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IMPACT OF STRATEGIC DEMAND MANAGEMENT ON RUNWAY CAPACITY AT OLIVER REGINALD TAMBO INTERNATIONAL AIRPORT

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

Johannesburg, 2011

DECLARATION

I declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Science to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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ABSTRACT

The overall capacity of an airport is determined by the airfield, particularly the runway system. The demand for runway access at major airports is expected to eventually exceed the capacity of the existing runway systems. The lack of adequate runway capacity at an airport results in congestion and expensive delays. Airport authorities, in response, plan to make significant investments on new runways where possible. There is consensus amongst researchers that the lack of adequate runway capacity cannot only be addressed by building additional capacity. Innovative ways which aim for better utilisation of existing facilities should be considered. Therefore, the research question is posed: Can demand management be successfully applied to defer capital expenditure. A detailed literature review of international best practices and analysis of their suitability is undertaken using ORTIA as a case study. The literature review identified: collaborative decision making; air and rail integration; demand management and technological improvements as likely interventions. The most significant finding of this research report is that the capacity of a runway system can be improved by implementing these measures.

Keywords: ORT International Airport; runway congestion; demand management.

ACKNOWLEDGEMENT

My thanks go to my supervisor, Doctor Anne Fitchett, for her valuable guidance, assistance and advice during all stages of the research and to my family for all their support, patience and understanding.

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LIST OF ACRONYMS

Where possible, acronyms are written in full at the beginning of each section in which they are found.

ACSA	Airports Company South Africa
ACI	Airports Council International
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
AMSL	Above Mean Sea Level
APH	Analytical Hierarchy Process
APT	Air Passenger Transport
ATFM	Air Traffic Flow Management
ATNS	Air Traffic Navigation Services
ATM	Air Traffic Movement
ATZ	Air Traffic Control Zone
BAA	British Airports Authority
BOS	Boston Logan International Airport
CAA	Civil Aviation Authority
CDM	Collaboration Decision Making
CPT	Cape Town International Airport
CTR	Control Zone
DME	Distance Measuring Equipment
EU	European Union
EWR	Newark Airport
FAA	Federal Aviation Authority
FAGC	Grand Central Airport
FAGM	Rand Airport
FASK	Swartkop Airport

FALA	Lanseria Airport
FAWK	AFB Waterkloof Airport
FCFS	First Come First Served
FL	Flight Level
GA	General Aviation
GHP	Ground Holding Programme
HDR	High Density Rule
HSR	High Speed Rail
IATA	International Air Transport Association
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
JFK	John F. Kennedy International Airport
LCY	London City
LGA	LaGuardia Airport
LHR	London Heathrow
LOS	Level of Service
MTOW	Maximum Takeoff Weight
NEXTOR	National Centre of Excellence for Aviation Operations Research
ORTIA	Oliver Reginald Tambo International Airport
OTP	On-Time Performance
PACE	Programme for Air Field Capacity Efficiency
PFC	Passenger Facility Charge
PANYNJ	Port Authority of New York and New Jersey
PATMS	Passenger Air Traffic Movement
PHCAP	Practical Hourly Capacity
SACAA	South African Civil Aviation Authority

SCC	Schedule Coordination Conference
SIDs	Standard Instrument Departure Routes
SPA	Special Rules Area
TEB	Teterboro Airport
TMA	Terminal Manoeuvring Area
USA	United States of America
VFR	Visual Flight Rules
VOR	VHF Omnidirectional Radio Range

1 INTRODUCTION

1.1 Background

Runway capacity is a fundamental topic to modern airport planning and design because it is the capacity of the airfield and specifically of the runway system that determines the ultimate capacity of an airport. The runway system is in most cases the primary “bottle-neck” of the air traffic management system because it is at the runway and its immediate vicinity that air traffic transitions from three-dimensional flows in air-space to the “single file” regime that must be followed for runway operations. It is a difficult and time consuming task to increase substantially the capacity of the runway system of an airport. New runways, along with associated protection zones, noise buffer space, require acquisition of a large amount of additional land area with significant capital investment (De Neufville and Odoni 2003:396).

New runways have significant environmental and other external impacts that require long and complicated review-and-approval processes with uncertain outcomes.

In contrast, the capacity of the landside facilities (passenger and cargo terminals, road access etc.) and of other airfield facilities (taxiways, apron stands) can in most instances be increased, in one way or another, to equal or exceed the capacity of the runway system. Airport capacity and delay has received a significant amount of attention, from airport professionals and the public at large, as airport traffic delays have increased. Some airport stakeholders believe that the most significant threat to the long-term sustainability of the global air transportation system is the inability of runway

capacity to keep up with growing air traffic demand at many of the world's most important airports (De Neufville and Odoni 2003:397).

The solutions advocated by airport operators and airlines are to build additional facilities at congested airports or to find ways to make more efficient use of existing facilities. The efficient use of existing facilities is considered as a better option because it requires less capital investment and avoids many of the challenges related to increasing the size of the airport and infringing on the surrounding communities at airports where available airport land has been developed. A third course advocated is not to increase capacity but to manage demand by channelling it to off-peak times or to alternative sites. The rationale underlying all these approaches is that capacity and demand must somehow be brought into equilibrium in order to prevent or reduce delay (Wells 2000:239-240).

From a South African context, since 1994, Airports Company South Africa (ACSA) has invested in excess of 30 billion Rand at ORTIA on improving existing airport infrastructure and on additional capacity. Since 2010, the focus has shifted from adding new facilities to utilising existing facilities in a more efficient manner. Despite these efforts, traffic projections indicate that by 2017, ACSA will have to invest significant financial resources on additional capacity. The investment proposal includes a third runway and an extension of the existing secondary runway. To enable these runway developments at ORTIA, ACSA will have to acquire a significant amount of privately owned land currently used for residential and business purposes.

South Africa in general and ACSA in particular have not explored what is referred to above in this document as the "third course"; to manage demand by channelling it to off-peak times or to alternative sites. Another unexplored

alternative, which is introduced in the literature review, is air/rail integration. These approaches to capacity management are the focus of this research report.

1.2 Objectives

The objective of this research report is to conduct a case study of the impact of demand management approaches advocated internationally as an alternative to the construction of additional runway capacity at ORTIA.

1.2.1 Research question

From section 1.1, the solutions adopted for resolving airport congestion are to build additional facilities, or find ways to make more efficient use of existing facilities. These measures are aimed towards managing the supply side. Another solution aimed towards managing the demand side is not to increase capacity but to manage demand by channelling it off-peak or to alternative sites and/or other transport modes. Therefore the following research question is posed:

Can demand management be applied to defer capital expenditure for new runways at airports such as ORTIA?

1.3 Methodology

The following steps are undertaken in this study:

- Defining the objectives and a research question to focus the research and to enable the author to work towards a specific goal;
- Undertaking a literature review of international approaches to addressing the aircraft delay and runway congestion issues as well as external issues that could affect the findings of this research report;

- Undertaking a case study of the various approaches advocated in literature to addressing aircraft delay and runway congestion.
- Analysing impact and feasibility of the various approach from the ORTIA Context.

1.4 Deliverables

A research report containing the following:

- A literature review detailing the extent of aircraft delays and runway congestion and the alternative approaches to addressing the problem;
- A case study analysing the impact of alternative approaches to addressing aircraft delays and runway congestion from a South African context;
- Recommendations regarding suitability of the alternative approaches to the South African context.

1.5 Scope

The literature review focuses mainly on published work with unpublished work consulted only when no published work is available on the subject. The research focuses mainly on congestion resulting from lack of adequate runway capacity.

1.6 Structure of the report

Chapter 2 of the report describes the existing academic literature on alternative methods of addressing airport congestion and the associated delays. Chapter 3 gives an overview of the global trends in aviation traffic development and highlights the expected traffic growth at ORTIA. Chapter 4 provides an evaluation of the suitability of the various demand management

approach to different airport settings. Chapter 5 describes impediments to the implementation of congestion pricing. Chapter 6 describes existing facilities at ORTIA and outline the airport's runway development strategy. Chapter 7 discusses the ORTIA case study and Chapter 8 details conclusions and makes recommendations on further research work.

2 LITERATURE REVIEW

2.1 Background

This chapter describes the impact of the approaches discussed in the literature on runway congestion in general, with specific focus on those that could inform a study of ORTIA and similar airports. According to Poldy (1982:3), capacity gains through the construction of new airports or the expansion of existing facilities are considerably expensive; have long lead time; are subject to social and political objections. Furthermore, these negatives are more pronounced in respect of runway developments than any other airport sub-system. This research report, therefore, focuses on non-infrastructure interventions aimed at enhancing the capacity of the runway system.

The demand for access to the runway system at ORTIA is expected to continue to grow from the current peak demand of 51 peak hour movements to approximately 80 peak hour movements by year 2022. Demand is expected to also start “filling-up” the low demand hours of the day between 07:00 in the morning till 19:00 in the evening. Similar to other international airports, ORTIA has two distinct morning and evening peaks. These peaks are driven by: international arrivals; domestic and regional departure in the morning and international departure; domestic and regional arrivals in the evening. The average demand in between the peak periods is expected to grow from an average 40 movements to approximately 65 movements by year 2022 (ACI 2010).

To accommodate the expected demand, ACSA plans to invest in excess of R3 billion on a new runway and associated taxiways and navigational aids.

The new runway will be accompanied by a 1000 meter northward extension of the existing secondary runway. A fourth runway is planned beyond year 2022. To accommodate these developments, ACSA will need to acquire extensive privately owned land within the vicinity of ORTIA (ACSA 2010).

Although in the long term, the need to construct new runways cannot be completely removed, the literature indicates four basic alternative approaches to relieving runway congestion in the short to medium term: collaborative decision making; technological improvements; air and rail integration; and demand management. The effectiveness of each approach in addressing runway congestion and its implementation challenges are evaluated. The scope of this research report is confined to the runway subsystem of the airport.

The role of an airport is to provide an interface between the air and surface phases of an overall transportation network. An airport provides a variety of facilities to meet the demands associated with the movement of aircraft, vehicles, passengers and freight. The concentration of airport facilities in a relatively small area, and the focussing of the air and surface movements on that area, have made airport capacity one of the key issues to be addressed if the growing demand for air transportation is to be met. Air transportation has experienced sustained growth over the last two decades. This growth was fuelled by among other things the growth of the global economy (Poldy 1982).

The capacity on an airport is determined by a number of systems: access roads, terminal building, aircraft stands, runways and taxiways. In most airports, the capacity of all these facilities except for the runways can be relatively easily increased. This research is therefore concerned with one

aspect of airport capacity, the ability of the runway system to meet the demand for aircraft movements.

As the demand approaches the capacity of the runways, congestion increases, and costly delays are experienced by aircraft on the ground and in the air.

2.1.1 Objectives of the Literature Review

In an attempt to gain a broader understanding into the subject of airport congestion in general, and demand management in particular, a study of international methods and best practices covering this subject needs to be undertaken. The literature investigated describes the following:

- Runway capacity problems associated with aircraft delay;
- Factors affecting runway capacity and aircraft delay;
- Demand and demand management;
- Problems associated with demand management application;
- Alternative approaches to providing airport capacity.

Furthermore, a review of international and local trends and events which could affect the implementation of demand management approach, identified through this research, is necessary to ensure that the outputs are applicable for use in coming years.

2.1.2 Type of Literature Reviewed

The literature review focuses on published work, with unpublished work referred to only where no published work is available on the subject. The

following bodies of literature were reviewed to meet the objectives described in section 2.1.1:

- Technical handbooks, journals and design manuals detailing international methods and standards used to determine aircraft delay, runway capacity and runway demand at major airports;
- Journals detailing alternative approaches to providing airport capacity;
- Reports from Air Transport and Navigation Services (ATNS), ACSA and International Air Transport Association (IATA) to determine current operating airside and airspace operating procedures.

The findings of each of these bodies of literature are discussed below. Section 2.2 discusses problems associated with aircraft delays and the lack of adequate airport capacity. Section 2.3 discusses the characteristics of aircraft delays. Sections 2.4 and 2.5 discuss the concept of runway capacity and the factors that affect runway capacity respectively. Section 2.6 discusses alternative approaches to address the lack of runway capacity. Section 2.7 discusses in detail the concept of demand management.

2.1.3 Sources of Literature Reviewed

From section 2.1.1 the objective of this literature review is to gain a broader understanding into the subject of airport congestion in general, and demand management, in particular. This is necessary to guide and ensure that the method proposed in this report for Oliver Reginald Tambo International Airport (ORTIA) is aligned with current thinking. No locally produced literature exists regarding the aforementioned topic: international literature has therefore been consulted. The following technical references have been reviewed:

- Airport Systems: Planning, Design and Management (De Neufville and Odoni 2003);
- Planning and Design of Airports (Horonjeff and Mckelvey 1994);
- Airport Engineering (Ashford and Wright 1992);
- Airport Planning & Management (Wells 2000);
- Airport Runway Capacity and Delay: Some Models for Planners and Managers (Poldy 1982).
- Journals on alternative approaches to addressing airport congestion.

2.2 Aircraft Delays and Capacity Problem

Problems associated with aircraft delays and with the lack of adequate airport capacity are well documented in literature. Airport congestion is a growing concern with the potential of negatively affecting the entire global air traffic network. There is also general consensus that this problem cannot and should not only be addressed by simply building additional capacity or completely new airport. Innovative ways in addition to building new capacity, which aim for better utilisation of the existing facility should be considered.

The consequences of the lack of adequate airside capacity at an airport are delays to landings and takeoffs and their related economic and other costs. When delays become large, other negative results such as missed flight connections, flight cancellations and flight diversions to other airports can also become increasingly common (Poldy 1982).

De Neufville and Odoni (2003:436) explain that airport and air traffic congestion is a growing problem on an international scale and is widely

considered one of the principal constraints to the future growth of the global air transportation industry.

2.3 Characteristics of Aircraft Delay

Wells (2000:240) defines delay as the difference between the time an operation actually takes place and the time that it would have taken place under uncongested conditions without interference from other aircraft. Flights cannot be started or completed on schedule because of the line of aircraft awaiting their turn for takeoff, landing or use of taxiways and gates at terminal buildings. He suggest that the cause of delay is a lack of capacity, meaning that the airport does not have facilities such as runways, taxiways, or gates in sufficient number to accommodate all those who want to use the airport at peak periods of demand.

Figure 2-1 indicates diagrammatically the weekday demand profile at Boston Logan International Airport (BOS) and compares it with three different levels of maximum throughput capacity, labelled “high”, “medium” and “low”. (See 2.4 for the definitions of runway capacity.) According to De Neufville and Odoni (2003:438), the demand profile has two peaks, typical of many busy airports with large volumes of business traffic. The number of movements scheduled in an hour is not always the same as the number of movements that will actually be requested during that hour.

De Neufville and Odoni (2003) attributes this to mechanical or logistical problems with aircraft, flight cancellations, late boarding passengers, late arriving crews and delays at other airports. The number of movements actually requested at a given airport during any particular period of time will fluctuate around the number scheduled. They observe the following about the delays associated with each of the three levels of capacity: queues of landing

and departing aircraft will form and delays will occur during those periods of a day when the demand rate exceeds the capacity for any significant time interval. This is because airport users will seek to use the runway system at a rate greater than the system's capacity.

They observe that when the capacity is "low", delays keep building up throughout the day. Aircraft scheduled to arrive or depart during the afternoon and evening hours may be subject to long delays. Due to the size of the expected delays, airlines would cancel a number of flights to this airport.

If there is an interval of time *T* during which the demand rate continually exceeds the service rate, then both the expected length of the aircraft queue and the expected waiting time per aircraft during that interval will increase in direct proportion to *T* and to the difference between the demand rate and capacity during *T* (De Neufville and Odoni 2003:439). This may include days during which the demand rate is less than the capacity for the entire day, as is the case when the capacity is at a "high" level in Figure 2-1. Such delays are due primarily to the variability of the time intervals between successive requests for use of the runways, as well as to the variability of the time it takes to process ("serve") each landing and takeoff.

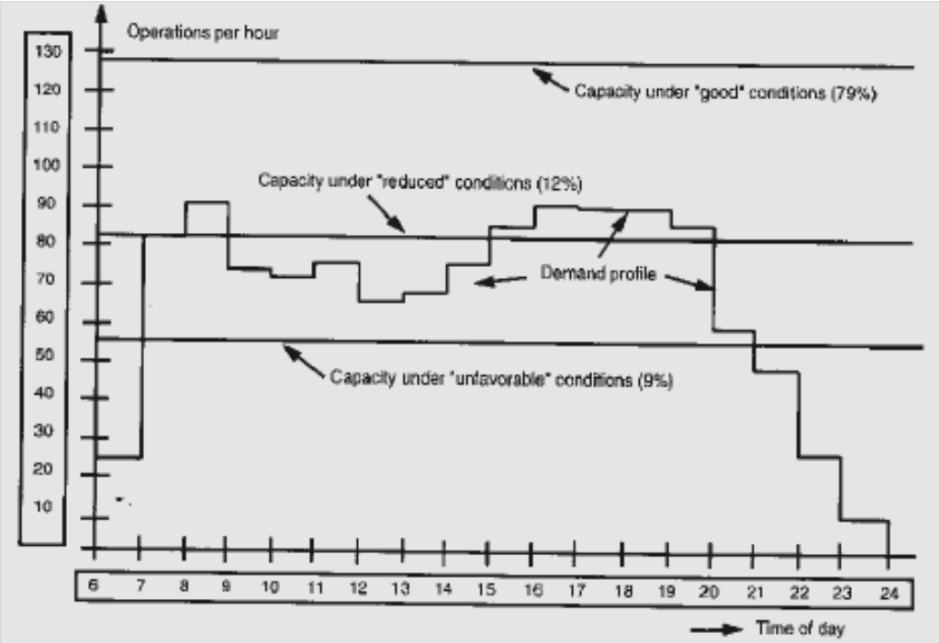


Figure 2-1: Weekday demand profile at Boston/Logan airport. De Neufville and Odoni (2003:438)

They identify the sources of this variability as:

- The time instants at which demands (arrivals and, especially departures) are scheduled to take place are not evenly spaced, but are "bunched together" around certain times (e.g. "on-the-hour" or "on-the-half-hour" departure peaks);
- The time instants at which demand actually occur on a day-to-day basis are "randomized" as a result of deviations from schedule due to the reasons mentioned above (mechanical problems, delays at other airports); and
- The amount of time it takes to serve departures and arrivals on the runway system is not constant, but varies with many factors such as

type of aircraft, separation requirements from preceding aircraft, runway exit used). These factors are discussed in detail in section 2.5.

The net effect is the presence of time intervals during which “clusters” of several closely spaced demands and/or of longer-than-usual service times occur. Queues of aircraft will then form on the ground and/or in the air. When the demand rate is smaller than the capacity but close to it, the queues may take a long time to dissipate. The new clusters of demand or of long service times may come along before the previously formed queue has dissipated and the waiting line(s) may get longer for a while. The resulting delays are referred to as stochastic, to distinguish them from overload delays. Long queues may form even if the demand rate is smaller than capacity in cases where there is a significant variation in the times between successive demands on the runway systems and/or in the service times at the runway system and the demand rate is close to the runway system’s capacity (De Neufville and Odoni 2003:440).

Wells (2000) agrees with De Neufville and Odoni (2003) that aircraft arrive and depart at a non-uniform rate, meaning that delay can occur even when demand is low in relation to capacity. The probability of simultaneous need for service increases rapidly with traffic density, so that the average delay per aircraft increases exponentially as demand approaches throughput capacity. Figure 2-2 indicates the relationship between practical and throughput capacity (practical and throughput capacity are defined in section 2.4). As demand approaches the limit of throughput capacity, delays increase exponentially and in theory become infinite when demand equals or exceeds throughput capacity (Wells 2000:244).

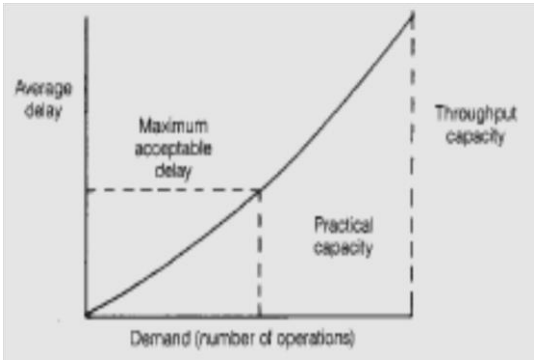


Figure 2-2: Relationship between throughput and practical capacity. Wells (2000:244)

Figure 2-3 indicates a typical distribution of delays encountered by aircraft at a particular level of demand. Most delays are of short duration, however, even though the average delay is relatively low (five minutes), there are several aircraft encountering relatively long delays of fifteen minutes or more, thus, while practical capacity is normally specified as the level of operations that, on average, will result in a given amount of delay, the average implies that some percentage of delays will be considerably longer (Wells 2000:244).

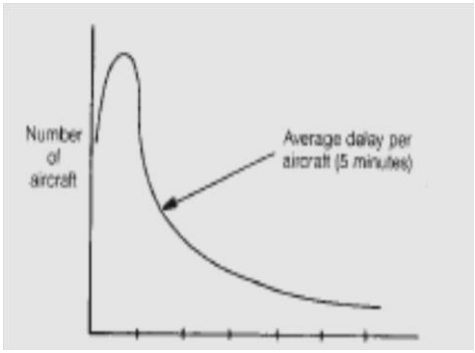


Figure 2-3: Typical probability distribution of aircraft delay. Wells (2000:245)

Wells (2000:245) considers the question of how much delay is acceptable, which he argues is a judgement involving the following factors: some delay is unavoidable because it occurs for reasons beyond anyone's control, such as wind direction, weather, aircraft performance characteristics, the randomness of demand for services; some delay, although avoidable, might be too expensive to eliminate in instances when the cost of remedial measures exceeds the potential benefit. Even with the most vigorous and successful effort, the random nature of delay means that there will always be some aircraft encountering delay greater than the "acceptable" length. Acceptable delay is in essence a policy decision about the tolerability of delay being longer than a specified amount, taking into account the technical feasibility and economic practicality of available remedies.

2.4 Runway Capacity

There are several measures of runway capacity all of them intended to provide an estimate of how many aircraft movements can be performed on the runway system of an airport during some specified unit of time. From a long-term perspective, runway capacity is a probabilistic quantity, a random variable, which can take on different values at different times, depending on the circumstances involved. The most fundamental measure of runway capacity, maximum throughput capacity or saturation capacity is defined as the expected number of movements that can be performed in one hour on a runway system without violating Air Traffic Management (ATM) rules, assuming continuous aircraft demand (De Neufville and Odoni 2003:370).

De Neufville and Odoni (2003) highlight the following points about this definition. First, in order to compute the maximum throughput capacity, one needs to know the specific conditions under which runway operations are

conducted. This means specifying the ATM separation requirements in force, the mix of aircraft, the mix of movements (arrival and departures), the allocation of movements among the runways (if the runway system consists of more than one runway), and several other factors described in section 2.5.

Secondly, the definition of maximum throughput capacity makes no reference to any level-of-service (LOS) requirements. It only considers the number of aircraft movements that can be processed on average per hour, if the runway system is utilized to its maximum potential in the presence of “continuous aircraft demand”.

The practical hourly capacity (PHCAP) is defined as the expected number of movements that can be performed in one hour on a runway system with an average delay per movement of four minutes.

This definition specifies a threshold value for acceptable LOS (“average delay of four minutes per movement”) and states that the runway system “reaches its capacity” when that threshold is exceeded.

The sustained capacity of a runway system is the number of movements per hour that can be reasonably sustained over a period of several hours. “Reasonably sustained” refers to the workload of the ATM system and of the traffic controllers. The rationale is that, to achieve maximum throughput capacity, the ATM system should work to its full potential all the time. However, operations at such a level of full efficiency and maximum performance cannot be sustained in practice for periods of more than one or two consecutive hours (De Neufville and Odoni 2003:371).

The declared capacity is defined as the number of aircraft movements per hour that an airport can accommodate at a reasonable LOS. Delay is used as

the principal indicator of LOS. Declared capacity is widely used especially in connection with “schedule coordination” and the allocation of “slots” at congested airports. Under this practice, each airport that experiences congestion “declares” a capacity, which is then used to set a limit on the number of movements per hour that can be scheduled at this airport (De Neufville and Odoni 2003:373). This method is adopted and utilised by ACSA, however, there is no agreement on the acceptable level of service among the various airport stakeholders.

According to them there is no generally accepted definition of declared capacity and no standard methodology for setting it. It is up to local or national airport and civil aviation organisations, in cooperation with other interested parties, to compute and set the declared capacity.

The approaches used for this purpose vary from country to country and even from airport to airport. This has long been a point of contention between ACSA and ATNS as ACSA is of the view that the declared capacity of ORTIA is on the conservative side.

This view is supported by literature on airports of similar traffic size, physical and environmental constraint, fleet mix and available infrastructure.

2.5 Factors Affecting Runway Capacity

De Neufville and Odoni (2003:376) provide an overview of these factors and of the way in which each affects runway capacity. These are:

- Number and geometric layout of the runways;
- Separation requirements between aircraft imposed by the ATM system;
- Visibility, cloud ceiling and precipitation;

- Wind direction and strength;
- Mix of aircraft using the airport;
- Mix of movements on each runway (arrivals only, departures only, or mixed) and sequencing of movements;
- Type and location of taxiway exits from the runway(s);
- State and performance of the ATM system;
- Noise-related and other environmental considerations and constraints.

Wells (2000:245) agrees that the capacity of an airfield is not constant over time; it varies during the day or the year as a result of physical and operational factors. According to him, when a figure is given for airfield capacity, it is an average based either on some assumed range of conditions or on actual operating experience.

He argues that it is the variability of capacity, rather than its average value, that is more detrimental to the overall operation of an airfield. Much of the strategy for successful management of an airfield involves devising ways to compensate for factors that, individually or in combination, act to lower capacity or to induce delay. De Neufville and Odoni (2003) give details of the ways in which each factor affects runway capacity as discussed below.

2.5.1 Number and geometric layout of the runways

The most important factor influencing a runway system's capacity is the number of runways at the airport and their geometric layout. From a practical point of view, a guaranteed method to achieve an increase in the capacity of an airport is by constructing a well-designed runway. However, in modern times, adding a new runway is a task that ranges from "very difficult" to "nearly impossible" at most of the world's busiest and most congested airports (De Neufville and Odoni 2003:377).

2.5.2 ATM Separation requirements

ATM systems specify a set of required minimum separations between aircraft flying under instrument flight rules (IFR). The purpose of these rules is to ensure safety. In turn, the separation requirements determine the maximum number of aircraft that can traverse each part of the airspace or can use a runway system per unit of time. In the United States, the required separation distances between aircraft operating under IFR at major airports are the least conservative anywhere in the world. This reflects the need to maximise airport capacity, as well as the proficiency and training of their air traffic controllers.

Several large European airports have also come to operate in recent years with separation requirements that are identical to those used at the busiest airports in the United States. Such conservative separation requirements recognize the need for more capacity at these airports and have been made possible by the improvements in ATM capabilities that have been developed there (De Neufville and Odoni 2003:377-378).

ATNS have indicated that they are in a process reviewing their operational procedures with a view of shortening the required separation distances. This is intended to improve the capacity of the existing runway system.

2.5.2.1 Separation requirements for aircraft operating to/from the same runway

The longitudinal separation requirements for aircraft landing on or departing from the same runway are important in determining runway capacity. Each type of aircraft is assigned to a number of classes according to the aircraft size and/or weight. The separation requirements are then specified in unit of distance or of time (De Neufville and Odoni 2003:278).

Each set of requirements gives the minimum separation that must be maintained at all times between two aircraft operating successively on the runway as shown in Figure 2-4. The requirements are specified for every possible pair of classes and every possible sequence of movements: “arrival followed by arrival”, A-A; “departure followed by departure”, D-D; “arrival followed by departure” A-D; and “departure followed by arrival”, D-A.
In the United States, the FAA assigns all aircraft to three classes, according to their maximum certified takeoff weight (MTOW): heavy (H), large (L) and small (S). Aircraft with:

- MTOW greater than 116 tons are in class H;
- MTOW between 19 tons and 116 tons are in L;
- MTOW less than 19 tons are in S;
- The Federal Aviation Authority (FAA) also identifies the Boeing 757, whose MTOW places it at the borderline between the L and H classes, as an aircraft class by itself.

Arrival followed by arrival (A-A)

A. Throughout final approach, successive aircraft must be separated by at least the distance (in nautical miles) indicated by the table below:

		Trailing aircraft		
		H	**L + B757**	**S**
Leading aircraft	**H**	4	5	5/6*
	B757	4	4	5
	L	2.5 (or 3)	2.5 (or 3)	3/4*
	S	2.5 (or 3)	2.5 (or 3)	2.5 (or 3)

*Separations indicated with an asterisk are distances required at the time when the leading aircraft is at the threshold of the runway.

B. The trailing aircraft cannot touch down on the runway before the leading aircraft is clear of the runway.

Arrival followed by departure (A-D)

Clearance for takeoff run of the trailing departure is granted after the preceding landing is clear of the runway.

Departure followed by departure (D-D)†

Clearances for takeoff run of successive aircraft must be separated by at least the amount of time (in seconds) indicated by the table below.

		Trailing aircraft		
		H	**L + B757**	**S**
Leading aircraft	**H**	90	120	120
	B757	90	90	120
	L	60	60	60
	S	45	45	45

†D-D separations shown here are simplified and approximate—see details in the text.

Departure followed by arrival (D-A)

The trailing arrival on final approach must be at least 2 nmi away from the runway at the time when the departing aircraft begins its takeoff run. The departing aircraft must also be clear of the runway before the trailing arrival can touch down on it.

Figure 2-4: Single runway IFR separation requirements in the United States in 2000. De Neufville and Odoni (2003:380)

2.5.2.2 Separation requirements for aircraft operating to/from parallel runways

The separation requirements for aircraft landing on or departing from a pair of parallel runways play a critical role at those major airports that operate with

more than one active runway. Most of these multi-runway airports rely on operations to and from parallel runways (De Neufville and Odoni 2003:384). As indicated in section 6.3, ORTIA has a two runway system.

The FAA summarizes the separation requirements for operations on parallel runways under Instrument Flight Rules (IFR) as described Table 2-1. The “arrival/arrival” column refers to the required separation between a pair of arriving aircraft, the first of which is landing on one of the parallel runways and the second on the other.

Table 2-1: IFR separation requirements between aircraft movements on parallel runways in the United States. De Neufville and Odoni (2003:384)

Separation between runway centrelines	Arrival/ arrival	Departures/ Departures	Arrival/ departure	Departures/ Arrival
Up to 762m	As in single runway	As in single runway	Arrival touches down	Departure is clear of runway
762 - 1310m	1.5 nmi	independent	independent	Independent
1310m or more	independent	independent	Independent	Independent

Similarly, “departure/arrival” refers to the situation in which the first aircraft in the pair will depart from one of the parallel runways and the second will land on the other. The “departure/departure” and arrival/departure” columns in Table 2-1 should be interpreted in a similar way.

2.5.3 Visibility, ceiling, and precipitation

Cloud ceiling and visibility are the two parameters that determine the weather category in which an airport operates at any given time (De Neufville and Odoni 2003:388). Figure 2-5 indicates the various operating procedures for varying cloud ceiling and visibility.

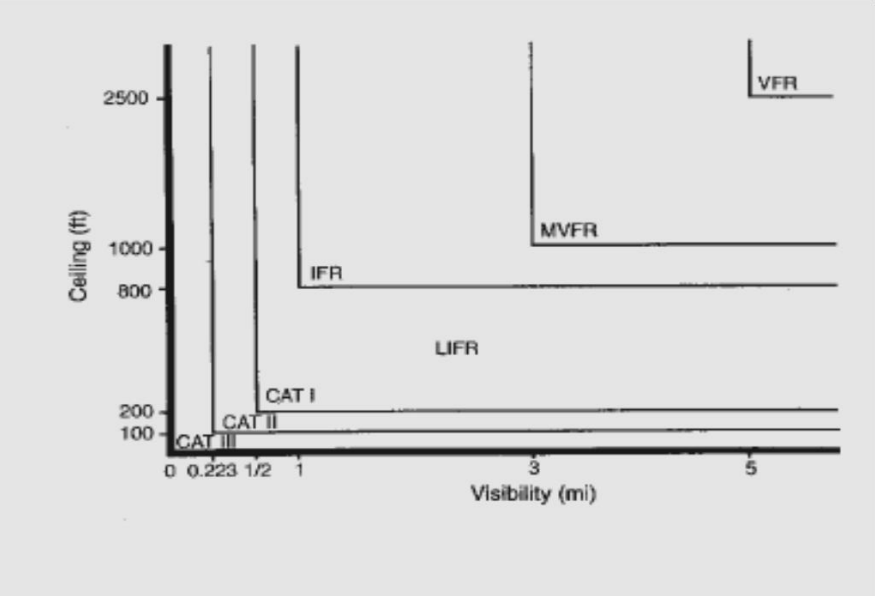


Figure 2-5: A typical classification of weather conditions at an airport in the United States. De Neufville and Odoni (2003:388)

2.5.4 Wind direction and strength

A runway can be used only when crosswinds are within prescribed limits and tail winds do not exceed nine to eleven km/h. This means that the orientation of runway operations and the combination of the active runways depend on

the direction and strength of the prevailing winds at any given time. At locations that experience strong winds from several different directions at different times, this can be the cause of considerable variability in the available capacity of the runway system (De Neufville and Odoni 2003:391).

2.5.5 Mix of aircraft

A homogeneous mix of aircraft or a mix consisting of one or two dominant classes of aircraft is preferable to a non-homogeneous mix from the point of view of runway capacity. A homogeneous mix also offers advantages for ATM purposes, as it simplifies the work of air traffic controllers, who have to make fewer adjustments for wake vortex separations of varying magnitudes, for different approach speeds, and for other aircraft characteristics. When the mix of aircraft is very non-homogeneous, air traffic controllers at multi-runway airports often attempt to “segregate traffic” by assigning different aircraft classes to different runways (De Neufville and Odoni 2003:393).

The traffic mix at ORTIA can be considered as non-homogeneous with a relatively high percentage of class L and S. These classes have a significant portion of “slow” turboprops. The capacity of two independent parallel runways, if operated well by the ATM system, can provide more than twice the capacity of a single runway. The two runways provide an opportunity to optimise the assignment of aircraft types to each runway, as well as the mix and sequencing of movements (landing and/or departures) on each runway.

2.5.6 Mix and sequencing of movements

The mix of movements (arrivals versus departures) at the airport as a whole, and on each runway separately affects the capacity of the runway. For most ATM systems the separation requirements are such that the capacity of a runway that is used only for departures is higher than the capacity of a

runway that is use only for arrivals, given the same mix of aircraft. At some airports in the United States more than 60 departures may be performed in one hour from a single runway when the traffic mix includes a relatively small percentage of wide body aircraft (class H).

In contrast, it is difficult to perform more than 45 arrivals per hour per runway with similar aircraft mix. At airports with more than one active runway, air traffic controllers often use separate runways for arrivals and for departures (De Neufville and Odoni 2003:394). ATNS primarily uses separate runways for arrivals and departures specifically during peak periods at ORTIA. The main departure runway is used for arrivals when there are no departures or the number of departures is low.

The use of runways for arrivals or departures may simplify ATM operations, but is not optimal as far as overall airport capacity is concerned. It may overload one runway and underutilize another at times when the number of arrivals differs significantly from the number of departures. This may also create a serious imbalance between the delays experienced by arrivals versus those experienced by departures.

A better way to operate an airport with two parallel runways, when feasible, is to assign some arrivals to a runway used primarily for departures, whenever arrivals “overflow” their primary runway, and do the reverse whenever there is an excess of departures in the mix. It may be even more efficient to mix arrivals and departures on two or more runways at airports where the ATM system is sufficiently advanced to sustain this mode of operation well (De Neufville and Odoni 2003:394).

At ORTIA, the main arrival runway is approximately 1000 meters shorter than the main departure runway. This (main arrival) runway is also located

approximately three kilometres from the passenger terminal building making it unattractive for departure operations. The sequencing of movements on a runway also influences runway capacity, especially whenever a runway is used for mixed operations (arrivals and departures). Arriving aircraft are sequenced in roughly First Come First Serve (FCFS) order for access to a runway, and so are departing aircraft. Air traffic controllers, however, have latitude regarding the sequencing of arrivals versus departures on the runway.

Controllers can maintain an approximate FCFS discipline and sequence arrivals versus departures roughly according to the time when they can first make use of the runway, the earlier the time, the higher the priority given. Arrivals are given priority over departures for reasons of safety, controller workload and aircraft operating cost. Air traffic controllers process a string of several consecutive landings until the queue of arriving aircraft is exhausted and will then process a string of several consecutive departures. They will also look for some “free departures” and will try to insert one or more departures between two arrivals without disturbing the arrival stream and, thus, without reducing the arrival processing rate (De Neufville and Odoni 2003:395).

There are also occasions when a long queue of departures may form on the ground because the runway is continually busy with arrivals. In such instances, ATC may decide to interrupt the arrival stream for a while, assigning temporary priority to takeoffs until the departure queue returns to a reasonable length. Alternating arrivals and departures on the runway can be a very effective strategy for maximising overall runway capacity, as measured by the total number of movements per unit of time. This sequencing strategy can be implemented by “stretching”, as necessary, the separation between a

pair of consecutive arriving aircraft, in order to create a gap that is just sufficiently long to allow insertion of a departure between two arrivals.

ATM separation requirements make it possible to achieve such insertions with only a modest amount of stretching of the required A-A separations. Thus, by "sacrificing" only a modest arrival capacity per unit of time, the number of departures served by the runway per hour becomes roughly equal to the number of arrivals. However, this type of separation-stretching procedure is more demanding from the ATM point of view and requires skilled air traffic controller teams (De Neufville and Odoni 2003:396).

2.5.7 Type and location of runway exits

The runway occupancy time of an arriving aircraft is defined as the time between the instant the aircraft touches down on the runway and the instant it is on a runway exit, with all parts of the aircraft clear of the runway. The location of runway exits plays a significant role in determining runway occupancy times. Correctly designed and located high speed exit taxiways are an effective way of reducing runway occupancy (De Neufville and Odoni 2003:396).

At ORTIA, a total of three high speed exit taxiways were constructed (one per landing runway). The benefits of these taxiways has not been fully achieved or demonstrated.

2.5.8 State and performance of the ATM systems

According to De Neufville and Odoni (2003:397) a high-quality ATM system with well-trained and motivated personnel is a fundamental prerequisite (but not a sufficient condition by itself) for achieving high runway capacities.

2.5.9 Noise considerations

Environmental considerations, especially noise impact, exert influence in determining runway system capacity at a number of airports. In the daily course of airport operations, noise is one of the principal criteria used by air traffic controllers to decide which runway configurations to activate.

Noise-related considerations work, in general, as a constraint on airport capacity, since they tend to reduce the frequency with which certain high-capacity configurations may be used (De Neufville and Odoni 2003:397). In South Africa, there is currently no legislation restricting the impact of aircraft noise.

2.6 Alternative Solutions to the Lack of Airport Runway Capacity

This section discusses the various strategies proposed in literature to address lack of airport runway capacity.

2.6.1 Broad Overview

According to Hamzawi (1992:47) the solution to airport congestion should focus on finding ways of reducing the ratio of demand to capacity and that this could be achieved by increasing the capacity, reducing or limiting demand, or by both methods.

His proposed solutions to the airport congestion problem are structured along this line of reasoning and are outline in Figure 2-6.

Although developing new airports or expanding the existing ones directly increases the system capacity, it should be recognised that in an era of economic restraint, constraints on capital expenditures and growing

community resistance to developing new airports, have made it necessary to consider other alternatives including: low-capital capacity expansion options; management of traffic demand and peaking; and increased application of technology (Hamzawi 1992:47).

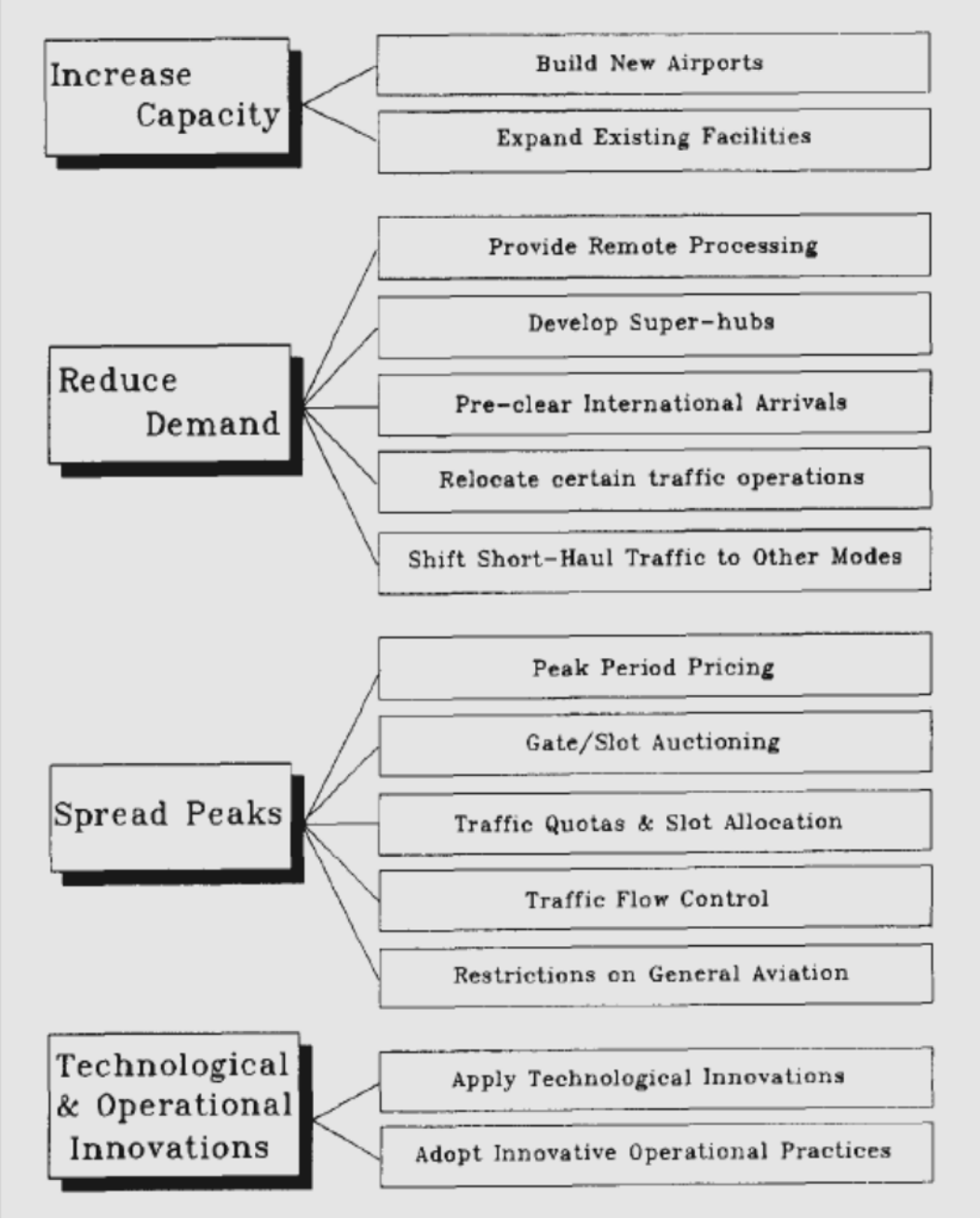


Figure 2-6: Options for balancing airport capacity and demand. Hamzawi (1992:49)

2.6.2 Improvements to slot allocation rules

A “slot” is an important aspect of runway capacity. Based on IATA and EU rules, a slot is the scheduled time of departure or arrival available or allocated to an aircraft movement at a specific date at capacity-constrained airports. Capacity constrained airports are referred to as slot controlled, slot restricted, slot constrained, or slot coordinated airports. A slot is effectively “permission to schedule a flight at a particular airport at a particular time”, it is not an absolute right given the potential for delays due to bad weather, airspace congestion, or ground handling problems. Slots exist only at slot-constrained airports where the demand for flights has outgrown existing runway capacity or supply (Bass 1994:145).

Historically, the allocation of airport runway slots has been administered by the airlines through IATA. Initially, the airlines convene to discuss inter-airline connections through IATA scheduling committees. These committees were administered by major airlines at each airport and operated based on Scheduling Procedures Guide published by IATA. The original objectives of the Scheduling Committees were to improve inter-airline connections among participating carriers and countries.

The objectives gradually changed as airlines began to experience difficulty obtaining slots at congested airports. At that time, price was never considered as a mechanism to ration demand to limited runway capacity. Instead, the allocation mechanism adopted by IATA was a process of administrative rationing where slot allocation is managed through twice-yearly IATA conferences. At the meetings, slots are administratively allocated by an independent coordinator working under the basic principles of “grandfather rights” and effective use (Debbage 2002:937).

According to Bass (1994:146):

> "The basic principle of grandfather rights is that an airline that held and used a slot last year is entitled to do so again in the same season the following year. Effective use means that preference is given to an airline that plans to use a slot more intensively: for example, a daily service rather than one that is less than daily, or a service that operates throughout the season rather than only in the peak".

The IATA system is not without problems. The principle of effective use favours daily scheduled carriers over less frequent. Less than optimal slots are made available to less frequent carriers. It has been suggested that the principle of "grandfather rights" is anticompetitive as it serves to advantage incumbents over new entrants. In response to this criticism, IATA modified the scheduling guidelines where half of all slots that become newly available are to be first offered to new entrants (defined as any airline with less than four slots per day at the slot-coordinated airport in question). IATA also introduced a "use-it-or-lose-it" rule to minimise slot hoarding by the dominant airlines where those not used 80% of the time within a two month period are relinquished and put back into a pool to be reallocated to other carriers, including new entrants (Debbage 2002:938).

According to Debbage (2002:938), in February 1993, the European Commission introduced Regulation 95/93 in an attempt to establish common rules for the allocation of slots at its slot-constrained airports. An administrative process based on "neutral, transparent and non-discriminatory rules" was established to facilitate competition and encourage entry into the air transport market. However, the EU guidelines mostly endorsed existing IATA procedures relating to slot allocations. Regulation 95/93 recognised the historical merit of slot usage or "grandfather rights" whereby an airline

inherited the option to a slot if it had already made use of the runway at the same time during the preceding equivalent season. Furthermore, policies relating to new entrants, the establishment of an independent slot coordinator and secondary trading are marginal deviations from existing IATA guidelines.

According to Langner (1996a:72), the only real difference between EU regulation and the IATA mechanism is that the latter relies on mutual agreements, whereas the EU regulation is a binding legal framework.

The EU 95/93 established a mandatory slot pool which included newly created, unused and/or returned slots, with half of all these to be reallocated to new entrants. However, a UK Civil Aviation Authority (1995) investigation of slot practices at Heathrow Airport in 1994 indicated that 95% of all slots were reallocated on the basis of “grandfather rights”.

After the inclusion of newly available slots due to expanded capacity at Heathrow, the mandatory slot pool only accounted for seven to eight percent of the total. Furthermore, although new entrants could claim up to half of the slot pool, they only took up around 20% of the pool, and only 40% of the slots in the pool were left unused due to the unattractive timing of the slots. In the busiest hours at Heathrow Airport demand continued to exceed the available slots by more than 30% in 1994 as shown in Table 2-2, almost two years after Regulation 95/93 had been passed by the European Commission. Given the difficulties experienced in London and throughout the EU with administrative rationing, European policymakers began to pay close attention to the American free-market-based slot-trading (Debbage 2002:939).

Hour (GMT)	0700	0800	0900	1000	1100	…	1700	1800
Arrivals								
Slot Demand	59	47	50	52	42	…	50	42
Slot Capacity	39	39	38	38	38	…	40	39
Excess demand	20	8	12	14	4	…	10	3
Departures								
Slot Demand	47	50	47	51	53	…	50	53
Slot Capacity	40	40	40	39	39	…	39	40
Excess Demand	7	10	7	12	14	…	11	13

Table 2-2: Heathrow slot capacity and initial demand for peak August weekday (1994). UK Civil Aviation Authority (1995)

According to Langer (1996a) and Starkie (1998), in the United States, the IATA-based system of administrative rationing does not apply, mostly for anti-trust reasons, and slots are allocated on a first come first serve basis at nearly all its airports.

US carriers schedule fights to account for expected delays at the more congested airports. At Chicago's O'Hare, New York's JFK and La Guardia, and Washington's National as a result of heavy traffic at these airports, a slot quota mechanism has been in place since 1968 to limit air traffic congestion and noise. The FAA allows domestic slots at these "high density" airports to be bought and sold for money, rather than being swapped for other slots as is the case in the "one-for-one" trading system established by IATA. The US approach to slot trading is in contrast to EU Regulation 95/93 which allows slots to be freely exchanged but does not address the issues of price and ownership. The "Buy-Sell-Rule" authorized US airlines and other institutions to purchase, sell, trade or lease slots pending certain conditions laid down by the FAA such as the "use-or-lose" rule and new entrant slot pool (Debbage 2002:940).

The ruling allowed a secondary market in slots to flourish where US airlines were allowed to trade historic entitlements to slots. However, they were traded through a clearing house operated by the Air Transport Association (the US airline trade body), rather than through an independent slot broker (Langner 1996b). Consequently, the process was not transparent and the financial terms of slot transfers were not made public (Starkie 1998).

According to Debbage (2002:940) even less clear is the issue of who actually owns the slots. The FAA has explicitly ruled that slots do not represent a property right for US carriers but instead are an operating privilege subject to FAA control. However, the private property status of existing slots has been highlighted in a number of transactions. Notably, the public auction of Eastern Airlines slots at the four high density airports suggested that slots were airline assets rather that FAA or airport assets. A significant number of slots are held by non-carriers and some US airlines have mortgaged their slots to financial institutions as shown in Table 2-3.

In Europe, Regulation 95/93 allows slots to be exchanged, although it is less clear that money transfers and slot ownership claims by airlines are against the rules (Air Transport World 36(5), 199a:11). Despite the ambiguities over monetarized trading and slot ownership issues in Europe, industry observers believe that the secondary market in airport slots in the United States has generated a dynamic and fluid market (Debbage 2002:940-941).

Airport/Slot Holder	% of Total		
	1986	1991	1996
Chicago O'Hare			
American and United	66	83	87
Other Established Airlines	28	13	9
Financial Institutions	0	3	2
Post-deregulation airlines	6	1	1
New York JFK			
Shawmut Bank, American and Delta	43	60	75
Other Established Airlines	49	18	13
Financial Institutions	0	19	6
Post-deregulation airlines	9	3	7
New York La Guardia			
American, Delta, and US Air	27	43	64
Other Established Airlines	58	39	14
Financial Institutions	0	7	20
Post-deregulation airlines	15	12	2
Washington National			
American, Delta, and US Air	25	43	57
Other Established Airlines	58	42	20
Financial Institutions	0	7	19
Post-deregulation airlines	17	8	5

Table 2-3: Slot allocations at the four High Density Airport. US General Accounting Office (1996)

According to Debbage (2002:946), Kleit and Kobayashi (1996) found no evidence that dominant carriers at Chicago O'Hare (American and United Airlines) were hoarding slots to prevent low-fare new entrants from entering the market. McGowan and Seabright (1989) also examined whether airlines with market power might engage in predatory bidding for slots and concluded that it is an unnecessarily expensive way to deter or drive-out competitors. They argue that it was more likely that incumbents would direct any entry deterring or predatory behaviour to the route-specific service they operate rather than through the hoarding of slots.

Furthermore, Starkie (1998) has suggested that the secondary market in slots has encouraged a more efficient use of scarce slots.

Pre-existing advantages are a concern because monetarized trading was introduced based on the grandfather rights of the existing incumbents. This is a fundamental problem because the pre-existing slot holders are, in effect, granted an unwarranted windfall gain by government. Starkie (1998:115) has suggested that a better approach might be to increase the price charged for landing aircraft because this act "would have the effect of reducing the scarcity rent enjoyed by the incumbent airlines, thus placing incumbent and entrant on a more equal footing".

According to Janda (1993), in the UK, airport charges are calculated based on aircraft weight plus, in some cases, passenger charges and a small contribution for aircraft parking. Charging formulas are based on guided lines provided by IATA and ICAO. The underlying principle of the guidelines is one of recovery costs, where 80% of landing costs are attributed to the effects of the aircraft's landing weight. However, "airport charges are a low and constant portion of airline operating costs, four percent worldwide in 1992" (Toms 1994:77).

Although the actual use an airline will make of its slot allocation will be significantly influenced by the price the carrier must pay, few airport authorities have introduced market-clearing pricing schemes based on the market demand for access at various times. Some observers have proposed that airports need to introduce a marginal cost pricing system that reflects the scarcity of slots during peaks, and is based on a system of market-clearing prices. Few airports around the world have introduced peak charges, the British Airports Authority (BAA) experiment is the most comprehensive and

well-known program in place (Debbage 2002:942). Section 5.2, discusses in detail peak pricing schemes that have been implemented and why they failed despite being supported by literature.

Since 1972, the BAA has gradually developed a peak hour landing fee scheme for Heathrow and Gatwick that essentially abandoned the weight related charge in peak periods. Instead, BAA moved to a fixed runway movement charge with a higher landing fee at peak periods to “Reflect the higher marginal cost of using scarce runway resources at peak periods,” (Doganis 1992:94). Additionally, peak passenger and parking charges were also introduced to encourage greater efficiency in the allocation of scarce airport resources and to coerce traffic into off-peak periods (Debbage 2002:943).

According to Debbage (2002:943), Doganis et al (1990) suggested that some evidence exists that BAA peak charge experiment encouraged few carriers to reschedule flights to off-peak times. He argues that part of the problem was that peak charge prices at Heathrow and Gatwick were still relatively low, and thus unlikely to substantially affect airline operations.

An Institute of Air Transport (1997) study found that on the Heathrow-Rome route, peak period airport charges only accounted for 3.1% of the share of the price of an economy class airline ticket whereas Gatwick-Rome route amounted to only 2.5%. There relatively low prices were put in place because of the limitations placed on the BAA by both the government price cap regulation and the “single- till” philosophy (Debbage 2002:943).

ORTIA is currently classified by ACSA as a slot coordinated airport. ACSA has adopted the IATA approach to slot coordination without any deviations. No attempt has ever been made to modify the administrative approach to slot allocation. From the above description of a slot coordinated airport, this classification applies only to airports where the demand for flights has outgrown existing runway capacity. From section 6.3, the declared runway capacity at ORTIA is 58 movements per hour and from section 3.3 the current peak hour demand is 42 movements per hour. ORTIA should therefore not be classified as a slot coordinated airport. This could explain ACSA's somewhat casual approach to slot coordination at ORTIA.

The literature points to the IATA slot allocation approach as a contributor to the overall congestion at airports, in particular the principles of "grandfather rights" and effective use. IATA recognised that the slot allocation approach has short comings and attempted to address these by introducing measures such as allocating half of all newly available slots to new entrants and by introducing the "use-it-or-lose-it rule". Despite these measures, congestion at major airports continued to increase.

Literature also points to the methodology used to determine airport charges as a contributor to airport congestion. The argument is that the landing fees are too low to encourage airlines to efficiently utilise airport slots. Some authors have proposed that airports need to introduce a marginal cost pricing system that reflects the scarcity of slots during peaks. Moreover scholars identify government price cap regulation and the "single till" philosophy as contributing factors to airport congestion. ACSA is a monopoly subject to Government Regulations, the regulatory framework prescribes the "single till philosophy therefore any attempt to substantially increase airport charges will require amendments to the current regulatory framework.

2.6.3 Price Based interventions to Congestion Management

The previous section 2.6.2 outlined the evolution of the slot allocation approaches. This section outlines and compared the effectiveness of price based slot allocation regimes.

To address congestion at Chicago's O'Hare Airport, the FAA took a micromanagement approach, prevailing on the airport's two major carriers (United and American) to cut their peak flight volumes while prohibiting smaller carriers from adding flights to fill the gap. Similar FAA interventions have occurred at New York Airports, where the FAA capped peak hour operations while gaining carrier commitments to shift some flights to less-congested times. The piecemeal nature of the interventions points to a need for a more-systematic approach to managing congestion at US airports. In recognising this need, the FAA proposals envision a future role for prices as a policy tool in attacking the congestion problem. In announcing the New York flight caps, the FAA proposed using an auction system to allocate a portion of the available slots, with carriers paying for slots instead of receiving them for free (Brueckner 2008:1).

A position paper issued by the US Department of Justice endorsed slot auction as a mechanism for addressing airport congestion. Following these policy decisions, the FAA changed its rules on landing fees. Landing fees traditionally dependent only on aircraft weight, the new rules allow the fees to vary by time of day. This change permits airports to implement congestion pricing, with high landing fees charged during peak hours and lower fees charged in off-peak periods.

According to Brueckner (2008) with these new developments, price-based solutions to airport congestion have gained credibility, mirroring progress in implementing congestion pricing for roads (London and Stockholm are prominent examples). He argues that the FAA's decisions allow different pricing approaches. Slot auction is one option, another approach involves a slot-sale regime, where the airport authority sets a slot price and allows carriers to purchase as many slots as they wish at that price.

Under congestion pricing, carriers pay a congestion toll that is analogous to the slot price, but under an ideal structure, tolls are carrier specific (depending on airport flight shares) rather than uniform. By contrast, under a slot trading regime, the airport authority distributes slots to the carriers, who trade them at uniform price. The current system at slot constrained airports, where carriers can sell, or lease the slots in bilateral trades, approximates such a regime, but the current low trading volume suggests a need for institutional improvements. Given the importance of airport congestion as a policy problem, it is important to understand the potential different impacts of these price based regimes.

Brueckner (2008:2) attempts to achieve such an understanding by comparing the outcomes achieved under congestion pricing, a slot-sale regime and a slot auction. The difference between a slot-sale regime and congestion pricing arises because of internalisation of airport congestion, which occurs because carriers at congested airports mostly operate a large number of flights. This means that, in scheduling an additional flight, a carrier will take into account the additional congestion costs imposed on the other flights it operates. The appropriate congestion toll then captures only the congestion imposed on other carriers, excluding the congestion the carrier imposes on itself.

An important implication of internalization is that asymmetric carriers should pay different tolls. A carrier with a large flight share at a congested airport, which internalizes most of the congestion from its operation of an extra flight, should pay a low toll, while a smaller carrier, which internalizes little congestion, should pay a high toll. Because a slot-sale regime, with its uniform price, cannot duplicate this inverse relationship between a carrier's flight share and its charge per flight, the regime is inefficient, unable to generate the socially optimal flight pattern. By failing to account for differences in the internalization of congestion, the uniform slot price excessively penalizes large carriers and insufficiently penalizes small carriers for the congestion created (Brueckner 2008:2).

As a result of this pattern, large carriers will operate too few and small carriers too many flights under a slot-sale regime, provided the number of slots sold is close to the socially optimal flight volume.

In the models, large and small airlines are replaced by asymmetric carriers, then the slot-sale regime's common price does not constitute an inefficient constraint, and the regime is efficient. The analysis shows that efficiency also obtains when carriers do not internalise congestion, Daniels (1995) and Daniels and Harback (2008) claim that this behaviour is realistic. They argue that non-internalization behaviour emerges in the presence of competitive-fringe carriers, who offset through their own flight increases any large carriers to limit self-imposed congestion.

In a slot trading regime, slots are distributed to carriers and then traded among them at a fixed price (also known as a "secondary market" for slots). The analysis shows that such a regime is efficient, overcoming the slot-sale regime's limitations, provided that the optimal number of slots is distributed.

The main difference between the regimes is that carriers participating in a slot-trading understand that the total flight volume is fixed by the number of distributed slots, while slot-sale participants perceive no such constraint, expecting total flights (and airport congestion) to be affected by their slot purchases. The differing view of carriers under a slot-trading regime generates an efficient outcome (Brueckner 2008:4).

According to Brueckner (2008:4) in an actual implementation of congestion tolls or a slot-sale regime, different behaviour could emerge. The implementation of tolls might rely on an iterative approach, where peak-period tolls are initially computed based on current traffic volumes and then adjusted downward as traffic shifts towards off-peak periods. The carriers, perceiving a connection between flight volumes and tolls, would then have an incentive to manipulate the system, acting on the basis of underestimated demands for airport usage with the goal of depressing the toll.

Similarly, under a slot-sale regime, the airport authority might take a trial-and-error approach in setting the slot price, encouraging the airlines to view the price as endogenous and thus subject to manipulation. The same incentive might arise under a slot-trading regime. If such manipulative behaviour occurs, then the results of the analysis are not strictly relevant, calling into question their usefulness as a guide for public policy. However, if the extent of manipulation is “small”, then the results may still have some practical value.

Brueckner (2008:5) assumes that slots are allocated via a uniform-price, multi-unit auction, and no strategic bidding, with carriers assumed to make bids based on their true valuation of slots. The analysis shows that, without strategic behaviour, the auction generates the same efficient outcome as the slot-trading regime.

Under these circumstances, optimal congestion tolls differ across carriers, and since a slot-sale regime (with its uniform slot-price) cannot duplicate this pattern: the equilibrium it generates is inefficient. Flight volumes tend to be too low for large carriers and too high for small carriers. Under a slot-trading regime, the distribution of a fixed number of slots causes carriers to treat total flight volume (and thus congestion) as fixed, and this difference leads to an efficient outcome as long as the number of slots is optimally chosen. A slot auction is efficient for the same reason.

A slot-trading regime, where slots are distributed to the carriers and then traded through a clearing house, is equivalent to an efficient regime of carrier-specific congestion toll. Since such a toll regime is bound to be controversial given that the tolls it generates are inversely related to carrier size, the analysis generates a presumption in favour of the equivalent slot trading regime. The bilateral system should be replaced by a central clearing house, and a slot purchase should confer clear property rights, replacing the current arrangement in which slots are ultimately the property of the FAA.

Although the analysis shows that a slot auction can also achieve efficiency, free distribution of slots might be preferable given the airline industry's opposition to new, cost-increasing charges. Slots could be allocated in proportion to current flight volumes, and trading would occur when carriers seek to adjust these volumes. Hoarding of unused slots, meant to deny airport access to a carrier's competitors, could be prevented by "use-it-or-lose-it" requirements, which are already in place. It might appear that new entrants (who hold no slots) are disadvantaged under this system, but their status is no different from that of an incumbent carrier seeking to increase its flight volume, which must purchase new slots to do so (Brueckner 2008:22).

The micro management approach adopted by the FAA of prevailing on the major carriers to cut their peak flight volumes and prohibiting smaller carriers from adding flights to fill the gap promises a quick solution to the congestion problem. It assumes, however, that demand is elastic. This is not the case at ORTIA as the majority of passengers in the morning and evening peaks are business. The demand from the business sector tends to be inelastic.

In the US, the US Department of Justice endorsed slot auction as a mechanism for addressing airport congestion. This prompted the FAA to change its rules on landing fees by allowing the fees to vary by time of day. The FAA's decision allowed slot-auction, slot-sale, slot-trade and congestion pricing to be considered as pricing options to address airport congestion.

Brueckner (2008)'s analysis identifies equivalent slot trading regime as the preferred approach. He, however, does not adequately address the issues of initial slot allocation and how to deal with new entrants. His proposed method of initial slot allocation is equivalent to "grandfather rights". Furthermore he does not address the contentious issue of slot ownership. He does suggest that a slot purchase should confer property rights.

2.6.4 Collaborative Decision Making

According to Auerbach and Koch (2007:40), operational airport capacity can be enhanced by the joint management of on time performance (OTP). The Association of European Airport (2006) reports reveal that since 2000, punctuality of intra European flights has improved from 74.5 to 80.7 percent while punctuality for intercontinental flights still remained at 70.8 percent. In 2003, Euro-control reported that European air traffic delays caused by shortage in airport capacity and inefficient airport operations have exceeded

those caused by en-route air traffic management for the first time. See Figure 2-7.

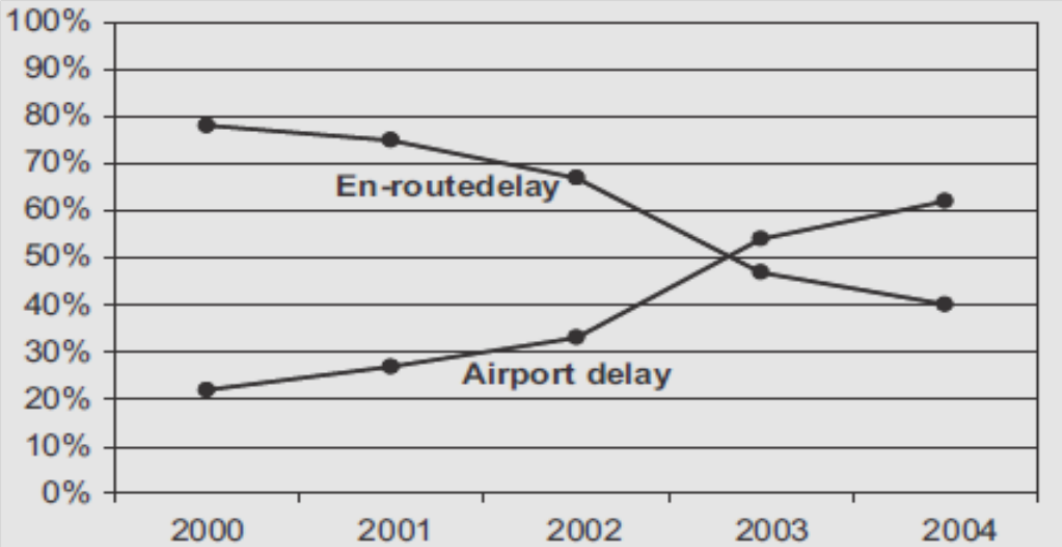


Figure 2-7: Airport and En-route delays 2000-2004. Auerbach and Koch (2007:40)

Airport operators make inefficient use of existing infrastructure, allocate airport slots poorly and supply insufficient information about late stand and gate dispositions. Ground handling service providers exacerbate the situation by providing poor service levels and by making poor use of their resources. They also suffer from low turn-around predictability due to last minute changes. Air Traffic control (ATC) service providers have to manage air space and have to cope with traffic and frequency overload, as well as late incoming information that reduces pre-planning flexibility.

On time operation is considered to be a key performance indicator in the airline industry and is an important service differentiator, particularly for high-yield passengers. As a result, many carriers have set up projects to realize cost saving potentials and service improvements.

A precondition for a successful project is awareness that delay may result from many different but often interdependent reasons.

Therefore, for an OTP improvement initiative to succeed, the project team needs to consist of representatives from airlines, airport, air traffic management and related parties (e.g. ground handling services providers). Collaboration decision making (CDM) is a means to cope with punctuality challenges at congested airports and could lead to an increase in operational capacity without significant investments in airport or air space infrastructure (Auerbach and Koch 2007:41). From an airline's perspective, CDM should be considered as allowing carriers to participate in air traffic decision-making that affects them as shown in Figure 2-8.

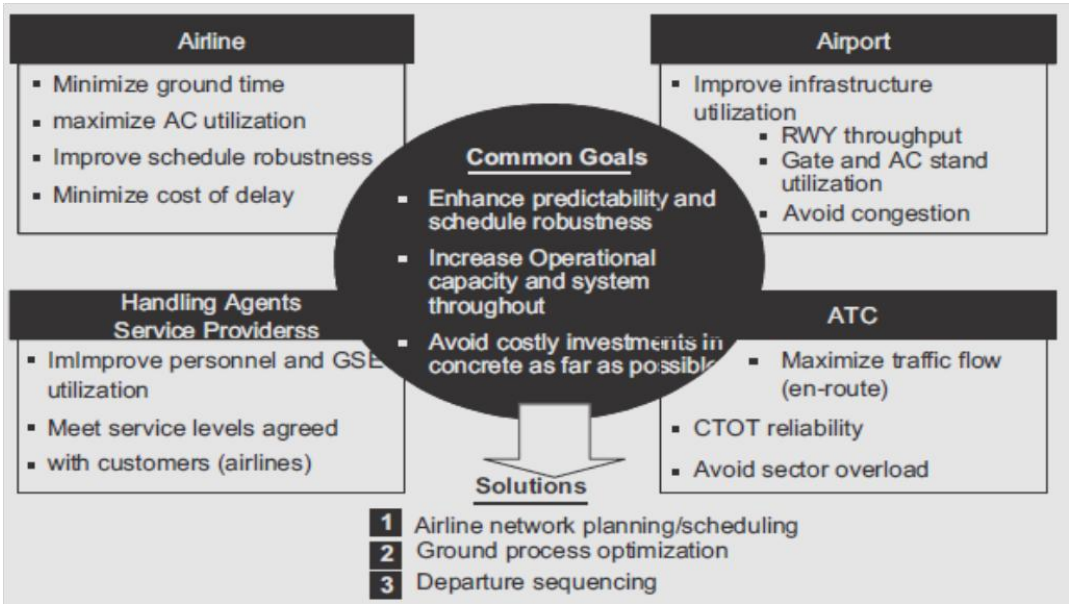


Figure 2-8: CDM and its benefits for the involved parties. Auerbach and Koch (2007:42)

In 2005, the introduction of CDM at Zurich airport led to improvements in OTP as indicated in Figure 2-9. Departure punctuality improved by three percent, passenger waiting time was reduced by 160 00 hours, and improved coordination of ground processes led to an increase of fifteen percent in landing capacity under bad weather conditions and an improvement of all landing ratios by three flights per hour.

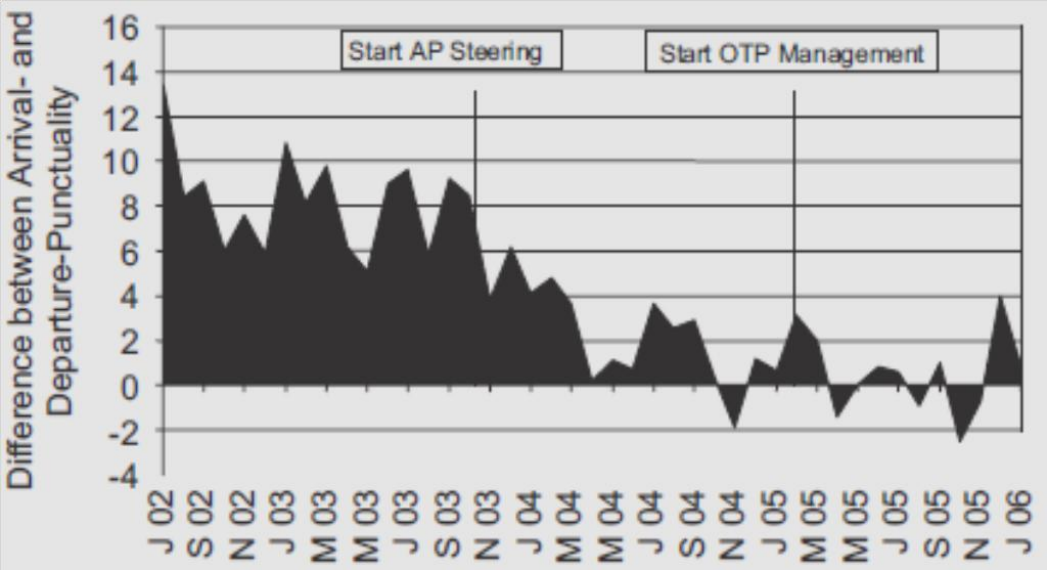


Figure 2-9: Arrival and departure punctuality at Zurich Airport. Auerbach and Koch (2007:43)

Figure 2-7 indicates that in Europe, aircraft delays caused by en-route delays have been exceeded by aircraft delays caused by lack of airport capacity. This could be primarily because of the increase in airport operations resulting from the increase in traffic at the various airports. Zurich airport responded by introducing CDM with the aim of improving OTP. CDM at Zurich airport improved departure punctuality, reduced passenger and aircraft delays and marginally improved the overall capacity of the airport.

At ORTIA, before 2009, there was no mechanism in place for measuring and monitoring delays. The demand on airport infrastructure increased rapidly and major infrastructure investments aimed at increasing capacity were implemented. As mentioned in section 2.6.2, the IATA based slot allocation approach was the primary means of managing runway capacity. This approach has been identified in literature as a contributor to airport congestion. In 2009, ACSA introduced its own version of CDM which is based

on the Zurich model in the form of an Airport Management Center (AMC). Since its inception the AMC has significantly improved the OTP as indicated in Figure 2-10, Figure 2-11 and Figure 2-12 and has reduced passenger delays as indicated in Figure 2-13. In Figure 2-10, the fifteen minutes refers to the buffet time allocated for late arrival and departures. Late arrivals and departures within the fifteen minute buffer are not considered as late. With the introduction of the AMC, OTP improved from 75 to 83 percent of flights. From Figure 2-11 flights departing on their exact scheduled time improved from 36 to 50 percent. From Figure 2-12 average aircraft delay decreased from fifteen minutes to five minutes. Figure 2-13, indicates that the average delay per passenger decreased from sixteen to nine minutes. The impact of the AMC on overall capacity has not been quantified however one can infer from these results that the will be some improvement. The full benefit of the AMC has not yet been realized, this is because not all airport stake holders responsible for operations are represented at the AMC. Participation in CDM via the AMC is voluntary and should be made a requirement for full benefits to be realized.

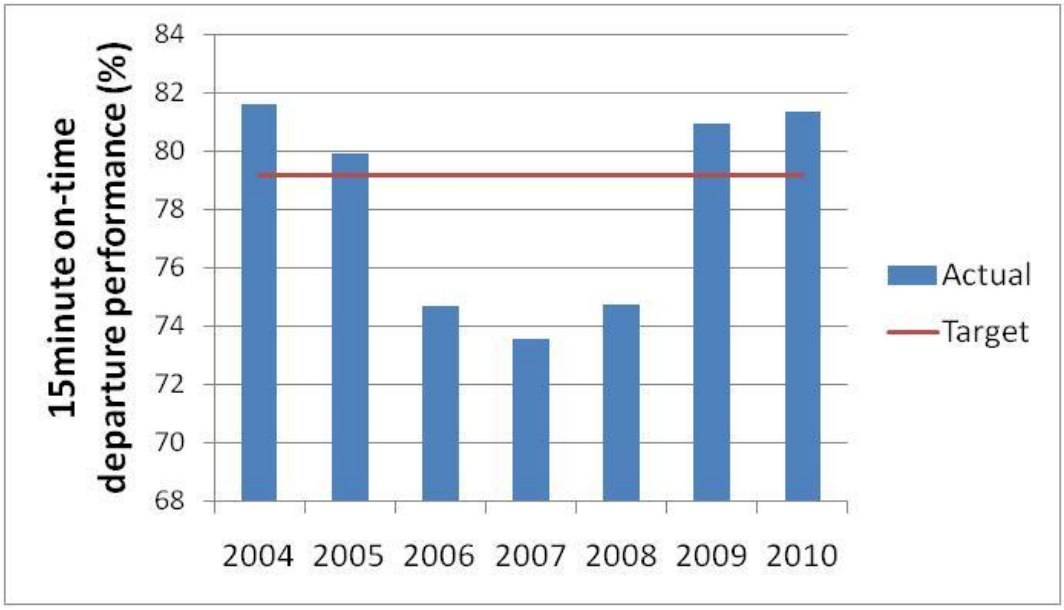


Figure 2-10: Fifteen minute on-time departure performance at ORTIA. ACSA (2011)

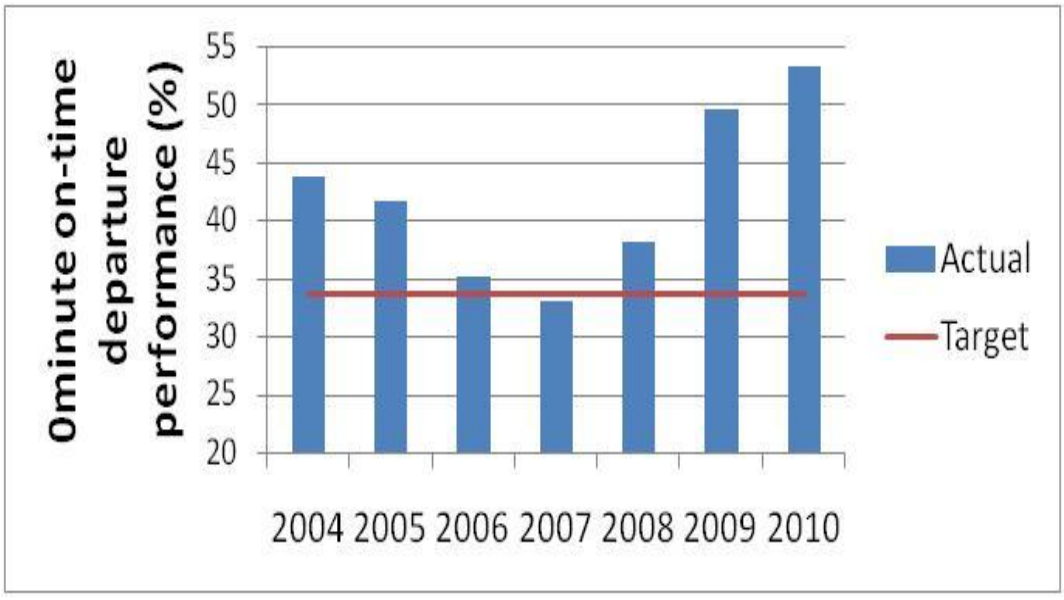


Figure 2-11: Zero minute on-time departure performance at ORTIA. ACSA (2011)

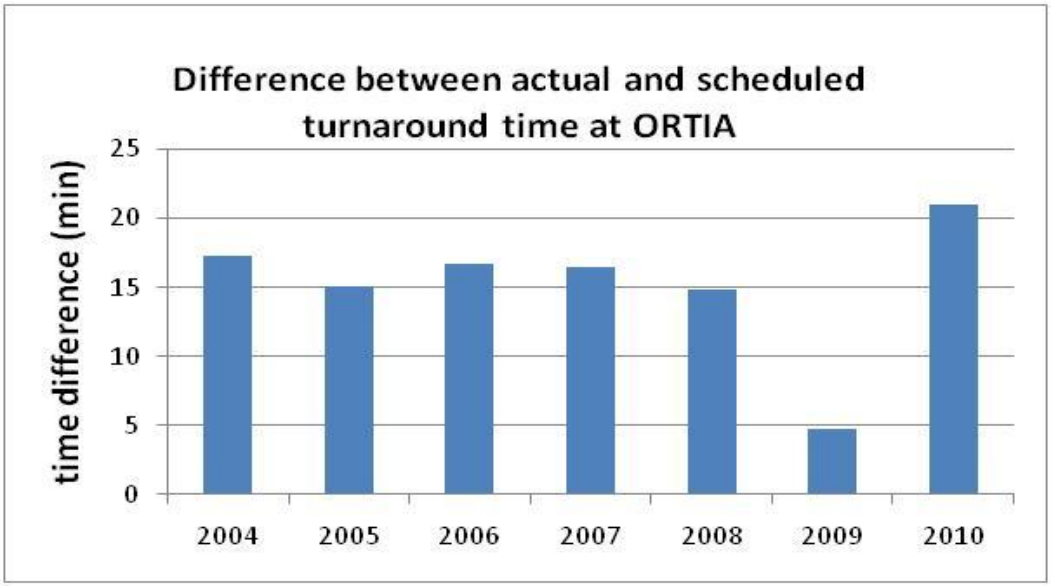


Figure 2-12: Difference between actual and scheduled times at ORTIA. ACSA (2011)

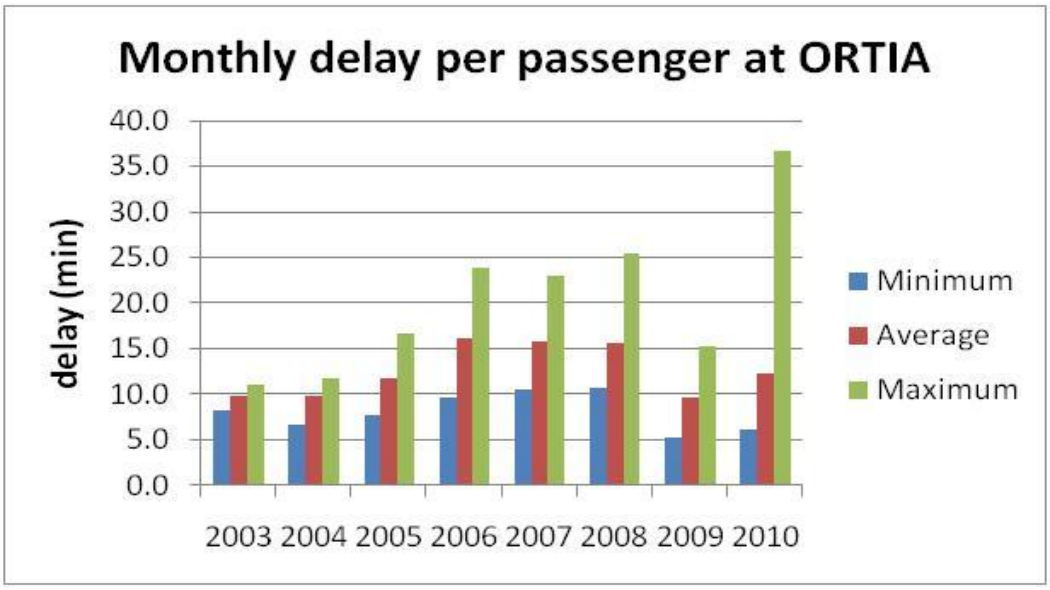


Figure 2-13: Monthly delay per passenger at ORTIA. ACSA (2011)

2.6.5 Systems approach to congestion management

Black and Larson (2006:1) propose strategies to overcome congestion in the broader infrastructure systems. The infrastructure systems they looked at include transport networks (rails, highways, airports and sea ports), telecommunication networks and utilities (electricity, water, gas, oil and sewerage). These infrastructure systems have predictable cyclic patterns of demand for their services, with demand peaks and demand valleys. The cycles have multiple frequency components: daily, weekly and seasonal. To meet peak demand, capacity needs to be expanded. At other times, the infrastructure supporting the service may sit idle. Therefore, these industries would benefit from some form of demand management.

They propose the following options to deal with the congestion:

- Capacity expansion;
- Capacity upgrade;
- Substitution;
- Rationing (discriminatory or non discriminatory);
- Loss or degradation of service;
- Demand management congestion pricing.

According to Black and Larson (2006:11-125), the most common means of alleviating congestion at airports is through the construction of new runways. Alternative means include improving the air traffic control system, and adding gates, taxiways or aircraft to the system. They argue that congestion pricing policies for the air traffic can be implemented at the consumer level, the flight level or both. Airlines have sophisticated, dynamic pricing schemes for managing consumer level demand and maximising capacity utilisation.

A similar system of congestion pricing for aircraft would enable the air transportation system to operate more efficiently. Peak demand in air transport has a time and location component. The hub and spoke system employed by major airlines leads to several congested hubs with coordinated flights to maximise connections and minimise consumer waiting times. In addition, there is a seasonal component to commercial air travel. Leisure travellers may be willing to adjust their flight schedules within a day or week, but it is unlikely that they are able to dramatically alter the seasonal pattern in their travel schedule. Business travellers have an inelastic demand and are unlikely to adjust their demand between days, and less willing to do so even within a day.

Due to the lack of substitute available for long distance flights, consumers must accommodate to the available flight schedules. For shorter flights, it is possible for rail, buses or motor vehicles to be substituted for flying. The immediate post “9/11” decrease in air travel demand illustrates that there is a degree of elasticity which can make congestion pricing effective at smoothing demand peaks. After “9/11”, air travel virtually came to a stand-still because of air space restrictions; therefore the demand elasticity observed by Black and Larson was as a result of the unavailability of air travel as opposed to passenger willingness to use alternative modes. Table 2-4 illustrates the potential for congestion pricing to reduce infrastructure investment costs for various infrastructure systems.

Domain	Peak Cycle time	Min Demand response Time	Method of response	Potential Savings
Electricity	Daily	instantaneous	Shift, forego	$10B per year
Roads	Daily	~ hourly	Substitute, shift	$5-11B[11] per year
Airports	Daily, Weekly	Hours to days	Substitute, forego, shift	$17B
Ports	??	Weekly or more	shift	Small
Pipelines	??	Instantaneous (with storage),	shift	??
Telecom	Seconds, daily	< seconds, hourly	Shift/delay	$80B

Table 2-4: Potential for congestion pricing to reduce infrastructure investment costs. Black and Larson (2006:22)

Black and Larson (2006) adopt a holistic view to addressing congestion in infrastructure systems. They use what is referred to as a "systems approach" to the infrastructure congestion problem. According to them, infrastructure systems have predictable cyclical patterns of demand for their services, with demand peaks and valleys. They notice that due to the cyclical nature of the demand for service, infrastructure systems supporting the service my sit idle for long periods of time. They argue that infrastructure systems would benefit from some form of demand management.

Black and Larson raise two unique options to deal with the congestion namely rationing (discriminatory or non discriminatory) and loss or degradation of service. They, however, do not elaborate on how the rationing would be implemented. Whether rationing is implemented discriminatory or non discriminatory, its implementation is bound to experience serious objections from the airline industry.

Loss or degradation of service is equivalent to the United States model of slot allocation at airports outside of the HDR discussed in section 2.6.2 where slots are allocated on a first come first serve basis and no limit is placed on the amount of slots allocated. The rationale is that the market will eventually establish some form of “equilibrium”. The airlines will by themselves choose to discontinue flights in the peak as delays get longer. De Neufville and Odoni (2003) argue that this is expensive and inefficient for both the airport authority and the airlines to establish market “equilibrium”.

Black and Larson (2006), argue that congestion pricing policies for air traffic can be implemented at the consumer level, the flight level or both. Airlines already have sophisticated, dynamic pricing schemes for managing consumer level demand and maximising capacity utilisation. A similar system of congestion pricing for aircraft would enable the air transportation system to operate more efficiently.

What Black and Larson do not address is the issue of implementation. In section 5, Schank (1994) investigates the implementation of peak pricing at Boston Logan, LaGuardia and Heathrow Airports. He concludes that there are socio-economic, institutional and political barriers to the implementation of peak pricing.

2.6.6 Optimum runway capacity utilisation

According to Le et al (2008:1-6), most airports in the United States do not place any limitations on airline schedules. At some major airports, the current scheduling restrictions, which are mostly administrative measures, have not been sufficiently strict to avoid consistent delays and have raised debate about both the efficiency and the fairness of the allocation.

They argue that airport expansion and technology enhancement alone are not enough to cope with the competition-driven scheduling practices of the airline industry and that the policy legacy needs to change to be consistent with airport capacities.

Their research studies how flight schedules might change if airlines had to restrict their schedules to be consistent with runway capacity. To obtain these schedules, they assume a different modelling approach. They model a profit-seeking, single benevolent airline and develop an airline economic model to simulate its scheduling decisions. The airline is benevolent in the sense that it considers historic pricing at LaGuardia airport and the associated price-elasticity and attempts to service this population while simultaneously remaining profitable. They explicitly incorporate the relationship between supply and demand through price elasticity, which they estimate by analysing the extensive data of publicly available databases.

Their case study demonstrates that:

- At Instrument Meteorological Conditions (IMC) runway rates, the market can find profitable flight schedules that reduce substantially the average flight delay while accommodating the current passenger demand at prices consistent with the current competitive market;
- The IMC rate provides a predictable on-time performance for the identified schedules in all weather conditions;
- The reduction of flights through consolidation of low load-factor flights and through aircraft up-gauging alleviate much of the current traffic pressure on high demand airports.

Le et al (2008:1-6) adopt a different approach to addressing the runway congestion problem. They look at how airlines schedule flights and attempt to develop flight schedule to match the current runway capacity. Although their research demonstrates that it is possible to develop such a flight schedule, the practicality of implementing such a schedule is questionable. Firstly, there are a large number of airlines operating at major airports. Secondly, arrival and departure slots must be coordinated at all the airports that are connected by flights. This would require coordination at an international scale. Furthermore, their findings are based on the assumption that airlines will operate bigger aircraft in order to increase passenger throughput, given the limited number of slots. This is only achievable over a relatively long period of time as some airlines may have to acquire new aircraft or reassign existing aircraft.

2.6.7 Airline and rail integration

Givon and Banister (2006:386) consider the concept of airline and rail integration in addressing the airport capacity problem. Most of the transport literature only looks at mode alternatives in competition with each other rather than exploring the potential for cooperation. They examine the possibility by making the case for aircraft and high speed train (HST) substitution under conditions of intermodal integration. Airlines use railway services as additional spokes in their network of services from a hub airport to complement and substitute for existing aircraft services. Airlines benefit from the slots that are freed up and they can support mode substitution. Society gains from the social and economic benefits of better integrated transport services at a lower environmental cost.

Givon and Banister (2006:386) study the model of integration at Heathrow airport against the background of United Kingdom air transport policy and assessed the benefits and limitations of it. According to them, aircraft services have traditionally been seen in competition with the established railway services, but this has changed with the opening of the air market.

Railways have started to recapture some of the traffic they lost to the airlines, as a result of the development of the HST. HST services can replace aircraft services on short haul air routes, and concerns about the environmental pollution from aircraft operations and the capacity shortage at major airports have increased the calls for mode substitution.

The European Union (EU) has claimed that:

> "we can no longer think of maintaining air links to destinations for where there is a competitive high-speed rail alternative… network planning should therefore seek to take advantage of the ability of HST to replace air transport and encourage rail companies, airlines and airport managers not just to compete, but also to cooperate," (CEC, 2001:38).

According to Givon and Banister (2006:386), where aircraft and HST substitution takes place it leads to competition between the operators, the airlines and the train operating companies (TOCs). The potential for benefits from mode substitution is then diminished as train services are added to the air services rather than replacing them. The competition between the modes has led the air transport industry to reject the idea of mode substitution, and it can even lead the airlines to increase their services.

However, when HST and conventional railway infrastructure is provided at airports, the air transport industry sees an opportunity in mode substitution, with the substitution of aircraft by HST, and the integration of railway services with flights.

They argue that policy makers fail to recognise the distinction between the two forms of mode substitution as they normally only support mode substitution where competition between the modes is encouraged. In addition, when the role of the railways is considered in terms of the future of the air transport industry, it is limited to the access to airport issue, and the potential for airline and railway integration is overlooked.

According to Givon and Banister (2006:389) the economic literature promotes intermodal competition, as this gives greater choice to the user and may assist in keeping prices down. In the case of aircraft and HST services, the potential benefits from cooperation and integration between the modes (operators) are greater than the benefits from competition. The socio-economic arguments given in support of the construction of new runways in general equally apply to the construction of a railway station at the airport, provided that it allows direct, fast and high frequency service from the airport to many destinations and an easy transfer between the train and the aircraft. Furthermore, increasing an airport's capacity through a railway station instead of a new runway secures these social-economic benefits at a lower environmental cost.

Their main finding is that the railways have an important role to play in the future of air transport, and recommend that the definition of air transport be expanded to include the railways.

This is necessary to make policy makers consider the two modes as part of one transport network and to promote airline and railway integration and to ensure adequate planning of railway services to and from airports.

Givon and Banister (2006:396) caution that, although airline and railway integration offers advantages, it is not a panacea to the environmental and congestion problems faced by the air transport industry, and it will not lead to meeting the growth in demand for air services. It will also not lead to balancing the economic, social and environmental costs and benefits of air transport if it is used only to meet new demand, by using the freed runway capacity for new air services. The balance would be achieved if the supply of air services is partly achieved through the use of the railways, and if new demand is not only met by new runways. Thus, a trade-off between social-economic benefits and environmental and congestion costs will still be necessary, even after the development of airline and railway integration.

Janić (2010) studies the potential savings of delays and related costs for airlines and their passengers that could be achieved by substitution of some comparable air passenger transport (APT) short- haul flights by high-speed rail (HSR) services at a large congested European airport. He develops a deterministic queuing model for quantifying the savings and he applies his model to a large congested European airport using the what-if scenario approach.

According to Janić (2010:78), in Europe, airports are considered as multimodal transport nodes if they are included in the surface long-distance network. In the period between 1990 and 2006, APT demand in the European Union (EU) and HSR has grown at five and sixteen percent respectively as shown in Figure 2-14.

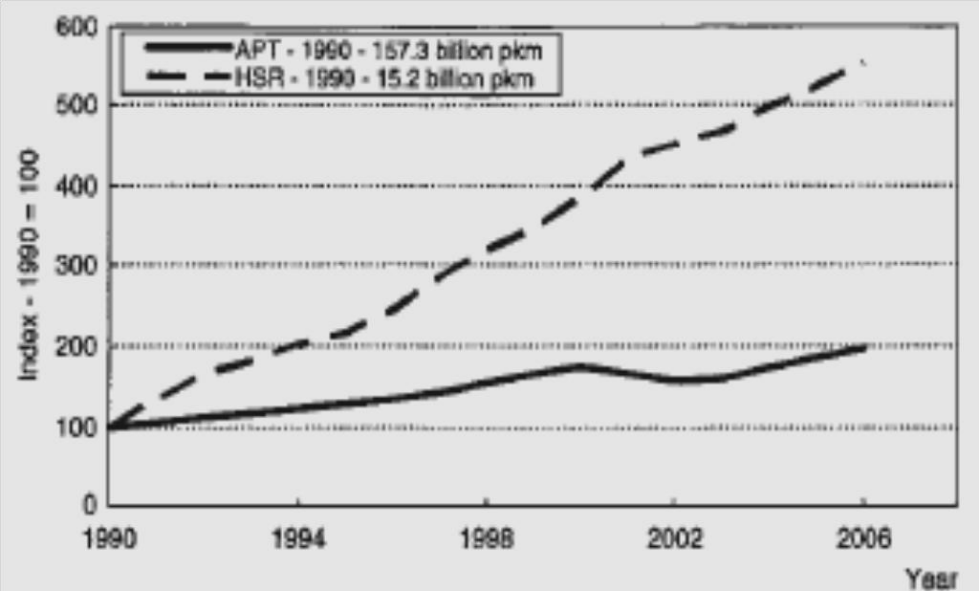


Figure 2-14: Development of ATP and HSR traffic in EU during the period 1990-2006. Association of European Airlines (2000-2006)

HSR and APT may interact in the areas of competition and complementarity. Both areas may result in substitution of services between the two modes. Such substitution, in addition to relieving congestion and aircraft-flight delays at airports at both ends of a HSR-APT market-route may improve internal efficiency of each mode and contribute to mitigating their overall burden on the environment. Figure 2-15 shows that with travel time between 1 and 3 hours, HSR has taken over from APT a significant, from about 30 to 60 percent.

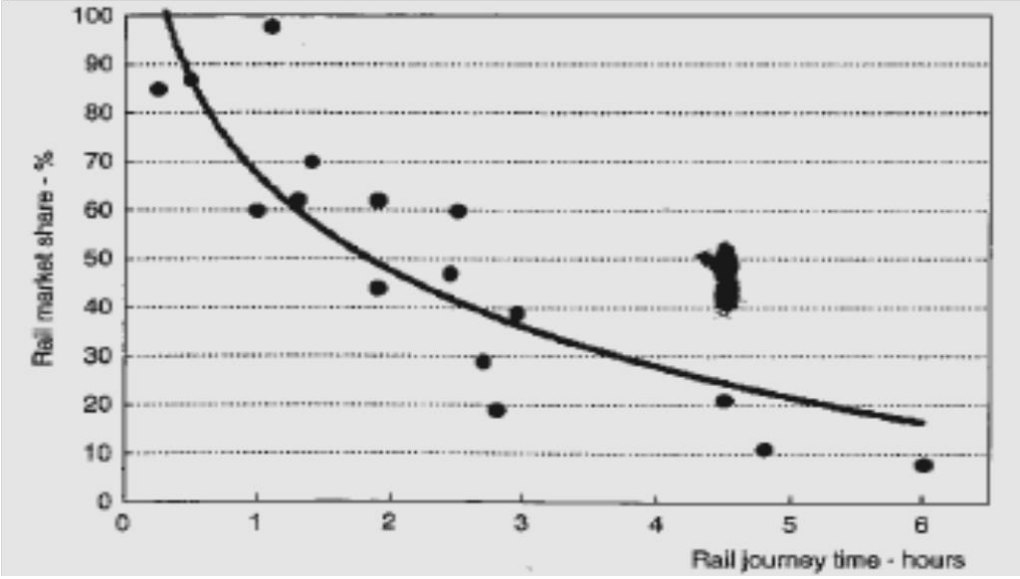


Figure 2-15: Market share of HSR competing with APT on journey time in selected European corridors-market. Air and rail competitions and complementarity (2000)

APT has responded by cancelling short-haul flights due to lack of their profitability or due to the lack of the convenient slots at some (congested slot-constrained) airports at the ends of particular market-corridors. Their latter reason implies not getting a slot at all or getting a slot at an inconvenient time when no substantive demand or long delays due to congestion might be expected.

On the one hand, these delays are unacceptable due to propagating through the airline network and thus compromise efficiency and effectiveness of the daily schedule of affected aircraft. On the other, preventing access for these short-haul flights mitigates the overall congestion and thus saves delays and related costs for other aircraft-flights and air passengers that come after these substituted flights at congested airports.

According to Janić (2010:80), HSR and APT complement each other by offering integrated services in specific market-corridors. Passengers perceive complementarity if they are offered seamless services by a combination instead of a single transport mode. He identifies two types of complementary networks:

- HSR may partially or completely replace APT “feeder” flights in collecting and distributing passengers between a hub airport included in an HSR network and spoke airports or cities. In such cases, the feeder HSR services connect to long-haul flights in accordance with a compatible timetable;
- APT may connect the associated spoke to a given hub airport while HSR may exclusively provide the surface connection between the hub airports themselves.

APT and HSR integration is expected to create the following effect:

- Substitution of some short-haul flights by HSR services can relieve demand on existing airport airside capacity and consequently mitigate congestion, delays and related costs of the remaining aircraft-flights on one hand and enable utilization of the freed slots by larger aircraft on the other;
- Extension of gravitational areas of specific airports as a result of their accessibility by high-speed surface transport;
- Diminishing of the environmental impacts at airports of noise, pollution and land-use in both relative and absolute terms on one hand and increasing of social welfare by increased employment on the other.

Janić (2010:83) applies his model to estimate the potential of substitution of some short-haul flights by HSR services at London Heathrow Airport. The results from the model application indicate that, in the Heathrow example,

modest substitution of short-haul flights (up to two percent) by HSR services could have a substantial daily savings potential of up to about twenty percent in the delays and seventeen percent in their costs.

The concept of airline and rail integration could potentially be implemented at ORTIA to complement the APT to KSIA. The major impediment not discussed by the authors is the initial capital investment required in countries like SA that do not have a well developed and maintained rail infrastructure. When one compares the required capital investment and the time it would take to fully implement a new HST line, it could be argued that it would perhaps be better to construct a completely new airport to complement the existing one.

2.7 Demand Management

2.7.1 Broad overview

De Neufville and Odoni (2003:461) define demand management as any set of administrative or economic measures and regulations aimed at constraining the demand for access to a busy airfield and at modifying temporarily the characteristics of such demand. According to them, the available approaches can be subdivided into three categories:

- Purely administrative;
- Purely economic and;
- Hybrid (combination of the former two).

The fundamental rationale behind the economic and hybrid categories is that they impose on airport users to consider the full costs of access, including the delay costs they impose on other airport users.

According to them all purely economic approaches to demand management involving some measure of congestion pricing, are based on the principle that

to optimise use of a congested facility users should be forced to internalize fully the external costs imposed by their use of the facility.

Hybrid demand management systems combine elements of administrative and economic approaches. Their common characteristic is the use of administrative procedures to specify the number of slots available at an airport. Hybrid systems rely on such economic devices as congestion pricing, slot markets and auction to arrive at the final allocation of slots (De Neufville and Odoni 2003:462).

2.7.2 Evolution of demand management

According to de Neufville and Odoni (2003:462), the relationship between demand and capacity and the air traffic congestion at major commercial airports have led to increased interest in airport demand management. Until the early 1980s, demand management was practiced at only a few airports worldwide. Primarily because of its potential for negatively affecting competition, scholars considered it to be a method of last resort for reducing airport congestion and congestion costs.

However, in modern times, the debate on demand management has shifted from whether it should be used at all to how it can be applied most effectively. The overall premise is as follows: capacity expansions should generally be the principal means for accommodating growth in airport demand, but it may require a long time or may even be entirely infeasible. In such circumstances, some form of demand management may be the only available alternative, at least in the short and medium terms, for keeping delays within reasonable bounds.

2.7.3 Justification for demand management application

The motivation for demand management comes from a fundamental observation that when the demand approaches the capacity of a system, the relationship between delay and capacity or demand becomes nonlinear.

A relatively small increase in capacity or a relatively small reduction of the demand rate results in a proportionally larger reduction in delay. Demand management aims at achieving those small reductions in demand or the shift in demand from peak to off peak periods that will bring about these large delay reduction benefits (De Neufville and Odoni 2003:465).

Some scholars argue that demand management is unnecessary even at the busiest airports because delay will act by itself as an access-control mechanism. According to this argument, as delays at an airport grow, aircraft operators will deem the situation unacceptable and will choose not to use the airport. The costs associated with delay, as perceived by individual users, will become so high that demand will cease to grow and “equilibrium” will be reached. However, this line of reasoning is fundamentally flawed because the equilibrium reached in this way will be inefficient economically, as delays to aircraft and passengers will be excessive and the mix of airport users may include a large percentage who have a low value of time and whose use of the airport cannot be justified on economic grounds (De Neufville and Odoni 2003:465).

Aviation experts have come to realize that the “do-nothing” alternative, allowing demand to grow unabated until the users themselves become discouraged by the high cost of delays, is wasteful and inefficient. This has motivated the extensive ongoing examination of the relative merits and effectiveness of the various demand management approaches.

Administrative approaches to demand management have been discussed extensively in section 2.6.2, therefore the following section focuses on economic and hybrid approaches to demand management.

2.7.4 Economic Approaches to demand management

Economic approaches to airport demand management utilize various methods of congestion pricing to exercise control over airport access. A system of charges based on congestion pricing principles takes into consideration the pattern of delay at an airport over time and attempts to reduce these delays to an economically efficient level. The access charges vary with time of day, as well as possibly by season and even by day of the week, with higher charges during peak demand periods and lower charges during off-peak periods (De Neufville and Odoni 2003:475).

2.7.4.1 Congestion pricing theory

Access to an airport is paid for through a landing charge/fee. The landing charge is proportional to the weight of the aircraft and is determined through the average-cost pricing method[1]. There are two aspects of this practice that are of interest. Firstly, as the amount of traffic at a congested airport increase, the landing charges will decrease, this is so because the cost of the airfield is divided among users and aircraft weight. Thus with average cost

[1] Briefly, average-cost pricing consists of three basic steps: (1) a target amount of revenue, *X*, to be collected from landing fees, is specified at the beginning of the airport's financial year (typically *X* is equal to the annual cost of the airfield, including a reasonable return on the airport's investment); (2) a forecast is made of the total number of unit weight, *Y*, of all the aircraft that will utilize the airport during that year; and (3) the landing fee per unit of weight, *Z*, is set equal to the ratio *X/Y.*

pricing, access to the airport becomes cheaper as congestion worsens. Secondly, there is a tenuous relationship between the landing charge an aircraft pays and the true costs imposed by that aircraft's operation.

A landing charge based solely on the landing weight of the aircraft essentially charges aircraft according to their "ability to pay", rather than in proportion to the costs they cause to others by operating at the airport (De Neufville and Odoni 2003:476).

Yet all aircraft will occupy the runway and associated final approach path for roughly similar amounts of time and runway occupancy time is the main issue in the case of congested airport facilities. De Neufville and Odoni (2003) argue that this fundamental inconsistency between the price charged and the true cost of using congested airport facilities has been pointed out by economists and is recognized by airport and civil aviation experts and administrators.

The theory of congestion pricing is well established in the literature of economics, therefore, only its main points are summarized in this report. According to De Neufville and Odoni (2003:477), every user who obtains access to the facility during periods when delays exist generates a congestion cost that consists of two components:

- An "internal delay cost"': the cost that this particular user will incur due to the delay that user suffers and;
- An "external delay cost": the cost of the additional delay to all other prospective facility users which is caused by this particular user.

When an aircraft pays only the traditional weight-based landing charge to operate at an airport, regardless of how congested that airport might be, the only cost in addition to the landing fee which the aircraft's operator will

perceive is the internal delay cost, the cost due to the delay the airplane in question suffers. Those airport users with the highest tolerance for internal delay costs, those with a low cost of delay time, will be the ones who will continue using an airport as congestion and delays increase.

By contrast, high-value-of-time operations, such as airline flights with large numbers of passengers, short connection and turnaround times on the ground, are the ones that will be the most sensitive to worsening congestion.

The fundamental principle that the theory of congestion pricing applies in such cases is that, to achieve an economically efficient use of the facility, one must impose a congestion toll on each user which is equal to the external cost associated with the user's access to the facility. Economists refer to this as forcing users to "internalize external costs". The underlying rationale is those who can pay the congestion toll can compensate "society" for the external costs they impose, must be deriving an economic value from the use of the facility that exceeds the external costs.

In other words, their use of the facility increases total economic welfare. Conversely, a user who is not able to pay the congestion toll must be deriving a net economic benefit from the use of the facility that is less than the cost imposed on others. Otherwise, the user would be willing to pay the toll. Prospective users in this category are denied access to the facility through the device of the congestion toll, because such access reduces total economic welfare (De Neufville and Odoni, 2003:478).

Figure 2-16 illustrates the situation. Curve *D* is the demand "curve" at the runway system of an airport facing capacity constraints. Curve *I* shows how the expected cost of delay suffered by each individual aircraft movement ("internal delay cost") increases as a function of demand. Curve *T* shows the

sum of the internal delay costs and the external delay cost generated by each additional aircraft movement at every level of demand.

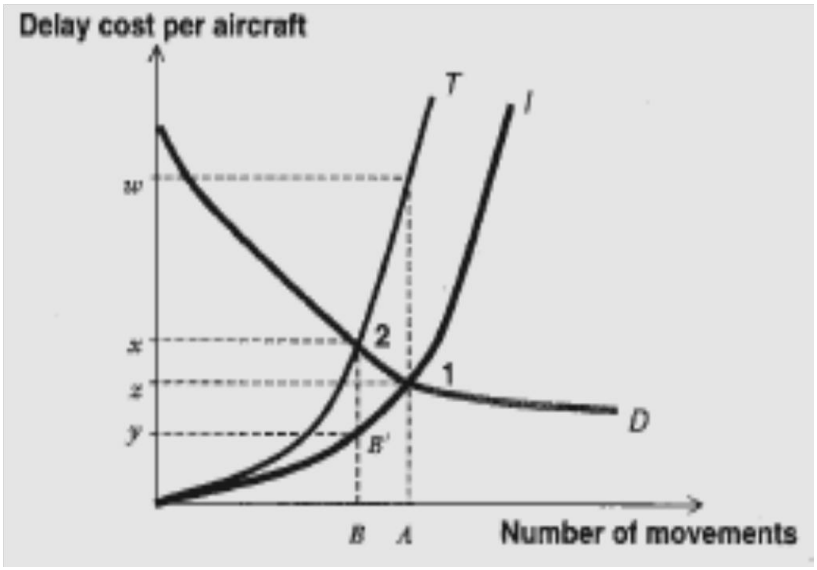


Figure 2-16: The effect of charging for external delay costs. De Neufville and Odoni (2003:479)

The difference between curve *T* and curve *I* at each level of demand is equal to the external delay cost generated by an additional or “marginal” aircraft movement at that level of demand. When there is no congestion toll, when aircraft do not pay for any part of the delays they cause to other aircraft, the equilibrium point is at 1, where the demand curve *D* intersects the internal delay cost curve *I*. the equilibrium level of demand is equal to *A*, the projection of point 1 on the demand axis.

When a congestion toll is imposed with a value equal to the external delay cost caused by the marginal runway system user, the new equilibrium is at 2, the point where the demand function *D* intersects the total cost curve *T*. Thus, the new equilibrium level of demand is equal to *B*. The demand has been

reduced by an amount equal to *(A-B)* because of the congestion toll. In turn, the congestion toll is equal to the external cost corresponding to a demand equal to *B*, to *(x-y)* in Figure 2-19. The total amount collected from congestion tolls is *B(x-y)*, the area corresponding to the rectangle *yx2B'* in Figure 2-16.

2.7.4.2 Practicalities of Congestion Pricing

The practicalities of implementing congestion pricing and the types of congestion pricing that were implemented in Europe and in the United States are examined looking specifically at why they were unsuccessful and are discussed in chapter 5 below. This section provides a broad overview of the practicalities of congestion pricing.

The application of the theory of congestion pricing to airports is a challenging undertaking. At a technical level, it is difficult to estimate accurately the marginal external cost for any given level of demand. It is more difficult to predict the exact effect of any proposed system of congestion tolls on demand. De Neufville and Odoni (2003:480) attribute this difficulty to limited existing information about the elasticity of airport demand with respect to the landing fee (Cao and Kanafani 2000). Consequently, it is also difficult to determine the size of the landing fees that will lead to a stable situation that will not drive away too many or few users (Odoni 2001).

The principal practical problem is more often a political one. The impact of congestion pricing is most severe on general aviation and on regional airlines. These two classes of users are the ones that can least afford to compensate others for external cost and oppose congestion pricing as being discriminatory against them.

Smaller and remote communities, which depend on regional airlines for access to major airports and to the national and international aviation

systems, typically join in opposition. The major airlines often find themselves in an ambivalent position in this respect. In principle, these carriers stand to benefit the most from congestion pricing. When the traffic mix includes flight operations by general aviation, regional airlines, and the major carriers, the application of congestion pricing reduces significantly delays to major carriers, by "driving away" from the peak traffic hours many general aviation and regional airline operations.

As a result, major carrier operations face reduced costs, even after paying the higher landing fees. Yet major airlines, especially in the United States, have assumed a stance on congestion pricing that ranges from guarded to adversarial. There are several reasons for this stance. Many major carriers have alliances with regional and commuter airlines or even own such airlines as subsidiaries and are reluctant to support measures that are perceived as detrimental to them. Major carriers at busy airports also benefit from "feeder" traffic carriers by smaller aircraft to and from smaller communities. Such flights may be affected or inconvenienced by congestion pricing (De Neufville and Odoni 2003:480).

According to De Neufville and Odoni (2003:481), the consequences of practical and political considerations, are that congestion pricing mechanisms that have been proposed or have been implemented are far less sophisticated than the theory suggests.

They also generally impose or propose congestion tolls that are much lower than the true marginal external cost at congested airports suggest. Their congestion pricing schemes involve one of the following approaches:

- A *surcharge* is applies to the weight-based landing fee paid by aircraft operating during the airport's peak period(s);

- A *flat fee*, entirely or partly independent of the aircraft's weight, is imposed on all aircraft operating during the peak period;
- A *multiplier* is applied to the weight-based landing fee charged to aircraft operating during the peak period and;
- A *minimum landing fee* is specified for aircraft operating during peak hours, to be applied only to aircraft that would otherwise have paid less than that amount.

2.7.5 Hybrid approaches to demand management

The starting point for all hybrid systems is the determination by some administrative authority of the number of slots to be made available at an airport. However, instead of, or in addition to schedule coordinators, hybrid systems rely on such economic devices as congestion pricing, slot markets and slot auctions to arrive at the final allocation of slots among potential airport users (De Neufville and Odoni 2003:486).

These three economic devices will be reviewed in the following section.

2.7.5.1 Slots plus congestion pricing

According to de Neufville and Odoni (2003:487) the application of this method involves the following steps:

- "Declare" the airport capacity by specifying the number of slots available in each time period;
- Develop and announce a schedule of landing fees and possibly other airport charges that vary by time of day and/or day of week and/or season;
- Invite requests for slots from prospective users; and

- Use a schedule coordinator or other administrative mechanism to allocate slots, whenever the number of requests for a time period exceeds the number of available slots.

They point out that the main difference between this and the purely administrative schedule coordination approach is that prospective airport users must now also consider the cost of access to the airport at different times when preparing their requests for slots. The higher cost of access during peak periods may dissuade some prospective users from requesting slots these times.

2.7.5.2 Buying and selling slots

This method treats airport slots as a commodity that can be bought and sold. Once the number of slots available has been specified and the slots have somehow been allocated to prospective users, they become the property of their current holders, who may continue utilizing them for the operation of their own flights, lease them to another user, or sell them just like any other asset (De Neufville and Odoni 2003:489).

An important part of this hybrid system is a clear explanation of the extent and duration of the rights inherent in a slot. The buy-and-sell approach, as well as the slot auction, enjoys an advantage over congestion pricing in at least one respect. Whereas congestion pricing has difficulty in determining, a priori, equilibrium congestion fees, buy-and-sell and slot auctions permit these prices to be determined directly by the market.

2.7.5.3 Slot auction

This method uses auctions to allocate slots. The following section gives a summary of the main steps involved:

- Provide a clear explanation of the extent and duration of the rights inherent in a slot;
- The capacity of the subject airport, the number of slots available in each time period is specified. Let the capacity per time period be equal to *C* slots;
- Airlines and other prospective airport users submit sealed bids for the slots they wish to obtain. A bidder can request more than one slot in any time period and can offer a different amount for the different slots;
- After all the bids are received, the slots in each time period are awarded to the *C* highest bidders. If there are fewer than *C* bids for a particular time period, then all slots requested for that time period are accepted;
- The price that a user actually pays for an awarded slot is set equal to the lowest successful bid in each time period. The rationale is that two successful bidders should not end up paying different amounts for slots that fall within the same time period.

According to De Neufville and Odoni (2003), there is no precedent that exists for the allocation of airport slots through auction. There is complexity with the slot auctions in the airport context that stems from the strong interdependence of slots, both at the local level and across airports. Because of these strong interdependencies, the true value of the slots acquired will not be clear to an airline until all the slots are allocated.

At that point, the airline will probably wish to dispose of some of the slots it has been awarded, revise the price it has offered to pay for others, and possibly acquire some additional slots.

De Neufville and Odoni (2003:492) argue that, to make such post-auction adjustments possible, a follow-up slot market is needed. This follow-up

market is, in fact, an indispensable part of any demand management system based on auctions. Thus, a more viable hybrid system may be one in which the slots at an airport are auctioned off to the highest bidder by the airport operator and/or by a civil aviation organization and they become commodities that can be bought and sold.

2.7.6 Quantitative impact of demand management

According to Fan and Odoni (2001:2), various approaches to demand management have been suggested in the research literature, but few studies have provided quantitative evidence on two important questions:

- The magnitude of the impact that demand management may have;
- The extent to which the current weight-based landing fee systems under-price airside access to busy airports.

Fan and Odoni (2001), address in quantitative terms these issues, using tools drawn from queuing theory. They discuss the question of the relative impacts of reductions in the total demand at an airport compared with a shifting in the distribution of demand by time of day. They then demonstrate how at congested airports, the current system of assessing weight-based landing fees contributes to congestion by greatly under-pricing access to a busy airport runway.

Their analysis suggests that, in the short-run, well designed demand management schemes can be more effective than any other types of alternatives, in relieving congestion. They further propose a framework for assessing demand management alternatives and developing future policies.

Figure 2-17 shows the combined take-off and landing profiles by hour-of-day on a typical weekday at LGA in November, 2000 and in August, 2001. Between these two months, the total number of scheduled airline operations

decreased by about ten percent (from 1348 per day to 1205 per day) primarily as a result of the lottery results that became effective on January 31, 2001.

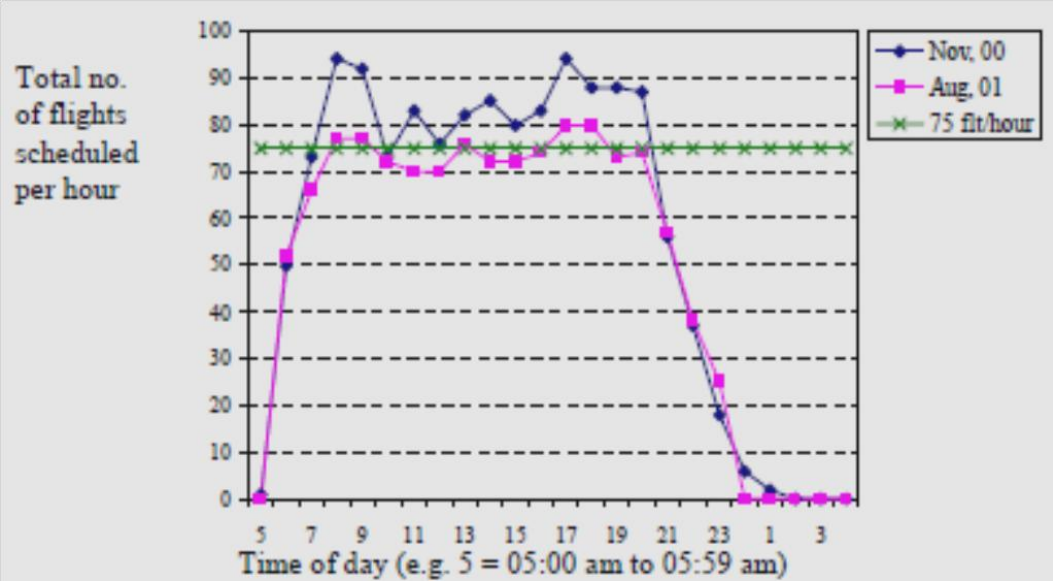


Figure 2-17: Flight operations at LGA before and after slot lottery. Fan and Odoni (2001:6)

Figure 2-18 compares average delay per flight, using the flight schedule in November, 2000 and August 2001. Each flight scheduled to depart or arrive at the evening peak period between 8pm and 10pm in November can expect to be delayed for one hour and twenty minutes, even if the VFR capacity is maintained throughout the day (highest numbers of runway movements are achieved under VFR). By contrast, flights scheduled to operate during the same period in August are delayed for an average of twenty minutes per flight. This represents an 80 percent reduction in delays during peak evening hours.

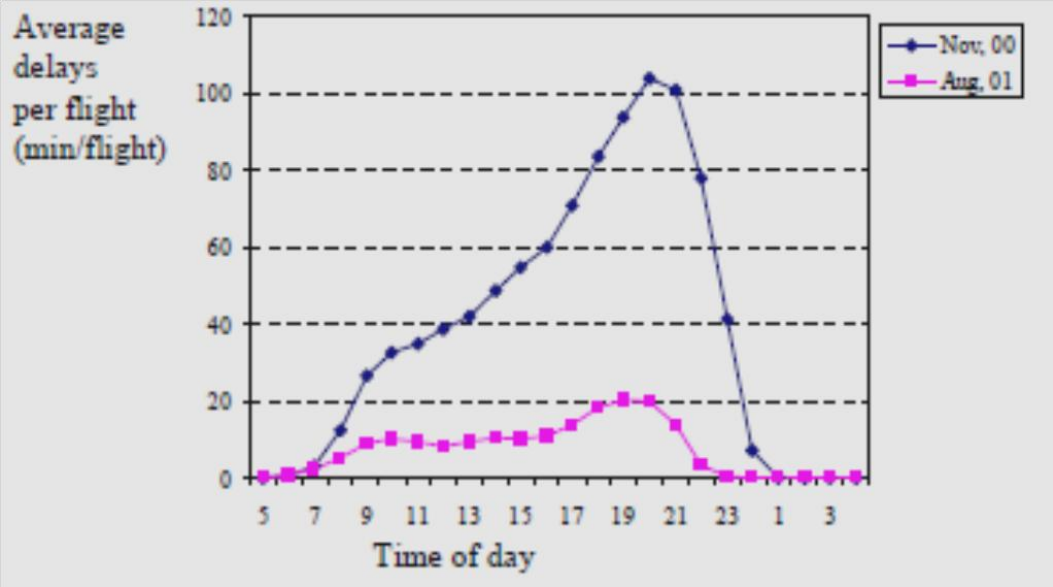


Figure 2-18: Average flight delays at LGA before and after slot lottery. Fan and Odoni (2001:6)

Figure 2-19 shows the total delay in aircraft-hours during the day, suffered by operations scheduled in each hour. Similar to average delays, the total delay during evening peak hours rose beyond 140 aircraft-hours in November, compared with about 25 aircraft-hours in August for the same time period. According to Fan and Odoni (2001:3), the area under the August aircraft delays in Figure 2-19, representing the total delays for the entire day, totaled 210 aircraft-hours, compared with 1160 aircraft hours for the November schedule.

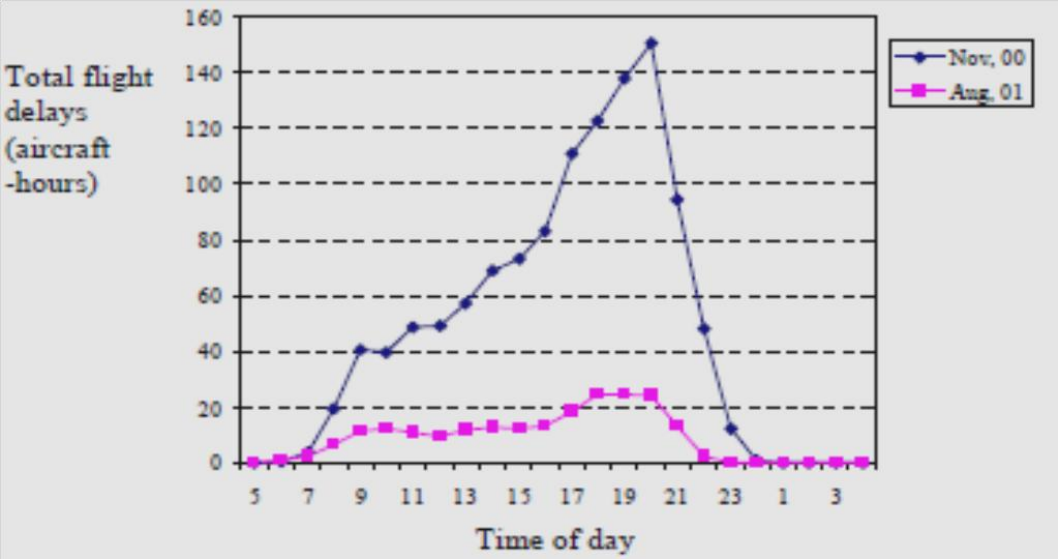


Figure 2-19: Total flight delays at LGA before and after lottery. Fan and Odoni (2001:6)

It is important for the airport to accurately determine its true capacity in handling aircraft operations. For a congested airport with demand for runway capacity close to or above its supply, the amount of delay is sensitive to the precise capacity number used. Figure 2-20 and Figure 2-21 show how the average and total delays in August, 2001 at LGA vary, if the capacity is at five operations per hour above and below the 75 operations per hour capacity used in the analysis. Reducing the 75 operations-per-hour capacity by five per hour increases the total delays between 6pm and 9pm from 73 aircraft-hours to almost 200; increasing the capacity by five per hour halves the total delays to about 30 aircraft-hours (Fan and Odoni 2001:3).

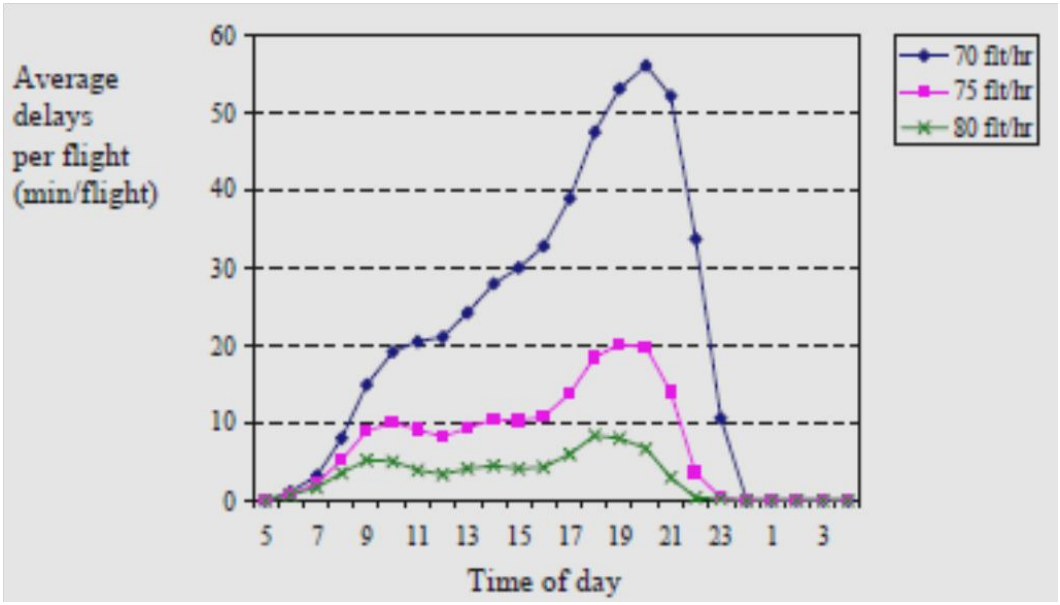


Figure 2-20: Average flight delays at LGA under different capacities. Fan and Odoni (2001:7)

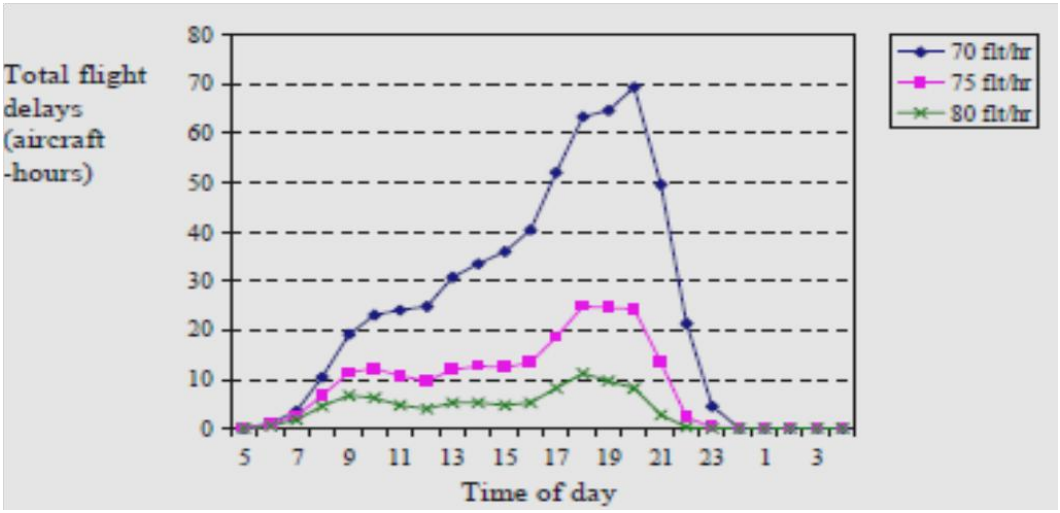


Figure 2-21: Total flight delays at LGA under different capacities. Fan and Odoni (2001:7)

Flight delays can be reduced by leveling demand peaks, after the overall demand has been reduced to the level experienced in August 2001. Figure 2-22 shows what the flight operations profile at LGA would look like in the case in which demand is evenly distributed throughout the period between seven in the morning and ten in the evening (72 and 73 operations/hour during this period).

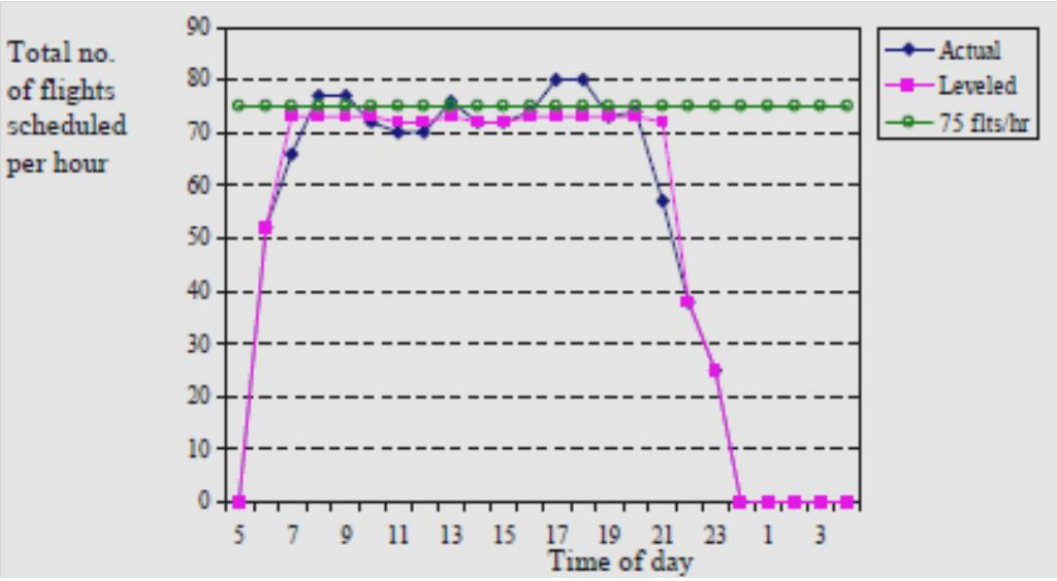


Figure 2-22: Leveling the hourly distribution of flight at LGA from August schedule. Fan and Odoni (2001:8)

As shown in Figure 2-23 and Figure 2-24, the average and total delays resulting from the de-peaking of flights are reduced by a further 40 percent during peak evening hours and 20 percent during the morning peak hours. Compared with the actual August schedules, this reduced the total delays on the typical weekday from 211 aircraft-hours to 168 aircraft-hours, representing a 20 percent reduction.

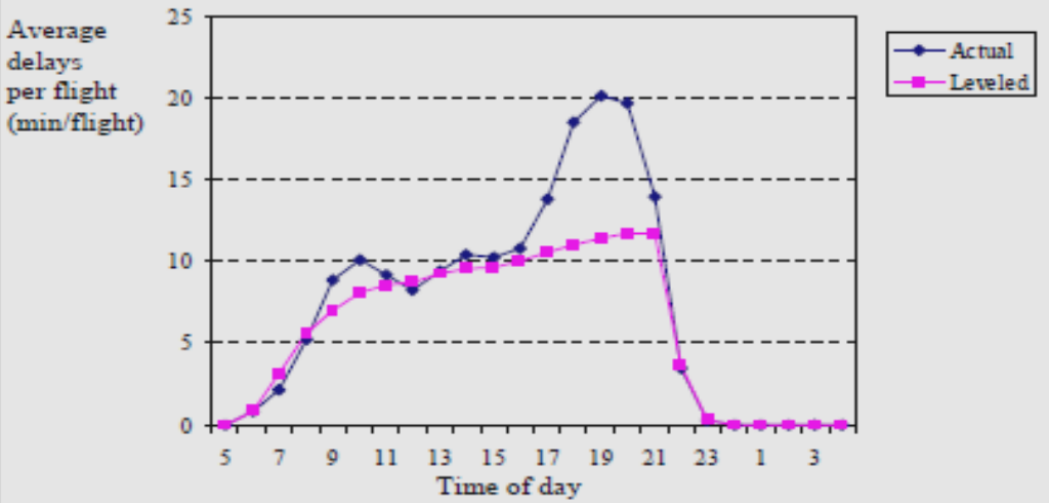


Figure 2-23: Average flight delays for leveled distribution of flight from August Schedule. Fan and Odoni (2001:9)

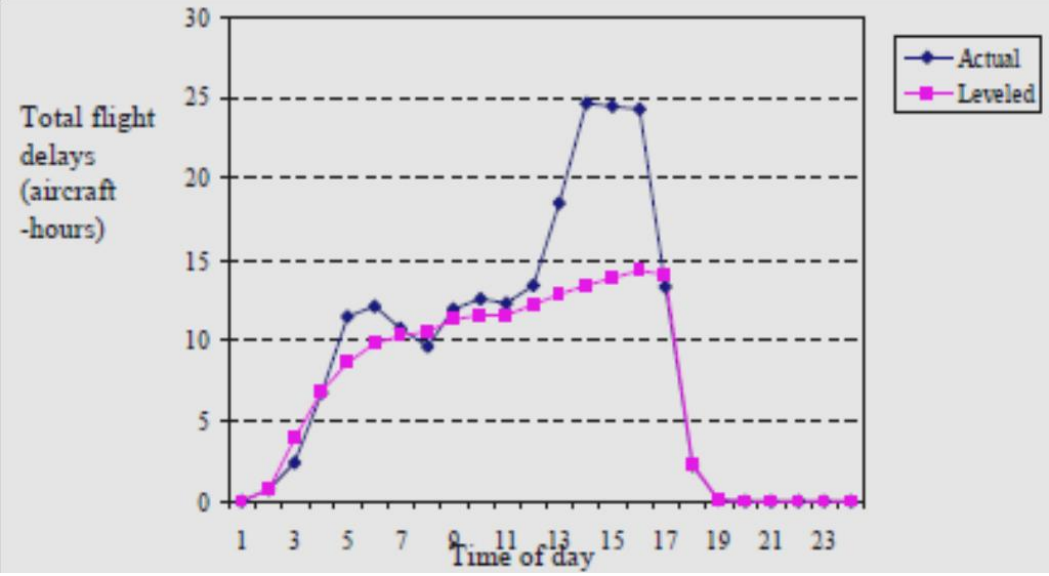


Figure 2-24: Total flight delays for leveled distribution of flight from August flight schedule. Fan and Odoni (2001:9)

To arrive at an order-of-magnitude estimate of the marginal cost of congestion, an average per-hour flight operating cost is used. From published

airline schedules, an average fleet size at LGA is 102 in seating capacity and 52 000kg in maximum take-off weight, corresponding roughly to a Boeing 737 aircraft. Using an estimate of $1600/hour operating cost for an aircraft of this size, the marginal delay costs is computed from Figure 2-18. The resulting marginal delay cost curve for the August 2001 schedule shown in Figure 2-25 can then be compared with the airport charge for each flight operation. As shown in Figure 2-25, from 8am to 8pm, the marginal delay cost caused by an extra flight operation is ten to twenty times as large as the average airport charge (landing fee levied 2001). Runway access at LGA is under-priced for most of the day and this, in part, contributes to the observed flight delays.

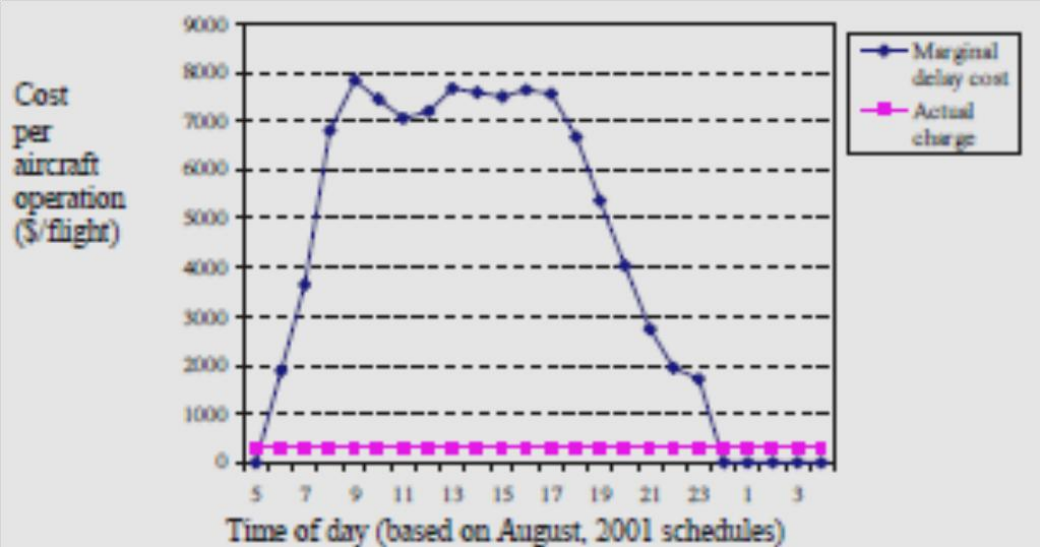


Figure 2-25: Comparison between marginal delay costs and actual charges at LGA. Fan and Odoni (2001:10)

Figure 2-29 illustrates the notional amount of flight delay reductions that may be achieved through a range of measures at airports with different demand-to-capacity ratios. On the far right is the case where the demand for airport runway access is close to or above the maximum (sustainable VFR) capacity

all day. For airports in this category, a significant fraction of delay can be eliminated by reducing the total demand for the runway access.

A mere leveling of the demand at such airports without reducing total demand to a level at or below the sustainable capacity will not be particularly effective. Reducing total demand requires relatively strong demand management actions, such as the imposition of a flat surcharge on landing fees for the greatest part of the typical day (Fan and Odoni 2001:4).

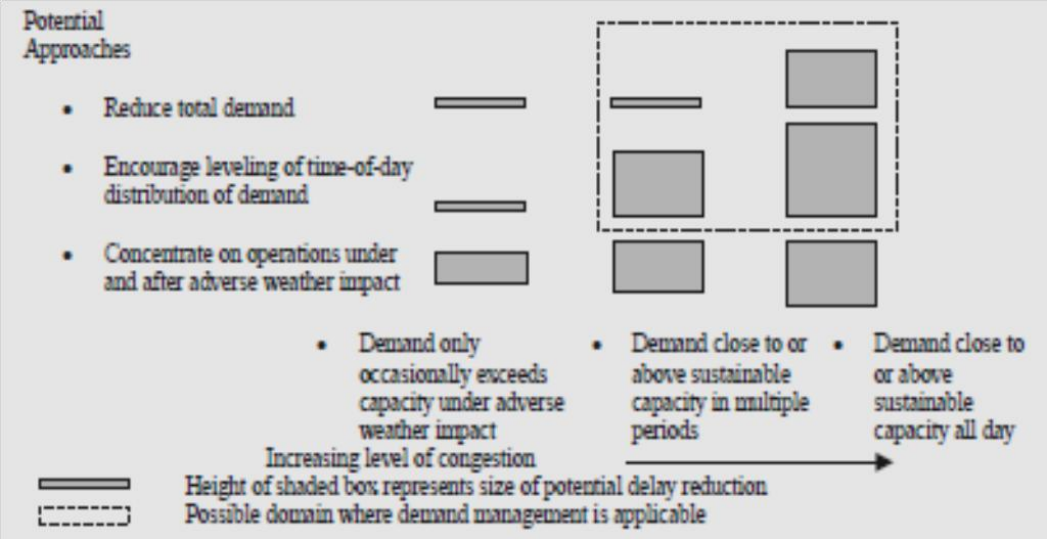


Figure 2-26: Notional illustration of delay reduction for different airports. Fan and Odoni (2001:10)

At airports where the demand is close to, or above, maximum capacity for only some periods of the day, a mere leveling of peak-period demand will lead to a sizable reduction in delays. Policy actions, such as mild forms of demand management, encouraging the shift of peak-period demand to non-peak periods; without significantly reducing the total demand; may be sufficient. At airports with low demand-to-capacity ratios throughout the day demand management measures are not appropriate.

The optimal use of a congested facility is achieved only if each user pays for the marginal (“internalized”) costs they impose on all other users. For airports where there is a large number of high-volume users (or low industry concentration) operating non-homogeneous, point-point services, the extent of such internalization is limited. Economic demand management measures can be very effective in moving towards a more efficient operating point in such cases. By contrast, at airports dominated by only one or two high-volume users (airlines with hubs there) operating connecting services, the high-volume users already internalize a substantial portion of the marginal costs. Economic demand management measures may therefore not be effective in these environments (Fan and Odoni 2001:5).

This section discusses the various demand management approaches and highlights the challenges associated with the practicalities of implementing them. It demonstrates quantitatively the possible gains that could be achieved by the application of demand management. According to the scholars, none of the approaches described above fully satisfies all the requirements for an ideal demand management system. However, for a specific set of circumstances, certain approaches are superior and more suitable than others. For policy-setting purposes, the traditional weight-based landing fees do not take into consideration the costs associated with airport congestion. In fact, the weight-based fees contribute to congestion, by lowering the cost of airport access as demand grows and by encouraging users with low direct operating costs and low value of time to use busy airports.

Demand management is not by any means intended to replace future airport developments. It primary role is to regulate demand for service on a system. It achieves this by through efficient utilization of existing facilities, limiting the growth in peak demand and by channeling some peak demand to off peak

periods. Economic theory suggests that channeling demand to off peak periods is nearly impossible in practice as demand for air travel specifically from the business sector is highly in-elastic.

De Neufville and Odoni (2003) contradict these findings by pointing out the changes in the travel patterns in the US following the events of 9 September 2001. This demonstrates that price on its own will not significantly alter travel patterns to achieve significant changes in travel patterns.

The argument by some scholars that demand management is unnecessary because delay will by itself act as an access-control mechanism might be justified. De Neufville and Odoni (2003) argue that the equilibrium reached this way will be inefficient economically. This might be the case in the short term, depending on how much delay cost the individual airlines are willing to incur. This will further eliminate the need for the airport authorities to quantify runway capacity and to administratively manage slot allocation as these will be done by the market. From an ACSA point of view, the responsibility to determine airport capacity could shift from ACSA to the airlines or ideally it could be a collective amongst all airport stakeholders.

Theory on congestion pricing expresses a qualitative view of runway congestion pricing: it does not address the fundamental issue of what is the actual congestion charge should be set at. De Neufville and Odoni (2003) attribute the difficulty of quantifying marginal cost for a given demand to the lack of sufficient information about the elasticity of airport with respect to landing charges.

The market based approach (“do nothing”) option will also eliminate most of the practicalities of congestion pricing. Hybrid Demand Management,

although it addresses some of the weakness inherent in the purely economic approach, does not specify how to deal with existing slot holders.

Fan and Odoni (2001) studied quantitatively the impact of the various demand management approaches. Their findings are consistent with the literature on demand management. They were able to demonstrate quantitatively the reductions in aircraft delays achieved at LGA by the introduction of a lottery system. The study, however, focused on the outcomes of a lottery system applied at one airport. Whether similar results will be achieved for other demand management approaches has not been tested.

From their study one can infer that, given the current levels of traffic at ORTIA, demand management measures are not appropriate at present as the demand-to-capacity ratio throughout the day is relatively low. However, the traffic levels at ORTIA are expected to grow in the next five to ten years to a level where maximum capacity for certain periods of the day will be exceeded. De Neufville and Odoni (2003) recommend levelling of the peak-demand through policies such as “mild” forms of demand management.

3 TRAFFIC OVERVIEW

3.1 Introduction

This section outlines the global view and trends of air traffic growth. It is intended to highlight the fact that global air traffic in general and ORTIA in particular is expected to grow, putting further strain on existing airport infrastructure. Airports Council International (ACI) conducted a survey that covered 230 airports from large to small covering all aviation significant regions in the world. In the survey, participants were asked to indicate whether or not their traffic forecasts were constrained by airport capacity limits. The results indicate that about 60 percent of the respondents produced an unconstrained forecast as indicated in Figure 3-1. The unconstrained forecast could be attributed to the considerable investments in infrastructure that airport authorities are planning in the medium to long term.

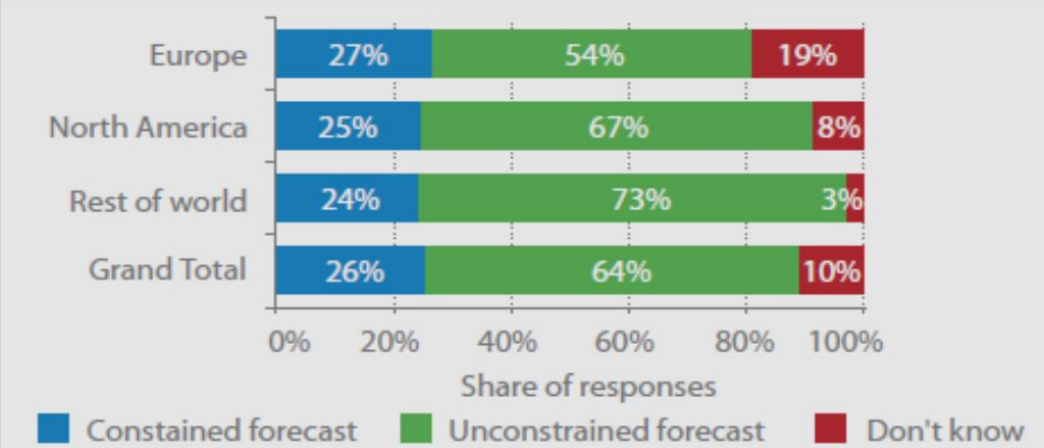


Figure 3-1: Share of constrained vs. unconstrained forecasts by world region. ACI (2007:11)

For the airports facing constraints the survey attempts to determine their source.

Noise constraints are significant in Europe and in North America, while terminal capacity is an important issue for North American airports. For airports in the rest of the world, the apron is often the most important as indicated in Figure 3-2. Although runways are not singled out as major capacity constraints in the survey, it is apparent from the literature review that they are a major obstacle to airport growth.

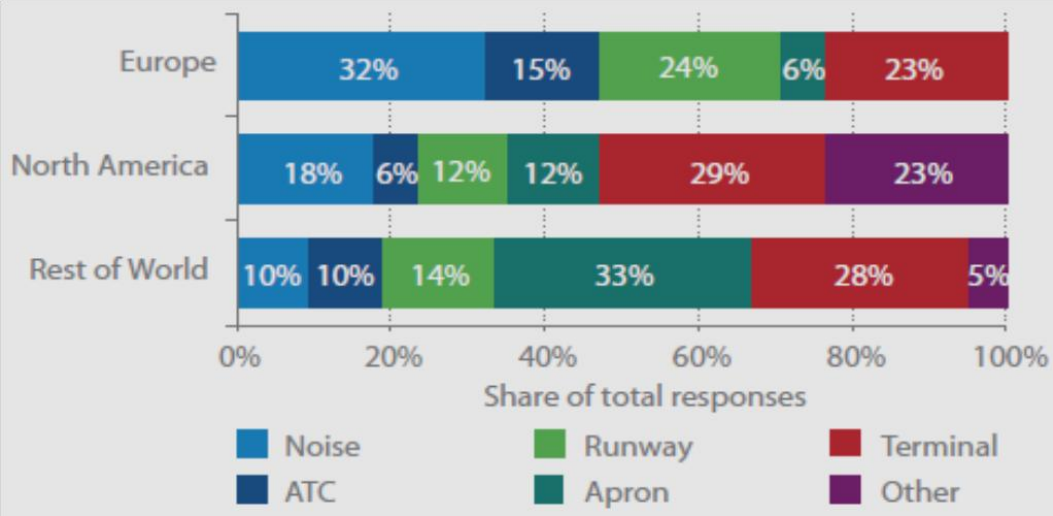


Figure 3-2: Sources of constraints by world regions. ACI (2007:11)

The survey also covers the status of the airport regarding the granting of slots. In general, larger airports tend to be fully coordinated (69 percent) and a substantial proportion of small airports are non-coordinated (37 percent) as indicated in Figure 3-3. (ACI 2007: 11-23).ORTIA is classified as fully coordinated.

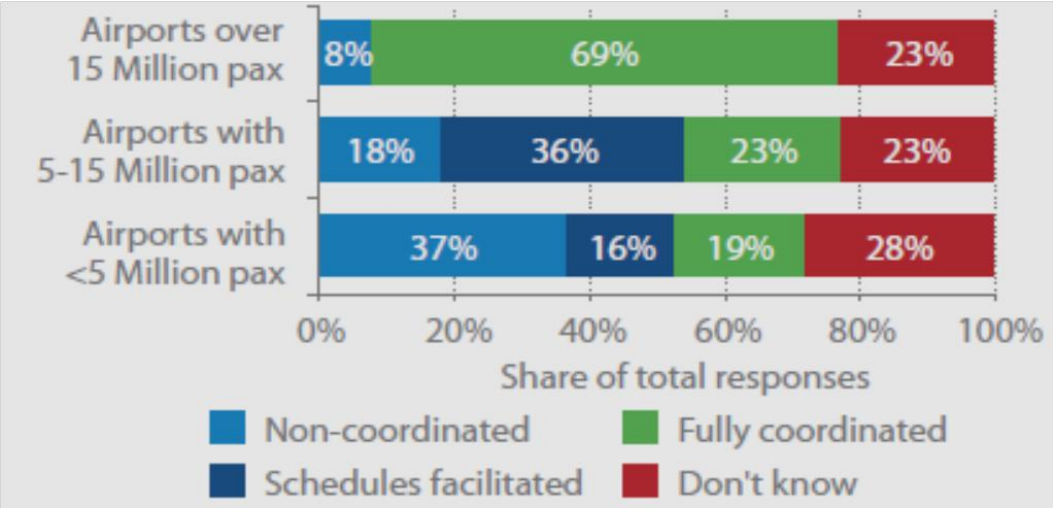


Figure 3-3: Airport status in terms of coordination of schedules. ACI (2007:23)

3.2 Passenger Forecast

In 2006, the twenty year global passenger growth rate was forecast to average four percent. Air transportation growth is predicted to be fuelled by a combination of economic growth, liberalizing markets and increased competition. Africa lags behind the rest of the world in terms of passenger numbers as indicated in Figure 3-4 and Table 3-1 to Table 3-3.

Africa is however expected to experience higher growth rates compared to the US and Europe because its aviation market is relatively “immature” compared to these regions. Although Africa’s economic growth is expected to be higher than the economic growth in these regions, Africa’s overall aviation market is expected to contribute less than 10 percent of the global market. One of the main reasons is that the African aviation market has not yet been fully liberalized.

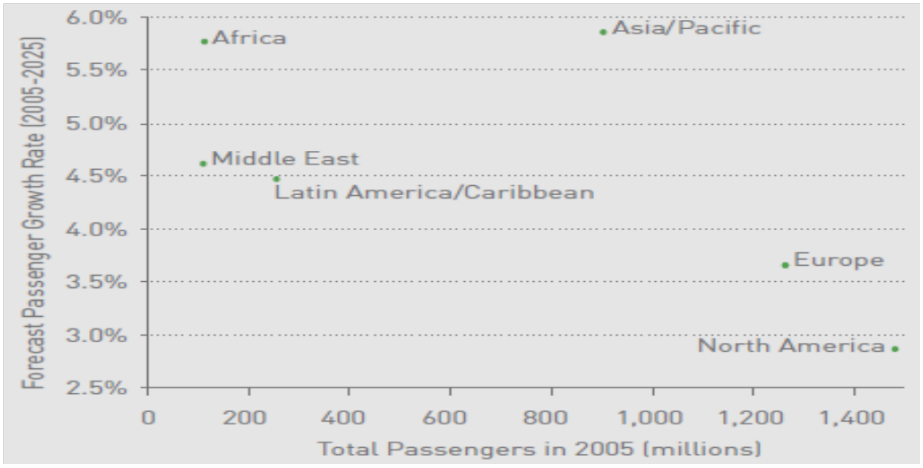


Figure 3-4: 2005-2025 passenger forecast vs. passenger volume. ACI (2007:12)

	2005	2006	2007	2008	2009	2010	2015	2025	Share 05	Share 10	Share 25
Africa	111.1	119.8	130.2	139.9	150.1	160.1	209.7	342.1	2.7%	3.1%	3.8%
Asia/Pacific	901.0	977.5	1,061.8	1,145.9	1,234.3	1,318.0	1,742.3	2,786.6	21.9%	25.1%	30.6%
Europe	1,261.4	1,340.2	1,412.0	1,476.6	1,538.4	1,603.3	1,912.3	2,562.6	30.7%	30.5%	28.2%
Lat Am/Caribbean	254.2	270.0	288.5	303.7	318.7	334.6	416.5	610.9	6.2%	6.4%	6.7%
Middle East	105.3	118.7	127.0	133.7	140.2	146.3	178.6	259.9	2.6%	2.8%	2.9%
North America	1,481.6	1,491.2	1,546.0	1,593.2	1,641.9	1,692.5	1,948.8	2,533.2	36.0%	32.2%	27.9%
World	4,114.8	4,317.4	4,565.3	4,793.2	5,023.7	5,255.3	6,408.1	9,095.3	100.0%	100.0%	100.0%

Table 3-1: Total passenger volume in (million). ACI (2007:14)

	2005	2006	2007	2008	2009	2010	2015	2025	Share 05	Share 10	Share 25
Africa	42.2	43.8	46.4	48.4	50.4	52.3	62.3	87.1	1.7%	1.7%	1.7%
Asia/Pacific	556.6	608.1	667.8	728.4	792.2	851.0	1,148.8	1,849.3	22.9%	28.1%	36.5%
Europe	351.6	370.0	385.5	398.1	407.9	422.8	482.2	593.9	14.4%	13.9%	11.7%
Lat Am/Caribbean	156.8	168.9	180.7	190.4	199.4	208.8	256.6	369.9	6.4%	6.9%	7.3%
Middle East	24.3	25.7	26.5	27.2	27.8	28.3	30.8	35.7	1.0%	0.9%	0.7%
North America	1,302.9	1,303.7	1,349.2	1,387.7	1,427.3	1,468.4	1,674.9	2,135.1	53.5%	48.4%	42.1%
World	2,434.4	2,520.3	2,656.1	2,780.2	2,905.0	3,031.6	3,655.6	5,071.0	100.0%	100.0%	100.0%

Table 3-2: Domestic passenger volumes in (millions). ACI (2007:15)

	2005	2006	2007	2008	2009	2010	2015	2025	Share 05	Share 10	Share 25
Africa	69.0	76.0	83.8	91.5	99.7	108.2	147.3	254.9	4.1%	4.9%	6.3%
Asia/Pacific	344.5	369.3	394.0	417.5	442.1	467.0	593.6	937.3	20.5%	21.0%	23.3%
Europe	909.9	970.2	1,026.5	1,078.5	1,130.5	1,180.4	14,30.1	1,968.7	54.1%	53.1%	48.9%
Lat Am/Caribbean	97.3	101.1	107.8	113.4	119.3	125.8	159.9	241.0	5.8%	5.7%	6.0%
Middle East	81.0	93.0	100.5	106.5	112.4	118.0	147.9	224.2	4.8%	5.3%	5.6%
North America	178.7	187.5	196.7	505.5	214.6	224.1	273.8	398.1	10.6%	10.1%	9.9%
World	1,680.3	1,797.1	1,909.2	2,013.0	2,118.6	2,223.5	2,752.6	4,024.2	100.0%	100.0%	100.0%

Table 3-3: International passenger volumes by region (million). ACI (2007:16)

3.3 Aircraft movement forecast

To meet rising passenger and freight demand, aircraft movements are expected to grow. Movements will nearly double, requiring not only new airport infrastructure but also investment in en-route and terminal air-traffic control systems. Figure 3-5 indicates the expected growth rate in aircraft movements internationally.

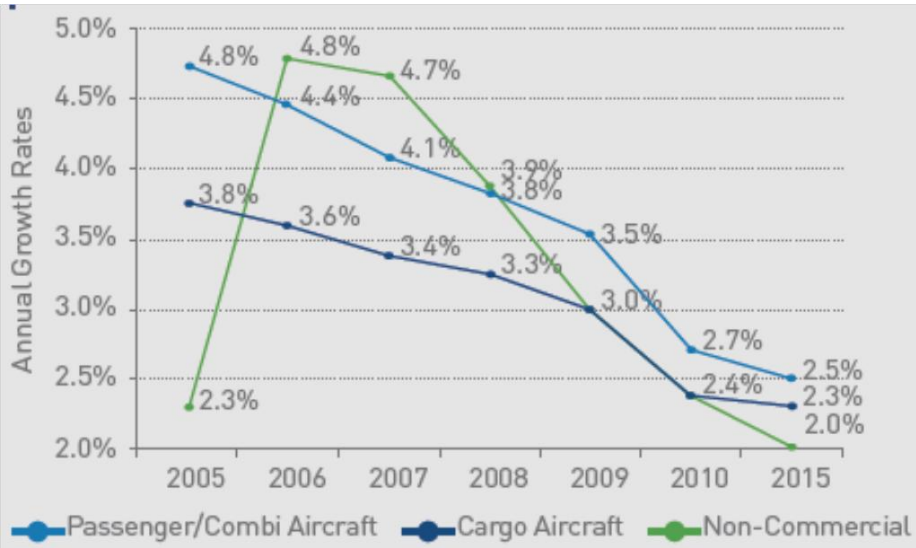


Figure 3-5: Projected annual growth rates of world aircraft movements. ACI (2007:21)

In the first quarter of 2011, ACSA commissioned ACI to undertake a review of the busy day traffic profiles at ORTIA, taking into account the most recent trends in air traffic developments in South Africa. From Figure 3-6, ORTIA has two distinctive aircraft movement peaks in the morning between 7:00 and 11:00 and in the afternoon between 14:00 and 17:00.

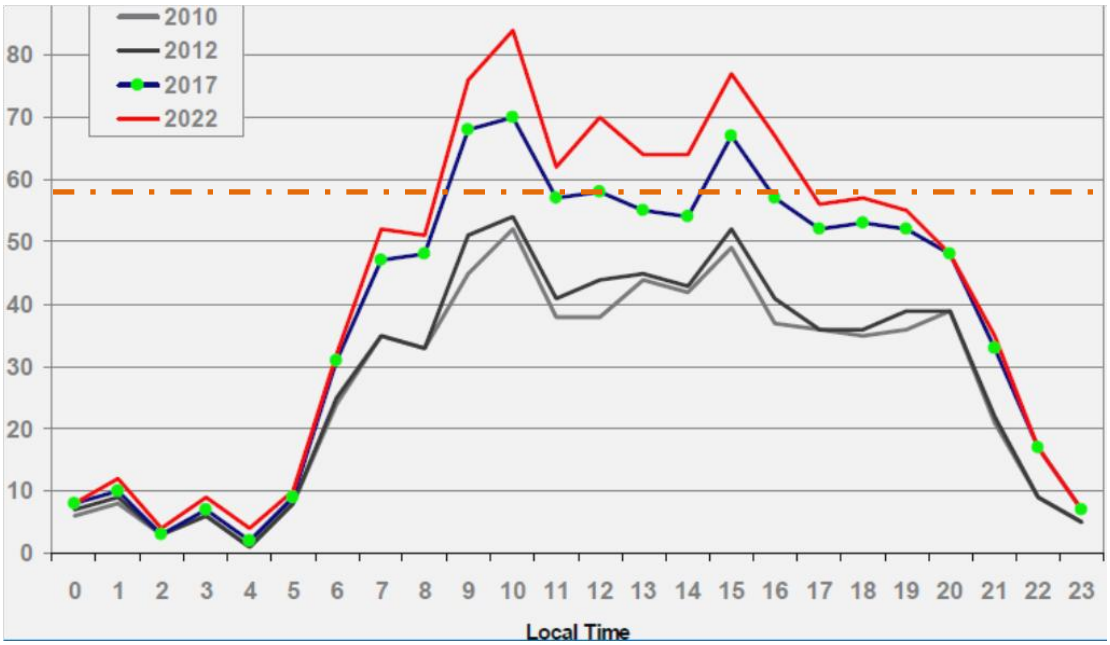


Figure 3-6: Busy day hourly distribution of aircraft movements. ACI (2011:28)

The declared capacity of the existing runway at ORTIA is roughly 58 movements per hour as indicated in Figure 3-6 by the orange dashed line. The declared capacity is expected to be exceeded by 2017. Aircraft arriving or departing between 9:00 and 11:00 in the morning and 15:00 and 17:00 in the afternoon from year 2017 can expect to encounter delays. By 2022, the expected delays will be more severe and will occur almost throughout the day between 8:00 in the morning and 18:00 in the evening. ACSA plans to invest in excess of R 3 billion on a new runway with it associated taxiways by 2017 to alleviate the expected congestion. The objective of this research report is to investigate alternative methods of alleviating the expected congestion with the aim of deferring the planned capital investment or possibly reducing the required scope.

3.4 Aircraft size forecast

Orders for the largest aircraft, the Airbus A380 and the Boeing B787, could change the configuration of the global fleet and increase average passengers per movement. This coupled with higher load factors means the forecast anticipates an increase in passengers per movement. Three factors help explain this trend: the “low cost carrier” model development centered around single aisle aircraft (one class configuration with about 150 seats); the fact that “low cost carriers” operate at a higher load factor than their counterparts; and finally a more rapid development of international operations compared to domestic operations. (ACI 2007:11-23). ORTIA is much further from international markets compared to its global counterparts. Furthermore, SA cities are on average much futher apart, therefore, “low cost carriers” operating from ORTIA are focusing more on domestic and regional operations.

From Figure 3-7, in 2005 Africa had an average of 73 passengers per aircraft movement. This figure is projected to grow to 114 passengers per movement. ORTIA is currently performing better than the current average for Africa at roughly 97 passenger per movement (ACSA 2011).

This could be attributed amongst other thing to ”low cost carrier” activities and the introduction of the A380.

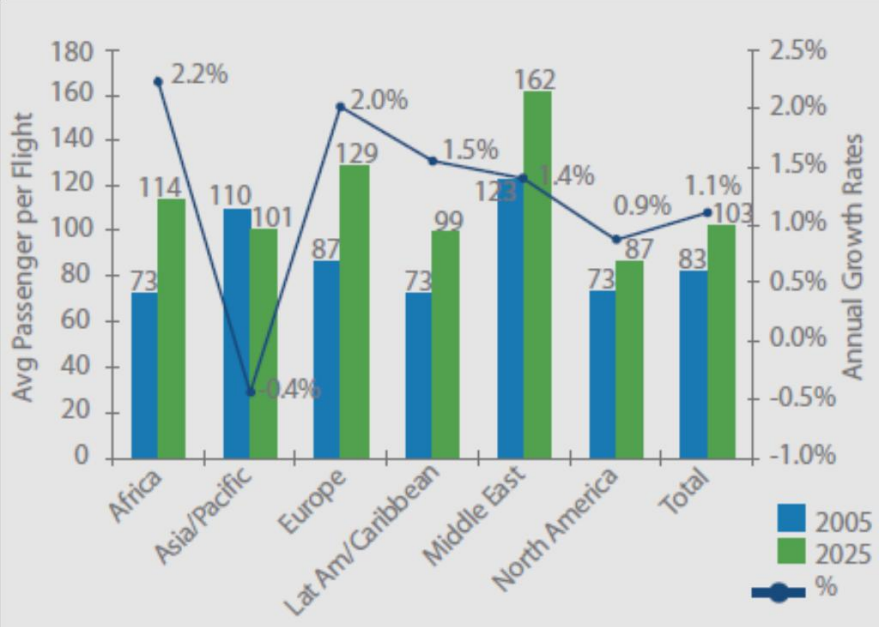


Figure 3-7: Average number of passengers per flight by region-total passenger operations. ACI (2007:22)

4 POLICY OPTIONS TO SLOT ALLOCATION

4.1 Background

This section highlights previous research work that has been conducted with regard to the compatibility of alternative slot allocation strategies in different airport settings. The literature review has identified slot allocation as one of the major contributors to alleviating runway congestion and has proposed a number of strategies for slot allocation. According to Madas and Zografos (2006:209-211), a number of distinct airport slot allocation strategies are identified as:

- Status quo with recycling and centralised trading of the pool ("enhanced status quo-strat.1");
- Grandfather rights with recycling, auctioning of the pool, and secondary trading ("gradual-strat.2");
- Grandfather rights with full trading of all slots ("controlled trading-strat.3");
- Congestion based pricing strategy ("congestion pricing-strat.4");
- Removal of grandfather rights accompanied by decentralised auction and secondary trading ("Big Bang with auctions and secondary trading-strat.5").

The above strategies introduce varying application of market-driven allocation instruments in the following three aspects:

- Context (decentralized auctions, centralised trading, full trading, secondary trading, pricing);
- Scope (primary versus secondary);
- Extent (centralized trading, controlled trading, full trading).

Table 4-1 sketches the identified airport slot allocation strategies along with their key features, rules and components, the “Enhanced Status Quo” strategy (Strat.1) involves minimum departure from the existing system on the grounds that it fully maintains the overriding principle of historic slot holdings based on “grandfather” rights. It retains the rationale of administrative coordination of slot allocation in conjunction with primary slot trading (coordinated trading).

The “Gradual” strategy (Strat.2) also involves a conservative approach albeit with a more clear orientation to market mechanism and a slightly more drastic revision of the status quo with regards to secondary allocation. In principle, it also retains the grandfather rights in the primary allocation process. However, it attempts an application of market-driven mechanisms (auctions, monetary trading). Apart from “grandfather” rights, all remaining slots are auctioned at the airport level with monetary trading between airlines also being allowed on a secondary level.

The “Controlled Trading” strategy (Strat.3) combines conservative and innovative elements. It retains the principle of “grandfather” rights with minor modifications and adaptations, but simultaneously allows full (primary and secondary) monetary trading based on bilateral negotiations either between the airport and airlines (primary trading) or between airlines (secondary trading).

The “Congestion Pricing” Strategy (Strat.4) represents the most direct pricing method for addressing the real cause of mismatch between capacity and demand. Under the congestion pricing strategy, “grandfather” rights are abandoned and a congestion-based scheme is set by an administrative authority in the form of a three-part tariff including:

- The traditional weight based fees and passenger surcharges;
- A flat reservation fee applied per movement in the form of membership dues or “no-show” penalties;
- A congestion based fee with fees varying with congestion throughout the day.

The “Big Bang” strategy (Strat.5) represents the opposite extreme to the “Enhanced Status Quo” and the “Gradual” strategy, in which ”grandfather” rights are abandoned with the entire slot pool being allocated by means of market- based instruments (decentralized auctions accompanied by secondary trading).

Instruments and rules	Strategies				
	Enhanced Status Quo	Gradual	Controlled Trading	Congestion Pricing	Big Bang
Grandfather rights	√	√	√	Removed	Removed
Centralized trading with policy criteria	√				
Primary trading			√		
Secondary trading		√	√		√
Auctions		√			√
Congestion Fees				√	
Recycling	√	√	√		√
Use it or lose it rule	√	√			
Policy-designated slots	√	√	√	√	√
All slots?	(Only pool)	(Only pool)	√	√	√

Table 4-1: Alternative slot allocation strategies. Madas and Zografos (2006:209)

4.1.1 Airport classification strategies

Madas and Zografos (2006:212-215), develop an airport classification scheme in order to identify the various airport environments within which the various strategies could be evaluated.

According to them, different airport environments may exhibit different congestion patterns, delays and traffic characteristics, while they have different objectives and constraints and should comply with different policy priorities. Their clustering variables include the following:

- Declared capacity;
- Traffic volume (aircraft and passenger movements);
- Congestion levels;
- Measures of effectiveness of slot allocation and utilization (misused slots, unsatisfied demand, slot mobility);
- “Grandfathered” over total number of slots.

Table 4-2 details the cluster analysis properties used to develop the airport typology.

Cluster analysis properties and methodological decisions	
Cluster analysis method (Hierarchical vs. K-means)	Hierarchical method (i.e., the resulted classification has an increasing number of nested clusters and the result resembles a phylogenetic classification). It is the most widely used technique, fits better to the specific conceptual problem, and it is simple, fast, and reliable. Moreover, it can be efficiently applied for classifying a reasonable number (e.g., less than 400) of cases (i.e., airports) into groups that are homogeneous within themselves and heterogeneous between each other, while it does not necessitate the *a priori* determination of the number of clusters (required by iterative partitioning such as K-means clustering) (Aldenderfer and Blashfield, 1984)
Agglomerative vs. divisive	Agglomerative method: all cases/airports are initially considered as single-member clusters which are gradually fused to form larger, but still homogeneous clusters
Monothetic vs. polythetic method	Polythetic agglomerative (i.e., based on multiple clustering variables employed in the specific analysis)
Type of clustering variables/data	Interval data (e.g., number of passengers, number of aircraft movements, declared capacity in hourly aircraft movements, percentages/number of slots utilized or grandfathered)
Clustering objects (cases vs. variables)	Cases (i.e., airports)
Clustering sample	"Fully Coordinated" *and* "Schedule Coordination Request" EU airports
Distance vs. similarity measures	Distance measures (due to the type of selected variables, i.e., interval)
Type of distance measures	Squared Euclidean distance
Clustering algorithm	The Complete Linkage ("Maximum or Furthest Neighbor Method") algorithm has been used as the mechanism and rule of measuring distances. The complete linkage method is clearly appropriate for Euclidean distance metrics (Lance and Williams, 1967) and normally produces very tight clusters of similar cases, which conceptually fits with the purposes of the airport typology development process
Software used	The (Hierarchical) Cluster Analysis module of SPSS (version 12.0) has been used as the most widely used, reliable, and extensively validated statistical software package
Data sources	Data for the identified clustering variables have been collected from: (i) ACI Europe, (ii) European Union – Airport Coordinators' Association (EUACA), (iii) national slot coordinators, and (iv) EUROCONTROL Centre for Delay Analysis (CODA)

Table 4-2: Cluster analysis properties and methodological decisions. Madas and Zografos (2006:212)

The following airport clusters emerged according to the framework above:

Cluster 4 "small national airports". The airports included in this cluster are mainly small, satellite or regional airports acting as the spokes of their national airport network.

Cluster 3 "Large National Spoke and Small National Hubs". This cluster contains small and medium-sized airports acting mostly as large spokes of the national airport network (as compared to cluster 4) or small hubs channelling traffic from the national spokes to international hubs and vice versa.

Cluster 2 "Large International Hubs". This cluster contains major, metropolitan airports of the European airport network acting mostly as large international hubs with focus on Intra-European routes and with growing potential to become one of the major European hubs included in Cluster 1. The airports included in Cluster 2 are primary and secondary large hubs of some major European airlines, which use these airports as servers of traffic both between international destinations, as well as between domestic and international destinations.

Cluster 1 "Super Hubs". This cluster represents the largest, busiest and most congested European airports with a worldwide presence and a strategic role in the European airport network.

From Table 4-2, four clusters emerged from the sample of airports highlighted in Table 4-3.

Airport	IATA code	Cluster	Airport	IATA code	Cluster
Helsinki/Vantaa	HEL	4	Brussels	BRU	2
Berlin/Schonefeld	SXF	4	Copenhagen	CPH	2
Berlin/Ternpelhof	THF	4	Dusseldorf	DUS	2
Berlin/Tegel	TXL	4	Munich	MUC	2
Dublin	DUB	4	Stuttgart	STR	2
Turin	TRN	4	Milan/Malpensa	MXP	2
Milan/Linate	LIN	4	Rome/Fiumicino	FCO	2
Milan/Bergamo	BGY	4	Barcelona	BCN	2
Venice	VCE	4	Madrid/Barajas	MAD	2
Florence	FLR	4	Arlanda	ARN	2
Naples	NAP	4	Paris/Charles de Gaulle	CDG	1
Rome/Ciampino	CIA	4	Paris/Orly	ORY	1
Palermo	PMO	4	Frankfurt	FRA	1
London/Stansted	STN	4	Amsterdam/Schiphol	AMS	1
Manchester	MAN	4	London/Heathrow	LHR	1
Vienna	VIE	3	London/Gatwick	LGW	1
Athens	ATH	3	Lyon	LYS	Unclassified
Thessaloniki	SKG	3	Catania	CTA	Unclassified
Lisbon	LIS	3	Faro	FAO	Unclassified
Porto	OPO	3	Funchal	FNC	Unclassified
Alicante	ALC	3	Bilbao	BIO	Unclassified
Fuerteventura	FUE	3	Tenerife Norte	TFN	Unclassified
Gran Canaria	LPA	3	Bromma	BMA	Unclassified
Lanzarote	ACE	3	Eindhoven	EIN	Unclassified
Malaga	AGP	3	Rotterdam	RTM	Unclassified
Palma de Mallorca	PMI	3			
Tenerife Sur	TFS	3			

Table 4-3: Related airport clusters. Madas and Zografos (2006:213)

4.1.2 Policy compatibility assessment

According to Madas and Zografos (2006:216-217) one of the primary policy concerns in implementing a slot allocation strategy is the potential compatibility of alternative strategies (policy compatibility analysis) with different airport settings (airport clusters). They apply an evaluation framework which provides guidance for the selection of the most compatible strategy on the basis of the following:

- Multiple policy criteria and priorities;
- Various groups of stakeholders (policy makers, airlines, airport operators, academic/research experts);
- Different airport clusters.

The model involves the development of *n* hierarchies where *n* signifies the number of resulting airport clusters consisting of the evaluation goal, the relevant policy criteria and indicators, as well as the evaluation alternatives (airport slot allocation strategies) for each airport cluster as depicted in Figure 4-1.

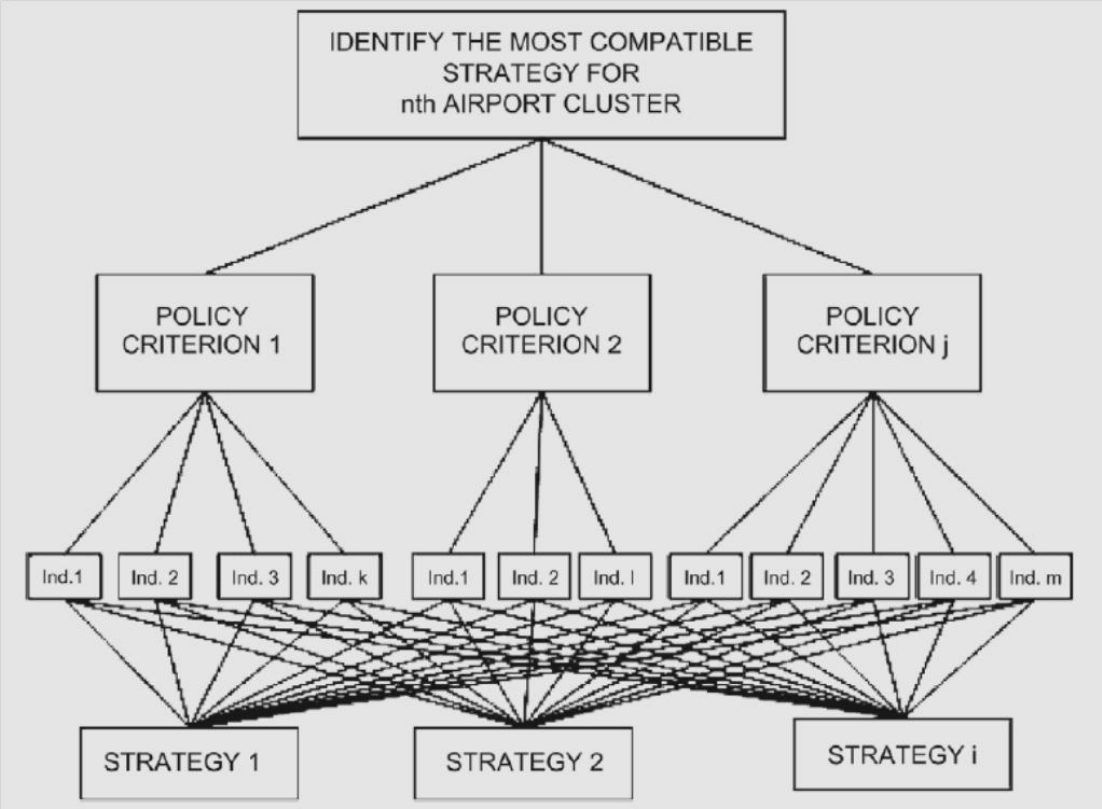


Figure 4-1: Hierarchical decomposition of the policy compatibility assessment problem. Madas and Zografos (2006:216)

The policy criteria and indicators involved in the selection of the most compatible strategy fall into one of the following broad categories:

- Efficiency criterion;
- Cost criterion;
- Implementation criterion;
- Acceptability criterion.

The efficiency criterion addresses the capability of a strategy to deal with the scarcity of slots and produce a rationalised slot allocation outcome.

The cost criterion assesses the cost aspects associated with the implementation of a certain strategy. The implementation criterion examines the ease and pace of implementation, while the acceptability criterion assesses the ease of acceptance and adoption potential of a certain strategy. The identified policy criteria and their associated indicators are defined in Table 4-4.

Criterion	Indicator	Definition
Efficiency	Allocative efficiency	It measures the capability of the strategy to allocate slots to those with the greatest willingness to pay (TUB, 2001; DotEcon Ltd., 2001; European Commission, 2001)
	Competitive efficiency	It measures the strategy's capability of promoting competition through the elimination of entry barriers to newcomers and discriminatory practices in favour of established carriers (European Commission, 2001; TUB, 2001)
	Infrastructural efficiency	It measures the extent to which the slot allocation proceeds are efficiently distributed. "Efficiency" provides for the distribution of slot allocation revenues to those having the means at their disposal to eliminate the scarcity in the short or long run (Airports Council International (ACI) Europe, 2002)
Cost	Cost-relatedness	It measures the extent to which airport charges are representative of actual costs. The structure and level of airport charges should reflect the externalities and real costs for providing the corresponding airport services, as well as the demand (and congestion) levels (European Commission, 2001; Airports Council International (ACI) Europe, 2002)
	Implementation cost	It measures the costs (e.g., transaction, organisation/coordination, technology) envisaged for the implementation of the various strategies (TUB, 2001)
Implementation	Complexity	It measures the degree of implementation complexity of a strategy in the form of administration, preparatory time required, horizon of the strategy, as well as the necessary organizational arrangements and coordination efforts (TUB, 2001)
	Flexibility	It measures the degree of flexibility of strategy's implementation in the form of: (i) flexibility to change in the short/medium run (temporal flexibility), and (ii) flexibility of simultaneous implementation of different strategies in the various airports (spatial flexibility)
	Fiducial protection	It measures the phasing and graduality of a strategy's implementation. A phased approach will allow for an early notification and gradual adaptation of airlines, and thereby will respect the principle of fiducial protection so as to avoid paying compensations to airlines for the abolition of grandfather rights (TUB, 2001)
Acceptability	Stakeholders' inertia	It measures the degree of expected resistance of the affected stakeholders (e.g., carriers, airports) to the changes introduced by the different strategies
	Transparency	It measures the degree of transparency of the strategy in that it will not be vulnerable to legal challenge

Table 4-4: Policy compatibility criteria and indicators. Madas and Zografos (2006:217)

4.1.3 Results of policy compatibility assessment

A panel of experts and key stakeholders was surveyed by Madas and Zografos (2006:219-222) using detailed survey instruments. Emphasis is placed in obtaining the perspectives and judgements of academic experts

and researchers, as well as aviation policy makers. The selection of individual experts has been made with view to the following:

- Substantial expertise in existing slot allocation procedures;
- Familiarity with the aviation industry developments in general and demand- capacity mismatch in particular;
- Representation of various industry roles and viewpoints with respect to slot allocation.

The experts were grouped as follows:

- Expert Group 1: nineteen academic/research experts with substantial expertise in slot allocation or involvement in relevant policy studies;
- Expert Group 2: ten experts from European airports or their associations expressing and promoting the airports' perspectives and interests;
- Expert Group 3: seven experts from European airlines with substantial presence in the European and/or their national airport networks.
- Expert Group 4: five senior European policy makers in the slot allocation domain who are responsible either for the formulation of the slot allocation policy or the implementation and monitoring of the slot allocation process.

Their observations and conclusion are drawn from the comparative analysis of airport clusters and synthesis of judgements among expert groups. The performance of the policy criteria does not vary substantially with airport cluster as indicated in Figure 4-2. The expert groups recognize the congestion problems and severe market distortion especially in busiest airports dominated by well-established carriers, thus placing higher importance on promoting the efficiency of the allocation process and eliminating market entry barriers.

The primary emphasis is placed on the efficiency of the slot allocation process that will potentially remedy the congestion problem and eliminate the imbalance between demand and supply along with their externalities (delays, noise and environmental concerns). The efficiency criterion constitutes by far the priority for all airport clusters that are congested or might become so in the near future. The expert groups converge on the finding that the implementation feasibility and complexity represent important aspects for the selection of a slot allocation strategy that will not compromise feasibility and realistic implementation in favour of increased efficiency. The acceptability aspects of the airport community are considered to have a lower priority as compared to efficiency and implementation.

The cost criterion obtained the lowest importance rating in all airport clusters. This can be attributed to the fact that cost and complexity aspects are not an issue for the largest, busiest and most severely congested airports, which have already both the resources and the in-house expertise to deal with more complicated and costly slot allocation options if they promise higher efficiency.

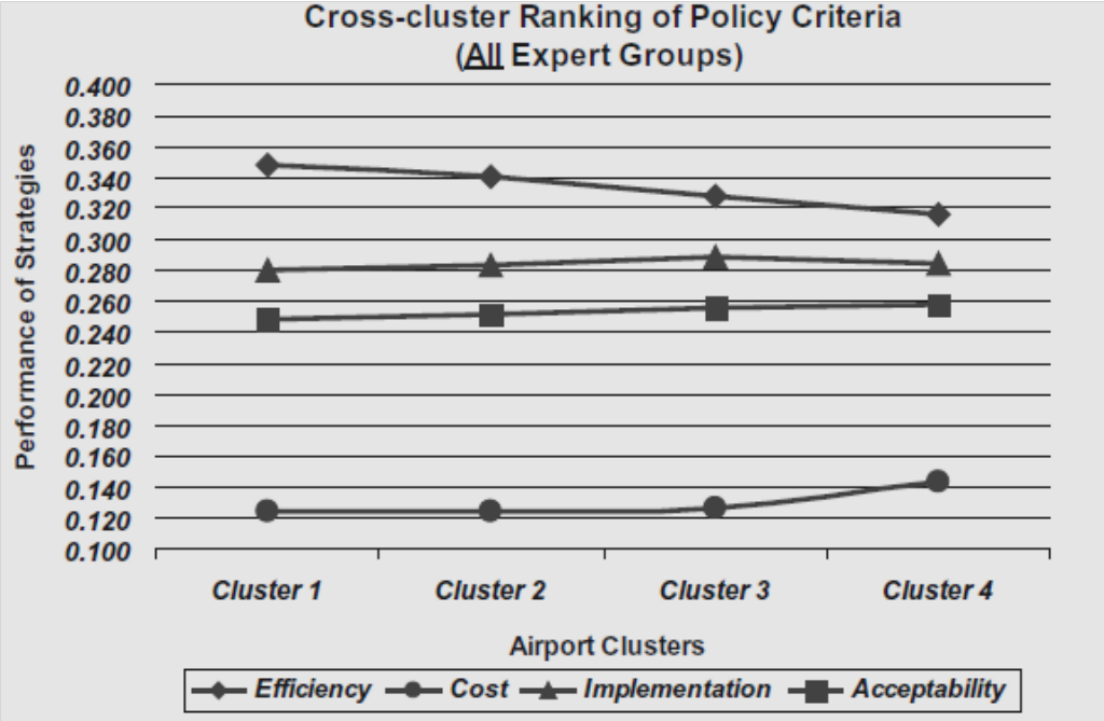


Figure 4-2: Performance and ranking of policies per airport cluster. Madas and Zografos (2006:219)

The efficiency criterion is assigned the highest importance rating in all airport clusters, but its importance gradually decreases by yielding ground to the implementation and acceptability criteria in the smaller (Cluster 3 and 4) airports. This is consistent with the empirical assumption that smaller national or regional airports mainly urge for the feasibility of implementation and the potential acceptance by the airport community even at the expense of efficiency. The cost, implementation and acceptability aspects gain increasing importance in smaller airports (Cluster 3 and 4), which may not have the financial resources or the in-house expertise to deal with more complicated or costly solutions.

Strat.4 (“Congestion Pricing”) has been generally considered as the most appropriate alternative for all airport clusters with respect to its compatibility with the identified policy as indicated in Figure 4-3. Strat.4 introduces an “open” and adaptive slot allocation regime, which can be easily customized with the needs and characteristics of the local airport context through the appropriate congestion fee schemes. This allows the horizontal implementation of this strategy across all airport clusters.

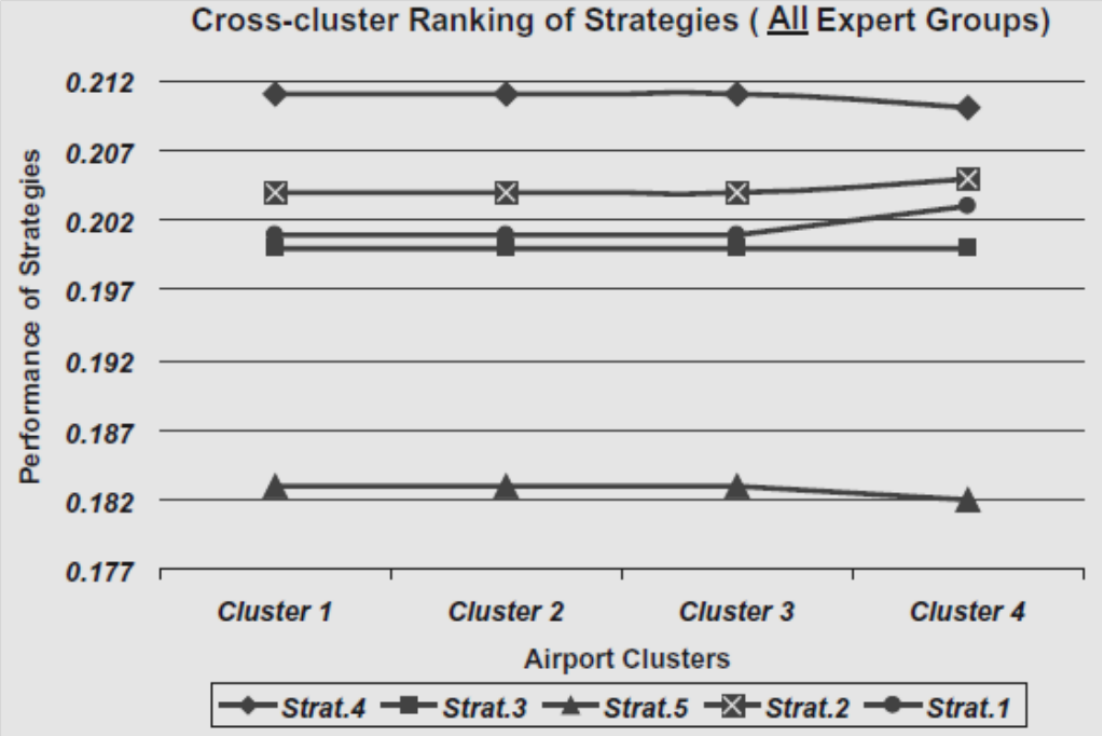


Figure 4-3: Performance and ranking of strategies per airport cluster. Madas and Zografos (2006:220)

Strat.5 (“Big Bang”) introduces the most radical departure from status quo on the grounds that it eliminates historic slot holding, it involves several drastic regulatory amendments, it is considered cumbersome in term of organizational and institutional arrangements, and introduces controversial allocation mechanism and rules. As a result, these progressive reforms were considered difficult to implement in large airports (clusters 1and 2) and impossible for smaller national airports (clusters 3 and 4). For similar reasons, more conservative strategies obtained better ranking in smaller airports (Cluster 3 and 4).

5 IMPEDIMENTS TO IMPLEMENTATING CONGESTION PRICING

5.1 Background

From Chapter 4, “Congestion Pricing” Strategy (Strat.4) has been identified as the most direct pricing method for addressing the mismatch between capacity and demand. This strategy is however not entirely “new”: it has been implemented without success both in the United Stated and in England. This section highlights the reasons why, despite being supported by theory, peak runway pricing has never been effectively implemented.

5.2 Review of peak pricing implementation

Schank (1994) investigates the impediments to implementation of peak pricing Boston Logan airport, New York (LaGuardia) and London (Heathrow). The following section describes the peak pricing mechanisms that were implemented and their outcomes.

5.2.1 Boston Logan Airport

Boston has proposed at least five pricing schemes intended to reduce congestion, and implemented two of those schemes since the 1980’s. Boston implemented a Program for Airfield Capacity Efficiency (PACE), which was not, strictly speaking, a peak pricing program as there was no distinction between any particular hours of the day. PACE simply changed the way the landing fees were assessed from a primarily weight-based formula. This was achieved by increasing the fixed cost for landings. Under PACE, a fixed cost of $91.00 per landing was assessed, plus $0.45/1000lbs for each aircraft.

The weight-based fee was recomputed every year to keep total revenues at the cost of airport operations. The fee was also computed with the intention of remaining revenue neutral and only accounting for the cost of the airport operations. Therefore, the fee in effect raises landing fees significantly for commuter and General Aviation (GA) aircraft while lowering fees significantly for larger commercial aircraft (Schank 1994:419).

Table 5-1 indicates the differences in landing fees. The first three aircraft listed are all commuter aircrafts; the other three are jet aircraft. While the prices for the commuter aircraft tripled or quadrupled, the price for the jet aircraft in this example dropped significantly. The largest aircraft, the Boeing 747-300, shows the greatest drop in price.

Aircraft type	Before PACE	Under PACE
Cessna 402	$25.00	$95.19
Beechcraft 1900	$25.00	$110.45
Shorts 360	$34.06	$105.86
Boeing 727-200	$200.43	$174.66
Boeing 747-300	$823.99	$432.51
Boeing 757	$259.38	$199.04

Table 5-1: Example of price changes from Massport's PACE initiative. Schank (2004:420)

Smaller aircraft users, including commuter carriers and GA, challenged PACE in court, arguing that the new charges did not represent a fair allocation of costs to smaller aircraft users. They pointed out that PACE was intended and designed to exclude GA from the airport. The Administrative Law judge who reviewed the case found that PACE was "a system of airspace management and economic regulation using fees as its proxy".

He argued that the fee structure was lacking in economic justification. The PACE structure was found to be discriminatory because there was no acceptable alternative airport for diverted users, and the fees were clearly designed to exclude certain users. As a result the Airport was forced to rescind PACE.

According to Schank (1994:420), Boston was trying to find a way to charge more per operation because excess operations were causing congestion. The Court's decision disagreed with their method of calculation. In part, this was because the Airport did not take into account the greater marginal costs imposed by larger aircraft, which require larger terminals, more airport personnel and a greater reserve of Fire Safety Rescue Operations. PACE illustrates the potential problems with making changes to pricing structures at airports. There are strong political interests that will fight such changes in court, especially if it appears that pricing initiatives are directed particularly at them.

5.2.2 New York

New York City has three major airports, John F. Kennedy International Airport (JFK), LaGuardia Airport (LGA) and Newark Airport (EWR), which are all operated by the Port Authority of New York and New Jersey (PANYNJ). However, another airport that plays a large role in the regional airport system is Teterboro Airport (TEB) in New Jersey. This airport does not have any scheduled traffic service. It is used exclusively by GA.

Despite the existence of TEB, the PANYNJ was facing increased airside congestion in the late 1960s and found that GA traffic at the three major airports accounted for 30 percent of the operations in peak hours and 25 percent of operations overall. In response to this problem, they imposed peak

runway pricing system, with a $25 fee for all operations during peak hours by aircraft with 25 seats or less. The peak period was defined 8:00 to 10:00 in the morning Monday through Friday, and 3:00 to 8:00 in the evening every day. Exemptions were provided for GA aircraft operating as air taxis providing connections to operations at JFK and EWR, as long as a runway was used that was not in use by scheduled airlines.

There were no exemptions at LGA because there were no such runways available during peak hours. The fee was explicitly targeted towards GA. The Aircraft Owners and Pilots Association (AOPA) sued the PANYNJ over the new charges. A court dismissed the complaint and held that the fee was a justified means of relieving congestion. The court agreed that allocating scarce runway capacity in a manner that favours larger aircraft is legitimate and legal (Schank 1994:420).

The court recognized that the PANYNJ had the “professed intention of influencing GA operators to transfer their operations where possible away from the runways and traffic control patterns at the three major airports during peak traffic periods”. However, given the adequacy of TEB as an alternative airport for GA, and limited facilities for air service in the region, the court found that it was reasonable for the Port Authority to give priority to mass transportation services. The court found that the fee was not discriminatory because even though it was targeted at a specific group of aircraft, PANYNJ had the right to differentiate among different kinds of flights. The New York case, like the Boston case, is not strictly speaking an example of peak pricing theory applied to practice, since prices were never set close to marginal cost and pricing was not market-based but rather directed at one particular group of airport users.

The Port Authority intended to direct pricing at general aviation and later commuter aircraft. The strategy appears to have been effective in reducing the congestion caused by GA aircraft; however, the Port Authority could never have implemented such a policy without the presence of TBE. This GA airport provided an alternative for those who did not wish to pay the extra fees installed at the major New York airports. Conversely, the commuter fee was too small to have forced any major changes in commuter airlines schedule, and the PANYNJ cannot raise it to an effective level because there would be no other alternative for the commuter aircraft.

The fact that an alternative existed is the key point. Pricing theory does not account for the passengers who are diverted as a result of the new pricing structure. In New York, there is what was determined by the courts to be an adequate alternative for GA aircraft. However, if TBE did not exist, New York would have run into the same problem as Boston in their attempt to target one group of aircraft to dissuade them from landing at their congested airport. There was no TBE equivalent for commuter aircraft out of its congested airports. The above illustrates the importance of considering the alternatives available when trying to reduce airport congestion through pricing (Schank 1994:421).

5.2.3 London

BAA introduced peak pricing by imposing a distance and per passenger element to the weight-based fee plus a surcharge on operations that varied with season and time of day. The distance element of the fee was based on the ability to pay and charges more for longer flights. Flights were divided into three categories: domestic, European and international, with international flights charged the most per ton and per passenger and domestic flights

charged the least. The passenger and weight elements of the fee structure were based on the ability to pay but the peak element was not.

The peak element of the new pricing strategy charged £20 per operation between the hours of 8:00 and 11:59 in the morning. The fee structure was later modified, and a £50 charge was applied to the peak of the peak, while the £20 charge was applied to the shoulder (Schank 2004:422).

A number of changes have been made to this initial pricing structure virtually every year since it was implemented. Table 5-2 indicates the frequent changes to the fee structure at Heathrow and suggests how difficult it was for BAA to arrive at a pricing structure that worked. Throughout all these changes, several airlines sued BAA.

Year	Change
1976	Peak passenger charge introduced
1976	Geographical classifications (domestic, European, international) changed to five distance-based classifications
1977	50% rebate during off-peak periods introduced
1978	Distance-related element eliminated
1978	Peak aircraft parking charges introduced
1980	Peak operations charge eliminated, replaced by fixed element in weight charge
1984	50% off-peak rebate eliminated

Table 5-2: Significant changes in Heathrow pricing structure, 1972-1984. Schank (2004:422)

American carriers complained about the BAA charges for Heathrow because of their distinction between international and European flights. This distinction was removed and distance differentials were also removed.

However, a significant increase in landing fees along with a greater focus on peak charges for all airlines accompanied these changes. Pan American Airlines sued BAA over the new fee structure, and eighteen other airlines formed a “British Airport Users Action Group” and refused to pay the higher fees. The core of the problem was that US carriers felt as if they had no choice but to land at peak times when charges were highest.

BAA attempted to prove their case by showing how the increased fees were calculated to pay for improved facilities. They carried out an analysis of the marginal costs incurred at Heathrow. The results indicated that the marginal cost of operating a flight in the peak at Heathrow was £125 and £50 at other times. This was substantially greater than the price being charged at the time. Table 5-3 indicates that there was a diminished use of smaller aircraft at Heathrow following these policy changes, although it is unclear whether this change was necessarily related to airport landing fees.

BAA’s pricing policy targeted both large and small aircraft operators. The policy was originally intended to smooth out the peak, primarily caused by large aircraft heading to and from the US, but it eventually impacted commuter carriers who could not afford to pay the landing fees. This latter effect was the original intent of most of the policies in Boston. The pricing scheme was used to target specific groups, who did their best to fight the policy and were successful in reducing its impact to some degree.

Year	Total air traffic movements	Movements by aircraft under 16 Tons	Percentage of movements by aircraft under 16 Tons
1984/85	267,675	9332	3.5
1985/86	280,046	8900	3.2
1986/87	292,323	11,257	3.9
1987/88	310,435	11,808	3.8
1988/89	310,376	7728	2.5
1989/90	351,307	2083	0.6
1990/91	361,235	1062	0.3
1991/92	373,890	112	0.03
1992/93	388,108	44	0.01

Table 5-3: Use of Heathrow by smaller aircraft, 1984-1993. Schank (2004:423)

It was commuter aircraft, for which there existed alternative transportation options (Stansted Airport and rail), that became the group that could not defeat the pricing system. Targeting a group with available alternatives worked for BAA, while targeting a group without them did not (Schank 2004:423).

The above demonstrates the difficulty of effectively implementing peak pricing for airport runways. The two main problems identified are: political and social equity; and the problem of displaced passengers. Schank (2004:424) suggests that for peak runway pricing to be implemented effectively, there needs to be an alternative mode of transport provided to accommodate displaced passengers.

Since its inception in 1994, ACSA has made significant investment in modernising existing infrastructure and in additional capacity at ORTIA. This

investment was made in response to growing passenger traffic, cargo and aircraft movements, amongst other things. ACSA uses the IATA slot coordination methodology to allocate and manage runway slots at ORTIA. This approach has been proved through research to have significant flaws when it comes to efficiently allocating scarce airport slots. Major airports in the United States and Europe have come up with strategies aimed at improving the efficiency of slot allocation.

The strategies adopted at these airports are aimed at the adoption of market-driven slot allocation mechanisms such as slot trading, congestion pricing and auctions. There are also calls for an integrated approach to the airport congestion problem.

From chapter 4, a study conducted by Madas and Zografos (2006), aimed at determining the optimal slot allocation strategy for various airport types; ORTIA would be classified under *Cluster two "large international hubs".* The results of this study indicate that for ORTIA, the most appropriate slot allocations strategy is the "Congestion Pricing" Strategy (Strat.4).
However, the above section highlights the fundamental reasons why, despite being supported by theory, peak runway pricing has never been effectively implemented. The literature suggests High Speed Rail as a possible adequate substitute for air travel in a complementary manner. However, Schank (2004) points out that in most of the world outside of Western Europe and Japan, there are few adequate ground transportation alternatives outside of the private automobile.

According to National Transport Master 2050 (NATMAP 2050a 2010: 6-10) South Africa's rail network of 30 000 kilometres was once recognised internationally as the most comprehensive and best maintained in the entire

African Continent. This has however changed over the years as a result of a systematic and gradual decline in network coverage, a closure of lines and decreasing traffic volumes on a range of products and trip distances that are typical rail associated traffic, together with a lack of new global rail standards and technologies.

A number of reasons have been given for the deterioration of the railway network over the years. Management inefficiencies and competitive ineffectiveness; governance obstacles and disinvestment over a long period of time; natural market forces and the monopolistic character of rail in South Africa, are reasons identified. Other external contributing factors have also been debated; such as an ample supply of road capacity, together with incorrect road use pricing and the lack of technical regulation of road traffic (NATMAP 2050b 2010:6-10).

To address the shortcomings in rail, NATMAP 2050b (2010:12-13) recommend that: a position paper be formulated that defines the future policy on the rail mode and an action plan and program for implementation; the potential of some shorter distance air services that could perhaps be better and cheaper served by high speed rail systems be investigated. Candidates in this respect are between Johannesburg and Limpopo, Nelspruit, Bloemfontein and Durban; and around the coast line between Cape Town, George, Port Elizabeth, East London and Durban.

6 EXISTING AIRPORT FACILITIES

6.1 Background

This section gives an overall view of the existing infrastructure at ORTIA. It further outlines ACSA's runway capacity development strategy. ACSA was established under the terms of the Airports Company Act (1993) to own and operate the infrastructure of the previously State-Owned Airports within the Republic of South Africa. ACSA currently owns and operates nine airports in South Africa. The three main airports, O. R. Tambo International Airport (ORTIA) in Johannesburg, Cape Town International Airport (CPT), King Shaka International Airport (KSIA) in Durban are together responsible for approximately 90 percent of all airport passenger volume in the Country. ORTIA alone handles 54 percent of the Country's total passengers and 81 percent of total air cargo traffic.

Figure 6-1 indicates the location of ACSA's three biggest airports. These airports are situated in the country's most densly populated areas. ACSA is a monopoly, therefore, the Airports Company Act (1993) provides for the establishment of a Govenmental Regulatory Committee within the Department of Transport to regulate ACSA from abusing its market position. The country has an active and morden aviation system with services to international, regional and domestic destinations. (ACSA Annual Report 2010). As in most cases worldwide, ACSA's economic regulatory framework prescribes the "Single Till" approah to airport revenue.

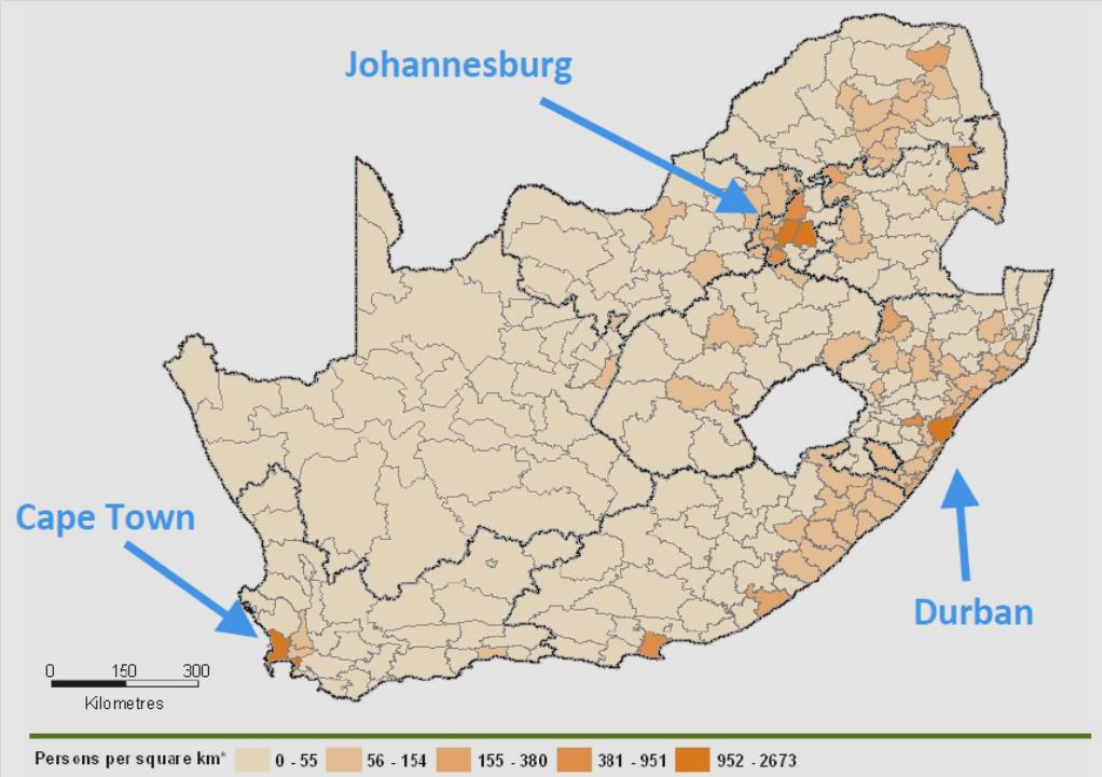


Figure 6-1: Location of South Africa's three main airports. Statistics South Africa (2000)

6.2 Passenger flows

6.2.1 International passenger flows

ORTIA is predominantly the international gateway to SA and handled approximately 7.5 million international passengers in year 2010. This figure is equivalent to 84 percent of total international traffic to SA (ACSA 2010).

6.2.2 Regional passenger flows

ORTIA acts as a primary hub for Sub-Saharan traffic with a significant number of inbound passengers transiting through ORTIA and continuing their journey to neighboring countries. The throughput of regional traffic at ACSA's

airports is 2.9 percent of the total with 90 percent transiting through ORTIA (ACSA 2010).

6.2.3 Domestic passenger flows

Two thirds of all the traffic handled by ACSA airports in year 2010 was domestic. This is an unsually high propotion of total passenger throughput, but is explained by the fact that the major cites of South Africa are located at considerable distances from each other. Therefore, this has made air travel a prefered mode of transport (Mott-McDonald 2010). According to Mott-McDonald (2010), this feature can be reffered to as “the tyranny of distance”, where air transport becomes a vital link for social and economic development, as alternative surface transport modes are unsuitable to or are incovenient and incapable of achieving the same level of mobility for both people and trade. Figure 6-2 indicates the domestic air routes in SA.

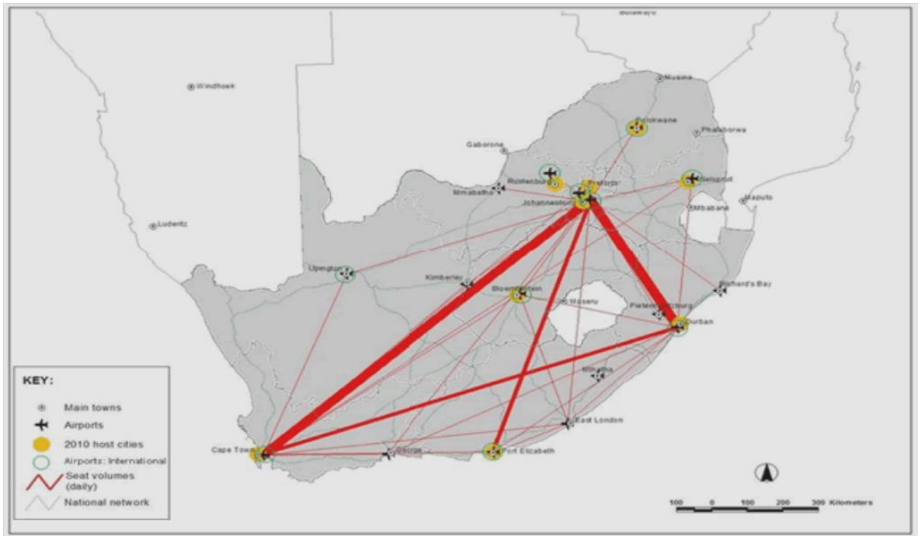


Figure 6-2: Domestic air routes in South Africa. (www.travelwithinsouthafrica.co.za)

6.3 Existing runway facilities

Figure 6-3 from the Aeronautical Information Publication (AIP) published by the South African Civil Aviation Authority (SACAA), indicates in diagrammatic form the primary arrangement of runways, taxiways, aircraft stands and other facilities at ORTIA. ORTIA has two parrallel runways which are offset by 1 870 meters. From Figure 6-3, the longest runway on the west side is designated 03L/21R and is 4 418 meters long by 60 meters wide. Runways 03L, 03R and 21L have a Catergory II Instrument Landing System Approach with a stardard three degree glidepath angle. At present, Runway 21R only has a instrument approach guided by the VOR/DME radio navigation beacon located to the south of the runway on the extended centerline.

The Aerodrome elevation is 1 694 meters above mean sea level, which along with ambient temperatures makes this runway system “hot and high”, requiring much longer than normal take-off runway distances. Runway 03L/21R which is the longest and closet to the terminal area is the prefered runway for take-off. The secondary runway on the east side is designated 03R/21L and is 3 400 meters long and 60 meters wide. The secondary runway is used exclusively for landing. The runways operate in the northbound (03) direction approximately 70% of the time (Mott-McDonald 2010).

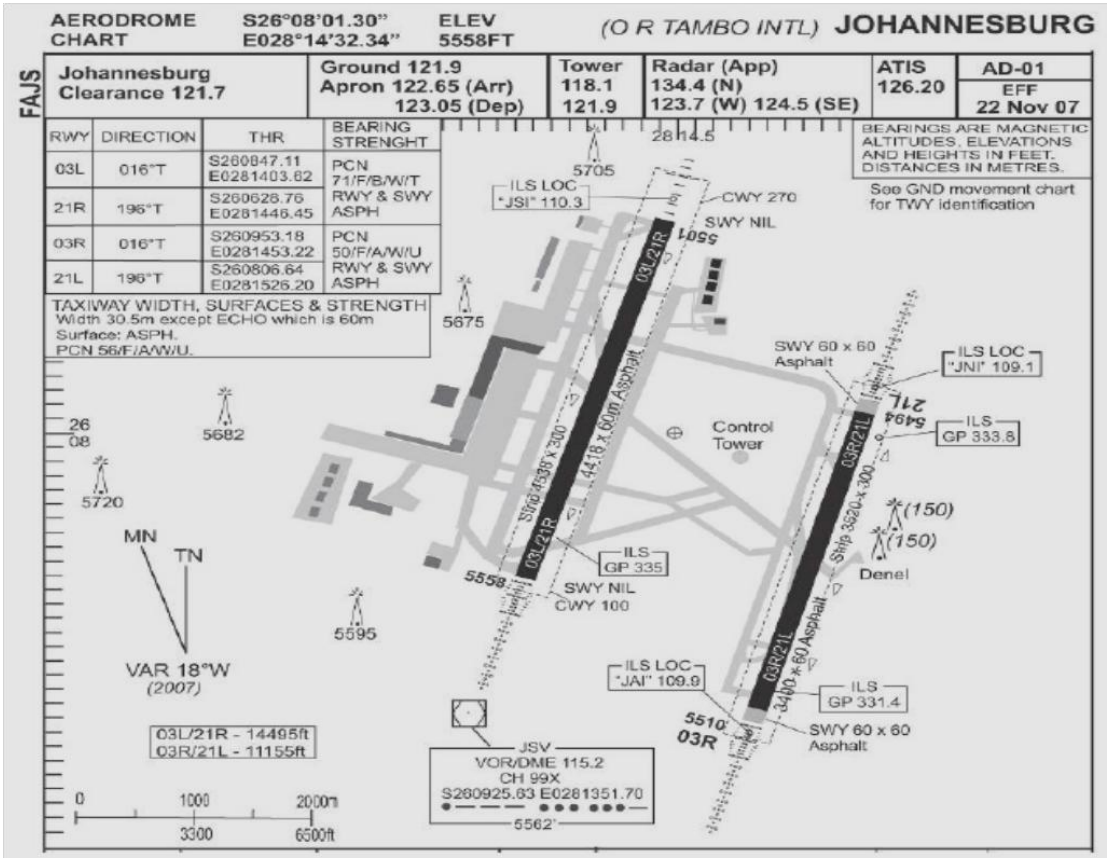


Figure 6-3: ORTIA aerodrome chart. SACAA (2007)

6.4 Airspace issues

According to Mott-McDonald (2010), there are a number of airspace controls in the Johannesburg area that have the potential to limit the number of aircraft movements which can be accommodated at ORTIA. In order to safely control the air traffic in the Johannesburg area, ORTIA sits at the centre of a Special Rules Area (SRA) which extends for a radius of approximately 75 kilometres around the airport. This also covers all other aerodromes in the Johannesburg area see Figure 6-4.

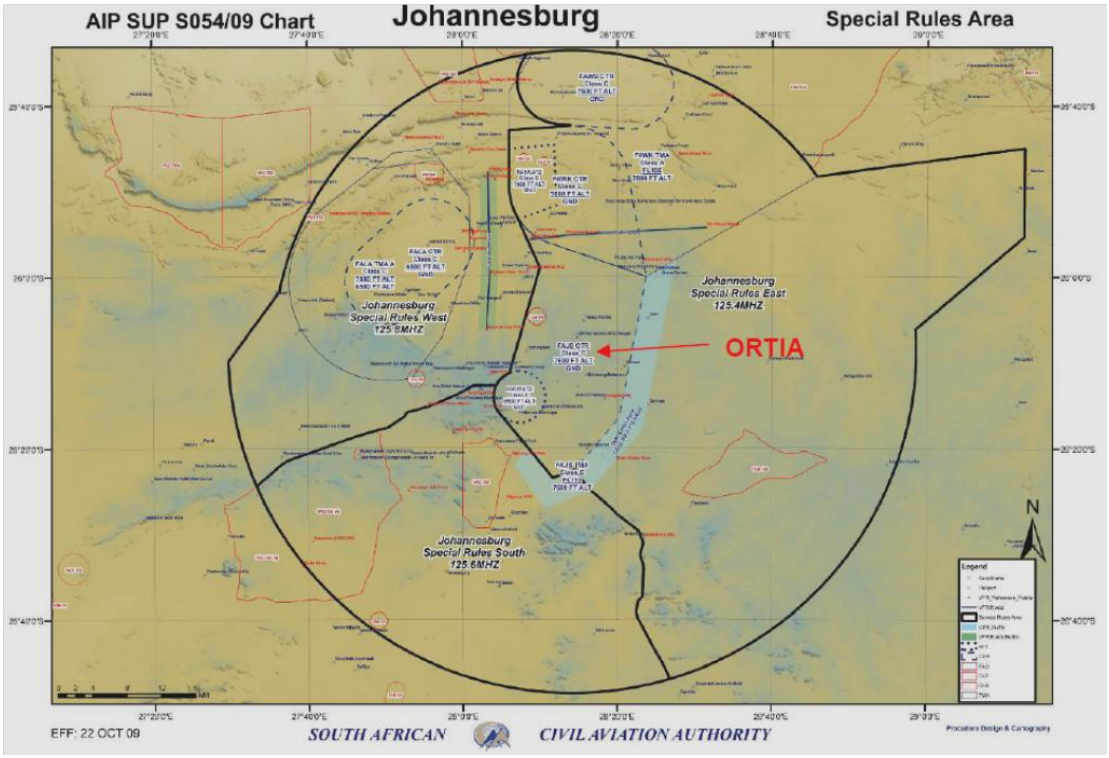
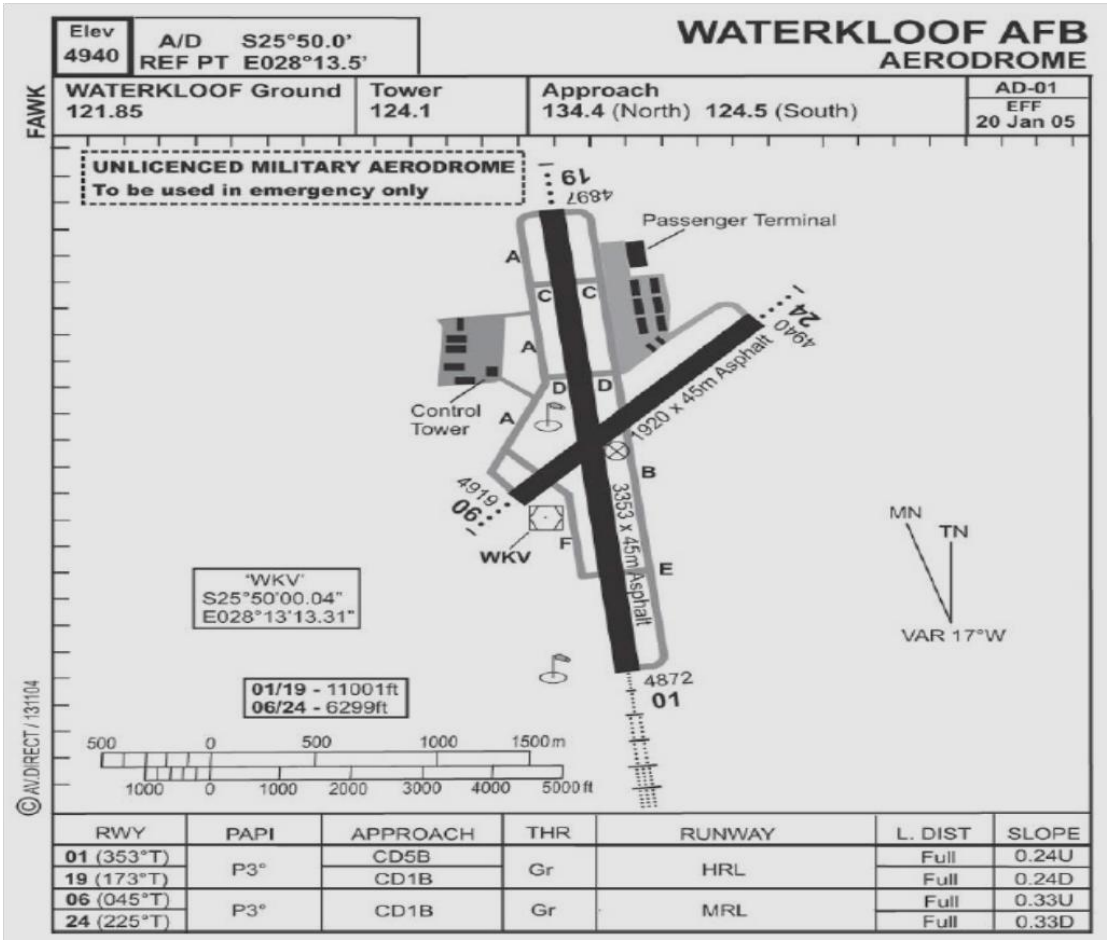


Figure 6-4: Johannesburg "Special Rules Area". SACAA (2009)

AFB Waterkloof (FAWK) is a military airport located roughly thirty kilometres north of ORTIA. See Figure 6-5 for FAWK's aerodrome chart. A major concern regarding FAWK is that the South African Air Force has installed an Instrument Landing System (ILS) on runway 01 and proposes to add ILS training movements to their existing aircraft movements. ATNS have objected to this on the grounds that it will reduce ORTIA movements due to potential conflicts. All south bound approaches to either of ORTIA's runways must commence in the FAWK' Terminal Manoeuvring Area. Figure 6-6 indicates the ORTIA southbound ILS approach.



RWY	PAPI	APPROACH	THR	RUNWAY	L. DIST	SLOPE
01 (353°T)	P3°	CD5B	Gr	HRL	Full	0.24U
19 (173°T)		CD1B			Full	0.24D
06 (045°T)	P3°	CD1B	Gr	MRL	Full	0.33U
24 (225°T)					Full	0.33D

Figure 6-5: Waterkloof Aerodrome Chart. SACAA (2005)

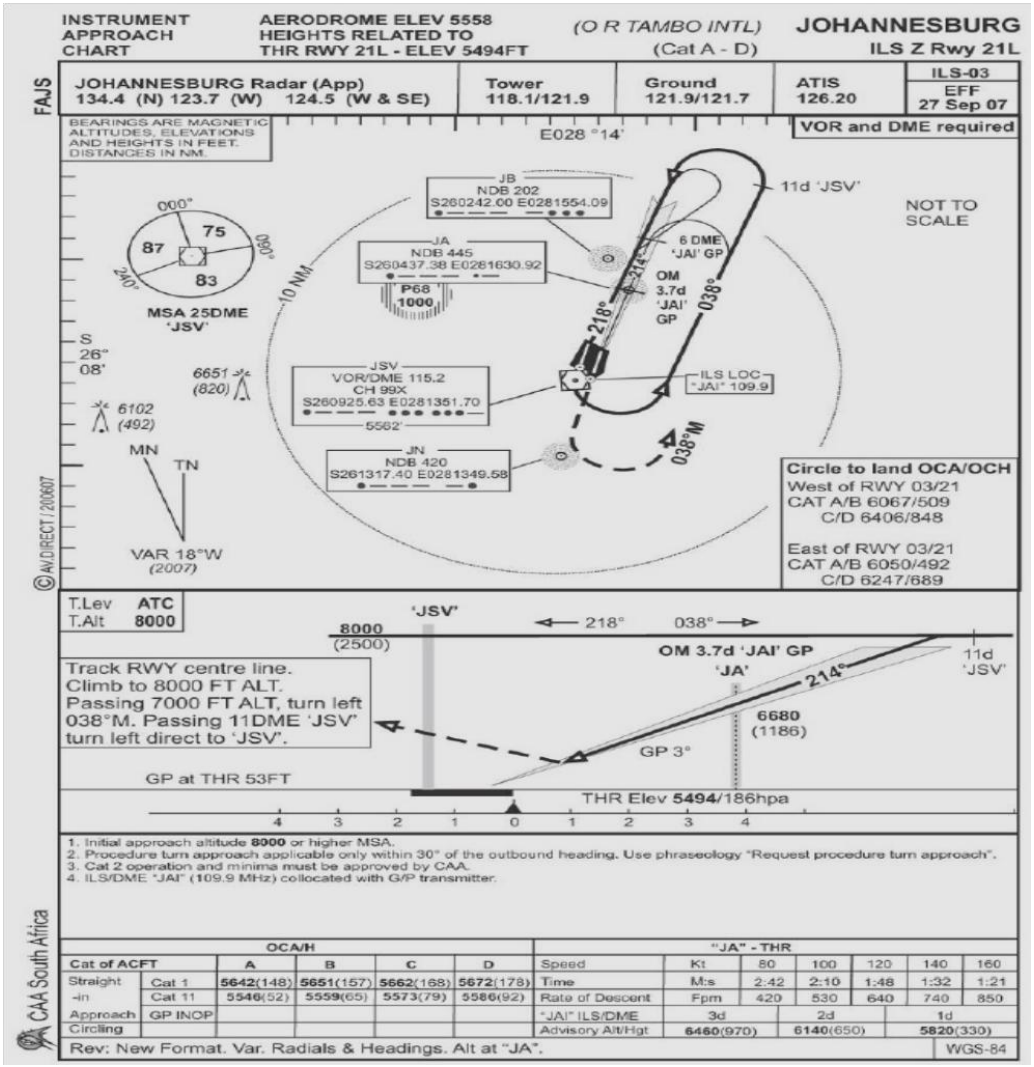


Figure 6-6: ORTIA Southbound ILS Approach. SACAA (2007)

Grand Central (FAGC) is a relatively small airfield located sixteen kilometres to the North West of ORTIA. It is primarily used for general aviation. Rand Airport (FAGM) is located thirteen kilometres to the South West of ORTIA. Its location has significant impact to northbound approaches to and southbound departures from ORTIA.

Lanseria International Airport (FALA) is located 38 kilometres to the Northwest of ORTIA. Aircraft fly over FALA on approach to ORTIA from the Northwest. Its main runway is orientated approximately perpendicular to the direction of over-flights to and from ORTIA. It has a second close parallel runway which is mostly used for small General Aviation (GA) aircraft. Until recently, there were no scheduled flights at FALA. In 2009 Kulula, a “low cost” operator began scheduled operations from FALA. There are no conflicts between ORTIA operations and the FALA airspace. However, this is the second busiest airport in the region and movements at this airport can be delayed by movements in the remaining airspace primarily those in or out of ORTIA (Mott-McDonald 2010).

6.5 Current ORTIA Master Plan

In 2006, ACSA initiated a process of updating the Master Plan of ORTIA and appointed NACO-SSI Airport Consultants to assist in the process. The ORTIA Master Plan was completed in 2007 and approved by the Board of ACSA. According to ACSA’s ORTIA Master Plan (2007), the future direction of the ORTIA development plan involves a series of key capacity enhancements:

- Lengthening runway 03R/21L to 4 400 metres;
- The addition of a second 4 400 metres close parallel runway on the east side of runway 03R/21L designated 03RR/21LL;
- The addition of a second 3 500 metre close parallel runway on the east side of runway 03L/21R designated 03C/21C, which would be shorter than the other three runways.
- The development of a midfield apron and terminal complex both for passenger and cargo with a new surface access and landside area to the south;

- Landside and airside passenger and road connections between the new midfield terminal and the existing Western Precinct.

Figure 6-7 depicts runway designations at ORTIA.

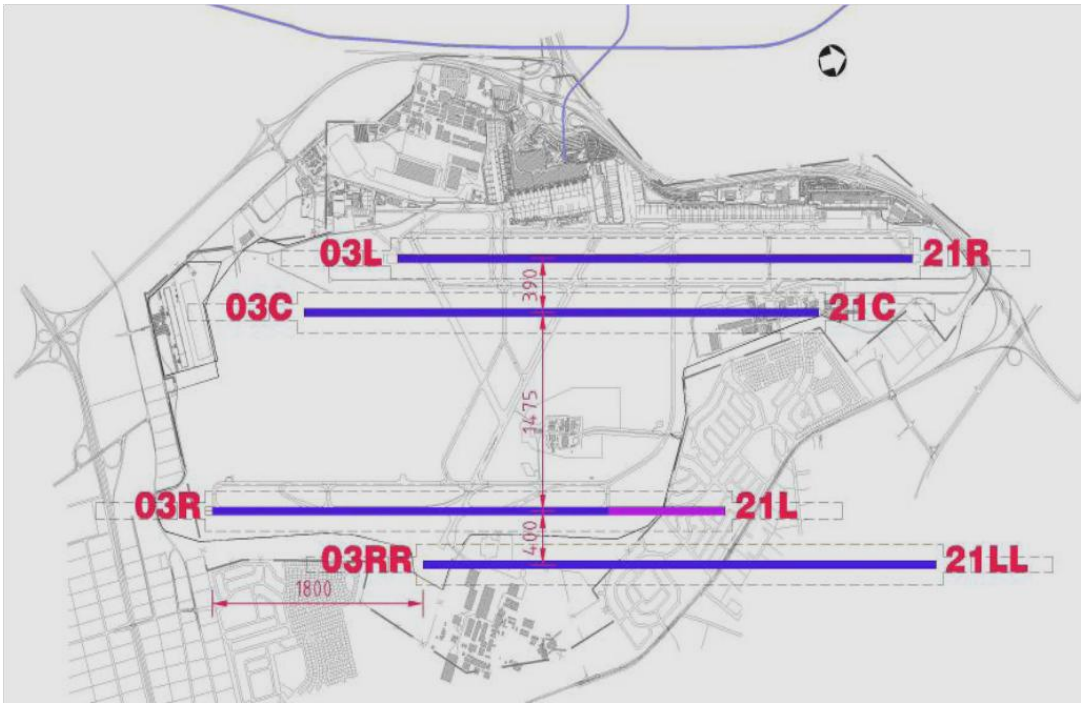


Figure 6-7: Proposed runway designations at ORTIA. ACSA (2007)

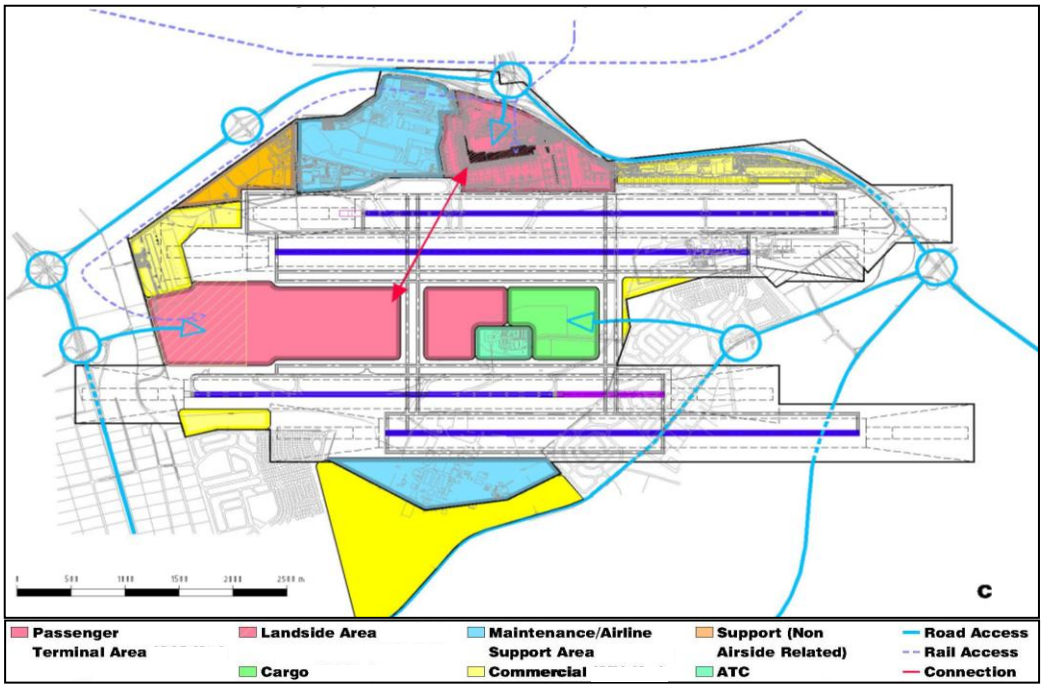


Figure 6-8: ORTIA Ultimate Master Plan layout. ACSA (2007)

6.6 Runway development strategy

The proposed runway development at ORTIA is expected to have significant land and financial impacts. In 2007, it was estimated that 1057 privately owned sites would need to be acquired at a total cost of roughly R1.3 billion in order to accommodate the proposed runway developments. Figure 6-9 depicts the properties to be acquired for the runway developments. Figure 6-8 depicts the preferred runway layout with its associated land-use whilst Table 6-1 indicates the capacity gains from the additional runways. From Table 6-1, the declared capacity of the existing runway system under IMC is 60 movements per hour. The declared capacity will be increase by the introduction of a third runway and the extension of the existing secondary runway by 1 400m to 88 movements per hour under IMC. The addition of a fourth runway will increase the capacity to 106 movements per hour under IMC.

Runway System	Operation	VMC			IMC		
		Arr (per hour)	Dep (per hour)	Total (per hour)	Arr (per hour)	Dep (per hour)	Total (per hour)
A. 4 runways	North-flow	54-56	54-56	**108-112**	54-56	54-56	**108-112**
	South-flow	59-63	53-57	**118-126**	53-57	53-57	**106-114**
B. 3 runways, westerly close parallel runway	North-flow	49-51	49-51	**98-102**	46-48	46-48	**92-96**
	South-flow	48-50	48-50	**96-100**	44-46	44-46	**88-92**
C. 3 runways, easterly close parallel runway	North-flow	44-48	44-48	**88-96**	43-46	43-46	**86-92**
	South-flow	46-50	46-50	**92-100**	44-48	44-48	**88-96**
D. 2 runways	North-flow	32-34	32-36	**64-72**	30-32	30-32	**60-64**
	South-flow	32-34	32-36	**64-72**	30-32	30-32	**60-64**

Table 6-1: Runway development capacities. ATNS (2008)



Figure 6-9: Close parallel centre and close parallel east. ACSA (2006)

The current Master Plan assumes marginal administrative demand management. This is achieved by assuming a slower growth in peak demand over time and that traffic will eventually fill the off peak periods. The Master Plan makes provision for only an infrastructure response to congestion (it considers only the supply side).

The major South African Cities (Cape Town, Johannesburg and Durban) are located far apart compared to European cities. This has lead to the assumption that only air travel is a mode of transport to link them. From the literature review, HSR could be a viable alternative between Johannesburg and Durban. FALA could play a significant role in the overall capacity plan for the region, although its potential contribution is not fully addressed in the ORTIA Master Plan.

7 CASE STUDY

7.1 Background

This chapter describes the impact of the approaches discussed in the literature on runway congestion at ORTIA. The literature indicates that capacity gains through the construction of new airports or the expansion of existing facilities are considerably expensive; have long lead time; are subject to social and political objections. Furthermore, these negatives are more pronounced in respect of runway developments than any other airport sub-system. This research report, therefore, focuses on non-infrastructure interventions aimed at enhancing the capacity of the runway system.

The demand for access to the runway system at ORTIA is expected to continue to grow from the current peak demand of 51 movements to approximately 80 peak hour movements by year 2022. Demand is expected to also start “filling-up” the low demand hours of the day between 07:00 in the morning till 19:00 in the evening. Similarly to other international airports, ORTIA has distinct morning and evening peaks. These peaks are driven by: international arrivals; domestic and regional departure in the morning and international departure; domestic and regional arrivals in the evening. The average demand in between the peak periods is expected to grow from an average 40 movements to approximately 65 movements by year 2022.

To accommodate the expected demand, ACSA plans to invest in excess of R3 billion on a new runway and associated taxiways and navigational aids. The new runway will be accompanied by a 1000 meter northward extension of the existing secondary runway.

A fourth runway is planned beyond year 2022. To accommodate these developments, ACSA will need to acquire extensive privately owned land within the vicinity of ORTIA.

Although in the long term, the need to construct new runways cannot be completely removed, the literature review identifies four basic alternative approaches that relieve runway congestion and defer the need for new runways in the short to medium term as: collaborative decision making; technological improvements; air and rail integration; and demand management. The effectiveness of each approach in addressing runway congestion and its implementation challenges are evaluated.

7.2 Collaborative decision making

Collaborative decision making (CDM) focuses on the flow of information amongst various airport stakeholders within the airport environment. Since its introduction at ORTIA, on-time performance has improved and the average delay per aircraft movement has been reduced. This has improved the utilisation of allocated slots. Additional efficiencies could be achieved if the full potential of CDM is utilised. Stakeholder participation in CDM at ORTIA is achieved through the Airport Management Centre (AMC) and is currently voluntary. ATNS, the main stakeholder in runway and airspace management does not have full-time representation at the AMC. With ATNS's participation in CDM, potential delays could be identified and communicated in real time and mitigating action taken to avoid delays. The overall utilisation of slots and hence the overall capacity of the airport could be improved.

ACSA has implemented the AMC concept in its three major airports (ORTIA, KSIA and CPT), therefore, no additional capital expenditure is required to

implement CDM. A policy decision is required to compel all relevant stakeholders to have full time representation in the AMC.

7.3 Technological improvements

ATNS employs out-dated technology to manage air and ground aircraft movements. This has forced ATNS to: assign conservative arrival and departure horizontal and vertical separations; limit their ability to sequence arrivals and departure aircraft; limit their ability to mix arrival and departure movements on a single runway. With these modifications, the declared capacity of the runway system can possibly be increased from the current 58 movements to between 70 and 80 movements per hour. This could defer the need for additional runway capacity to beyond 2022.

For these measures to be implemented, financial resource are required to update ATNS facilities and to train Air Traffic Controllers. This cost is considerably less than the cost of building additional runways; has lower social and political implications; and could be implemented in a relatively short period of time compared to building new runways.

7.4 Air and rail integration

The substitution of short haul flight with rail is not feasible at ORTIA currently. South Africa’s major cities are much further apart compared to their European counterparts where air and rail integration has been implemented. South Africa’s railway network is under-developed, poorly maintained, designed to lower standard that does not allow High Speed Rail Operations and has an aging rolling stock.

The required capital investment to facilitate air and rail integration is significantly higher than the investment required build additional runway

capacity at ORTIA. It will also take significantly longer to upgrade and expand the rail infrastructure than to build additional runways at ORTIA.

7.5 Demand management

Chapter 4 describes the suitability of various demand management strategies for different airport settings and policies. From chapter 4, strategy 4 is regarded as the most suitable for airports the size of ORTIA, this strategy entails the introduction of an “open” and adaptive slot allocation regime, which can be customized with the needs and characteristics of the local airport context through congestion fee schemes. Under strategy 4, “grandfather” rights are abandoned and a congestion based scheme is set by an administrative authority in the form of a three-point tariff including: the traditional weight based fees and passenger surcharges; a flat reservation fee applied per movement in the form of membership dues or “no-show” penalties; and a congestion based fee with fees varying with congestion throughout the day.

This strategy advocates for “grandfather” rights to be abandoned, however, no guidance is provided on how best to allocate slots. In section 2.6.2, slot allocation based on “grandfather” rights has been identified as a contributing factor to the inefficient utilisation of runway slots. However, current slot holders are unlikely to accept the abandonment of “grandfather” rights because they have invested considerable resources developing routes associated with the slots; furthermore, slots provide a competitive advantage for the slot holder.

There are important questions relating to slot allocation that need to be answered if strategy 4 is to be effectively implemented: firstly, how to deal with existing slots holders; secondly how to allocate existing unallocated

slots; and lastly how to deal with slots that become available due to reduction in demand.

A possible solution to the slot allocation problem is to leave the slots already allocated unchanged. Provided that the congestion fee is set sufficiently high, this would compel existing slot holders to release any slots they consider non-profitable to other airlines. The existing slot holders are likely to oppose such a move as it will enable competition on their most profitable routes. Unallocated slots and any slots that become available due to reduction in demand can be placed in a slot pool and allocated on a first come first served basis. For this method to work, the congestion fee will need to be revised regularly to ensure that it is not excessively high and drive away too much traffic from the peak on the one hand and that it is not too low to encourage airlines to hold on to slots simply to prevent other airlines from entering the market.

From chapter 5, one of the impediments to the implementation of congestion pricing is the unavailability of either an alternative mode of transport or a suitable airport for those passengers who will likely be “displaced” by the implementation of congestion pricing. In South Africa, minimal integration exists between the various modes of transport and furthermore, major cities are much further apart compared to European cities where modal integration has been achieved. This makes air the preferred mode for intercity travel.

For congestion pricing to be effectively implemented at ORTIA, an alternative airport in close proximity to ORTIA is required to accommodate the “displaced” passengers. From 6.4, there are three airports in close proximity to ORTIA: FALA, FAGC and FAWF. FAWF is a military base with airspace conflicts with ORTIA. FAGC is privately owned and is used exclusively for

GA. FALA is privately owned and used by both GA and scheduled traffic. The scheduled traffic that utilises FALA is the “low cost carrier”. Some of the reasons given by the “low cost carriers” for moving some of their operations from ORTIA to FALA are that FALA offers lower airport charges and shorter aircraft turnaround times compared to ORTIA. Short aircraft turnaround times are achievable at FALA because there are no congestion related delays.

Amongst the three airports, FALA is best suited to accommodate the displaced passengers because it already accommodates traffic that is looking for an alternative to ORTIA. There are a number of issues that need to be addressed if FALA is to play a meaningful role in the air traffic network:

FALA is a relatively small airport, so if additional traffic is to be diverted there, significant investment in upgrading facilities and capacity expansion needs to be made. FALA is a privately owned entity and may not be able to generate sufficient revenue to fund the required capital expenditure. If the Department of Transport (DOT) considers FALA an integral part of South Africa’s air transport network, the Department could enter into a Public Private Partnership and share the development costs with FALA. ACSA could acquire FALA and incorporate it in the overall air traffic master plan for the region as a reliever airport for ORTIA. This move is likely be opposed by some stakeholders who view FALA as an alternative to ORTIA offering lower airport fees and virtually no delays.

The two airports (ORTIA and FALA) are roughly 40 km apart. Ground transportation linkage needs to be provided. There is a system of freeways linking the airports; however, because of the distance between the airports and a possible high number of passengers connecting between them, a road link may not be viable. Congestion on the roads will lead to delayed flights

and missed connections. Because of the low traffic volumes at FALA presently, there is almost no requirement for a link between the two airports and they operate entirely independent of each other. Airlines are able to segregate passenger who originate and land at FALA from those who require connections at ORTIA. A rail link would be a better option; however, the economic, social, political and environmental costs of an additional runway at ORTIA would be significantly lower that the cost of building a rail link between the two airports. The railway link may also take significantly longer to build than an additional runway.

The current traffic demand profile at ORTIA where peak demand does not as yet exceed the declared capacity is not suitable for “full” implementation of peak pricing. The literature review recommends that peak pricing be gradually phased in as the demand approached capacity.

8 CONCLUSIONS AND RECOMMENDATIONS

The current demand on the runway system at ORTIA is insufficient to justify implementing drastic demand management measures. The demand, however, is expected to exceed the existing runway capacity by 2017, resulting in increased aircraft delays and congestion. The current delays experienced at ORTIA are not as a result of insufficient capacity, but rather are as a result of inclement weather and operational inefficiencies. The planned runway developments can be deferred beyond 2022 by improving operational efficiency through CDM; increasing the declared capacity of the existing runway system by making a significantly lower investment in technology through ATNS and Air Traffic Controller Training. These measures can be implemented in a relatively short period of time. Strategy 4 “congestion pricing” can be gradually phased in over a period of time from 2015 onwards.

Further research work needs to be conducted on: setting the initial congestion fee to be levied and periods which the fee will be levied; Integrating FALA in regional air traffic network in terms of its role and ownership; treatment of additional revenue generated through congestion pricing in the economic regulatory framework. Alternative ground linkage between ORTIA and FALA.

9 REFERENCES

(ACI), A. C. (2011). *Annual and Peak Airport traffic Forecasts-Projection of JHB Peak Hour Forecast .* Johannesburg: ACI.

Abeyratne, R. (2000). Management of Airport Congestion Through Slot Allocation . *Journal of Air Transport Management* , 29-41.

ACSA. (2010). *Annual Report.* Johannesburg: ACSA.

Andres Lopez-Pita, F. (2005). Impact of high-speed lines in relation to very high frequency air services. *Journal of public transportation* , 17-35.

Auerbach, S., & Koch, B. (2007). Coorperative approaches to managing air traffic efficiency: the airline perspective. *Journal of Air Transport Management* , 37-44.

Bass, T. (1994). Infrastructure Constraints and the EC. *Journal of Air Transport Management* , 145-150.

Brueckner, J. K. (2008). *Slot-Based Approaches to Airport Congestion Management.* Irvine: University of California.

Cao, J.-m., & Kanafani, A. (2000). The value of Runway Slots for Airlines. *European Journal of Operational Reseach* , 291-300.

Company, T. A. (2011). *ATM Capacity Declaration.* Johannesburg: ATNS.

de Neufville, R., & Odoni, A. (2003). *Airport Systems.* New York: Mcgraw-hill.

Debbage, K. G. (2002). AIRPORT RUNWAY SLOTS: Limits to Growth. *Annals of Tourism Research* , 933-951.

DKMA. (2007). *Global Traffic Forecast 2006-2025.* Geneva: Airports Council International.

Fan, T. P., & Odoni, A. R. (2001). *The potential of Demand Management as a short-term means of relieving airport congestion.* Cambridge: Massachusetts Institute of Technology .

Givon, M., & Banister, D. (2006). Airline and rail intergration. *Transport Policy 13* , 386-397.

Hamzawi, S. G. (1992). Lack of Airport Capacity:Exploration of Alternative Solutions. *Transportation Research Authority* , 47-58.

Janic, M. (2009). Management of airside delays. *Airport Management* , 176-195.

Janic, M. (2010). True Multimodalism for Mitigating Airport Congestion: Substitution of Air Passenger Transport by High-Speed Rail. *Journal of the Transport Research Board* , 78-87.

Jason W. Black, R. C. (2006). *Strategies to Overcome Network Congestion in Infrastructure Systems.* Massachusetts Institute of Technology, Engineering Systems Division. Massachusetts: Massachusetts Institute of Technology.

Langner, S. (1996). The Allocation od Slots in the Airline Industry: A transection Cost Economic Analysis.

Le, L., Donohue, G., Hoffman, K., & Chen, C.-H. (2008). *Optimum Airport Capacity Utilization under Congestion Management: A Case Study of New*

York LaGuardia Airport. Department of Systems Engineering and Operation Research. Virginia: George Mason University.

Madas, M. A., & Zografos, K. G. (2007). Airport capacity vs. demand: Mismatch or mismanagement. *Transport Research* , 203-226.

Madas, M. A., & Zografos, K. G. (2010). Airport Slot Allocation: a time for change. *Transport Policy* , 274-285.

Mckelvey, R. H. (1994). *Planning and Design of Airports.* United States of America: McGraw-Hill Companies.

Odoni, A. (2001). *New Concepts and Methods in Air Traffic Management .* Berlin: Springer-Verlag.

Poldy, F. (1982). *Airport Runway Capacity and Delay:Some Models for Planners and Managers.* Canberra: BTE Publications Summary.

Richard de Neufville, A. R. (2003). *Airport systems planning design and management.* United States of America: McGraw-Hill Companies.

Schank, J. L. (2005). Solving airside airport congestion: Why peak runway pricing in not working. *Air Transport Management* , 417-425.

Transport, D. o. (2011). *National Transport Master Plan 2050.* Pretoria: Department of Transport.

Wells, A. T. (2000). *Airport Planning & Management* (4th ed.). United States of America: McGraw-Hill Companies.

Wright, N. A. (1992). *Airport Engineering.* United States of America: John Wiley & Sons, Inc.