level; (ii) when an airport caters to a larger hinterland population, it will become less efficient than an airport that serves a smaller hinterland population; (iii) if the dominant airline(s) of an airport enters a global airline strategic alliance, this may improve its home-based airport's efficiency; and (iv) having an increase in GDP per capita of a country or city might increase an airport's efficiency.

Airport management should also seriously pay attention to other controllable factors under managerial control (e.g. outsourcing activities and concession revenues) affecting airport efficiency. Nowadays, many airports worldwide have outsourced some operational functions and services to the third parties for saving operating costs, and also made efforts to generate non-aeronautical revenues (e.g. concession revenues). Unfortunately, such important airport efficiency measurements could not be included in this study because of lack of available financial data related to most of the sampled Asia-Pacific airports. As an extension of this study, it may be meaningful to include such data (when available) that allows this study to take account of the effects of airports' strategy with regard to outsourcing activities and concession revenues on Asia-Pacific airports' efficiency.

Furthermore, it is important to consider the actual and likely impact of the global airline strategic alliance or other forms of airline partnerships on airport efficiency. For example, the recent partnership between Qantas Airways and

Emirates Airline, aims to deliver the best in their respective flight networks and frequencies, lounges, loyalty programs, and customer experiences. Under this agreement, Qantas Airways will move its hub at Singapore Changi Airport to Dubai International Airport, which may reduce the amount of transit traffic to Europe via Singapore Changi Airport.

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