THE AIR TRANSPORTATION SYSTEM IN THE 21ST CENTURY

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Summary

Air transportation is one of the most important components of the world's transportation system. Not only does it provide the major means of long-distance travel in the world, but its economic impacts on global and national economies is substantial In addition, because of the very nature of aviation infrastructure (for example, airports) and the current technology for flight (for example, jet engines that consume fuel and emit air pollutants), air transportation plays an important role in efforts to improve environmental quality and promote sustainable development. The major components of the air transportation system include airports, air traffic control systems, aircraft, and airlines. Changes in each of these components will have important consequences for the future of the aviation industry. For example, significant airside congestion is occurring at some of the world's largest airports. How can additional capacity be provided in an environment where major infrastructure investment is constrained? Technological advances are preparing for a major shift in air traffic control away from ground-based aircraft guidance to satellite navigation systems that allow aircraft to fly their own routes. One of the major trends in air transportation over the past 80 years has been ever increasing aircraft size and weight. If aircraft continue to get bigger, what will this do to airport capacity and environmental impacts? And finally, in a deregulated market environment, the airline industry is extremely volatile, with market conditions significantly affecting the viability of air service and the profitability of some airlines around the world.

The air transportation system impacts the human and natural environment in several

ways. First, airports are major centers of economic activity in regions and urban areas. In the modern economy, they represent nodes of economic activity that contribute significantly to gross domestic product. Importantly, however, airports and aircraft do have some negative impacts on the natural environment. The most noticeable of these is the generation of noise, which has been the subject of government regulation and industry research for decades. Air emissions and ecological effects are two other environmental factors that are associated with the air transportation system.
Some of the key issues that are likely to characterize the 21st century air transportation system include: providing security for air travelers, continuing to improve on the environmental consequences of air transportation, dealing with substantial airport capacity shortages, promoting stability in the airline industry, incorporating new technologies into the system in particular in air traffic control and aircraft design, using new pricing and management schemes to provide the most efficient service, and promoting multimodal access to airports.

1. Introduction

Air transportation can be viewed as a very complex system. Not only does this systems perspective focus on the many physical and operations components that must work together for the system to be effective, but it also emphasizes the important influence air transportation has in such areas as economic development, national security, and environmental quality. Ever since the 18th century, when the first balloons astonished Europe, air transportation has figured prominently in the imaginations of inventors and military strategists. It was not until the early 20th century, however, that heavier than air machines began to show the capabilities that in later years would transform long distance travel as well as warfare. The fact that the original number of airline passenger trips worldwide increased from 9 million in 1945 to over 1.6 billion today suggests that the traveling public has adopted air travel as a major means of long distance transportation. Today, the world's air transportation system is a critical element of the world economy...and it is growing. For example, revenue passenger-kilometers are expected to increase by 5 percent per year up to 2015 (even with fluctuations due to the repercussions of the September 11, 2001 terrorist attacks in the USA). It is the primary means of international travel, and for many nations and regions, it is a significant factor for economic success. For example, tourism, one of the world's largest industries (adding an estimated $3.5 trillion to the world's economy-12 percent of the total), would be significantly affected by disruptions to the air transportation system. Other industries, such as electronics and pharmaceuticals, depend heavily on air transportation for the delivery of its products.

One way of measuring the importance of the aviation industry to a national economic is through its contribution to gross domestic product (GDP). In Great Britain, for example, the aviation industry contributed 1.4 percent of the GDP in 1998, employing approximately 180,000 people. The 1.4 percent was the direct contribution of the aviation industry; it does not take into account the economic contribution that air transportation makes to other industries that depend on it for the transportation of resources or products.

In addition to the income generated by air travelers, the economic gain from airports

reflects their significant role as a part of a region's employment base. Some of the largest airports in the world, London Heathrow, Chicago O'Hare, Atlanta and Los Angeles, employ more than 50,000 people each, an economic contribution that when multiplied by the subsequent economic activity that supports the needs of airport employees, results in a significant role in the regional economy. In many ways, airports have become the major transportation-related generator of economic wealth that 100 years ago was a role played by the railroads. Furthermore, trends in airport development in recent years have taken advantage of airport pedestrian traffic to develop shopping and restaurant and businesses to turn airport passenger facilities themselves into economic generators.

As one would expect with any infrastructure that has such ubiquitous reach and uses such large amounts of land in urban areas, the air transportation system also faces significant challenges. The environmental impacts of airports and airplanes have been the focus of many government policies and regulations. Noise and air pollutant emissions, in particular, have been an important problem in urban environments. To minimize these impacts, newer airports have been built increasingly farther away from urban centers. Those airports remaining in close proximity to urban populations have implemented a variety of strategies to reduce the noise impact of airport operations. To meet an expected significant increase in air travel demand, most urban areas no longer have the massive amounts of land needed to build airport facilities. More efficient operations strategies and the application of new technologies are viewed by many as the most likely solution to this problem. Before discussing the impacts of air transportation on society, it is first important to understand the basic components of this system. Each component has an important role to play in the overall effectiveness of the air transportation system. In addition, each component often has its own unique environmental issues associated with its design and operation.

2. Overview of the Air Transportation System

For purposes of this discussion, the air transportation system will be considered from the perspective of airports, the air traffic control system, airplanes, and airlines. More complex depictions of this system have included passengers, the organizations that run the airports, and other stakeholders that are affected by airport operations. However, because this article emphasizes the impacts of the air transportation system and likely future developments, the focus needs to be on those factors that will most likely be the catalysts for change, that is, on technology, infrastructure, and the airport and airline operators.

2.1 Airports

In many countries, airports are either classified for civilian or military use (although in some countries, civilian airports also serve military purposes). Civilian airports, those open to the public, are further categorized into air carrier (larger airports handling passenger airliners) and general aviation (smaller airports handling usually privately owned and operated aircraft).

Air carrier airports serve commercial aircraft. Annual passengers enplaned (one

passenger boarding an aircraft) may range from 5,000 passengers at the smallest air carrier airports to over 40 million passengers, as occurred at Atlanta's Hartsfield International Airport during the year 2000. The larger air carrier airports will usually handle over 500,000 aircraft take-offs and landings or operations per year. The busiest airports have handled over 800,000 operations annually. In some major urban areas where more than one airport exists, that area's airport system has handled many more passengers. For example, London's five airports handled almost 100 million passengers during 1999. Table 1 shows the world's busiest airports for passengers, cargo, and operations. A general aviation (GA) airport is one that usually handles small aircraft that are privately owned and operated. These aircraft range in size from the smallest single-engine propeller aircraft to small private jets (referred to usually as business jets). The smallest GA aircraft weighs approximately 2,500 pounds fully fueled; the largest business jets typically can weigh approximately 91,000 pounds at maximum take-off weights.

Approximately 5,300 airports are open for public use in the USA, the vast majority of which are GA airports. Of these 5,300 airports, 526 have commercial air service. Because GA airports require less land than air carrier airports, and due to the many users of general aviation, there are often multiple GA airports serving a large city. The existence of several GA airports in one urban area provides pilots and their passengers with options for trip making that often are not available for regular commercial air travel. Air cargo has a special role in the air transportation system. The growth in air cargo has been dramatic over the past 20 years, and is expected to grow even more over the next several decades, especially in some markets like those linked to Asia. Much of this growth is related to the changing production processes of many products in the global economy. Just-in-time manufacturing requires a reliable 24-hour delivery service, which is especially true for high value goods. Most air cargo, in fact, consists of such high value goods. In the United Kingdom, for example, air cargo consists of, in order: express mail, specialist machinery, electronics, telecommunications equipment, medical/ pharmaceuticals, textiles, food stuffs, and photographic equipment.

Whether an airport handles primarily passengers or freight, they can be divided into two distinct functional areas--landside and airside operations. At airports in the USA, airside operations begin where passenger security screening occurs. In other airports of the world, airside operations are considered to be those areas where aircraft are either parked or where aircraft movement takes place.

Airside: By far the greatest expanse of airport space is occupied by the runways. Air carrier airports often have multiple runways in many different runway layouts. Some airports have numerous intersecting runways, such as Chicago's O'Hare International Airport, and some have all parallel runways, such as Los Angeles International Airport. Runway layouts and orientations are usually dictated by wind direction or other constraints such as the presence of nearby mountains. Runways are sometimes directionally configured to reduce aircraft noise exposure over a given community. Runways at air carrier airports are typically 150 feet (46 m) wide and range in length from 7,000 (2,240 m) to 12,000 feet (3,657 m). However, there are runways that are shorter or longer, such as JFK International Airport in New York City, which has runways exceeding 14,000 feet (4,266 m).

Airport	Passengers	Rank	Airport	Cargo (metric tons)	Rank	Airport	Operations
Atlanta	80,162,407	1	Memphis	2,489,078	1	Atlanta	915,454
Chicago	72,144,244	2	Hong Kong	2,267,609	2	Chicago	908,989
Los Angeles	66,424,767	3	Los Angeles	2,038,784	3	Dallas/Ft. Worth	837,779
London (LHR)	64,606,826	4	Tokyo (NRT)	1,932,694	4	Los Angeles	783,433
Dallas/Ft Worth	60,687,122	5	Seoul	1,874,232	5	Phoenix	637,779
Tokyo	56,402,206	6	New York (JFK)	1,817,727	6	Detroit	555,375
Frankfurt/Main	49,360,630	7	Anchorage	1,804,221	7	Minneapolis	523,146
Paris	48,246,137	8	Frankfort/Main	1,709,942	8	Las Vegas	521,300
San Francisco	41,040,995	9	Singapore	1,705,410	9	Denver	520,073
Amsterdam	39,606,925	10	Miami	1,642,744	10	Paris (CDG)	517,657
Denver	38,751,687	11	Paris	1,610,484	11	Miami	517,440
Las Vegas	36,865,866	12	Louisville	1,519,528	12	Philadelphia	484,308
Minneapolis	36,751,632	13	Chicago	1,468,553	13	Houston (IAH)	483,570
Seoul	36,727,124	14	London (LHR)	1,402,089	14	St.Louis	481,025
Phoenix	36,040,469	15	Amsterdam	1,267,385	15	Boston	478,873
Detroit	35,535,080	16	Taipei	1,208,838	16	Cincinnati	477,842
Houston	35,251,372	17	Indianapolis	1,165,431	17	London (LHR)	466,815
Newark	34,188,468	18	Newark	1,082,406	18	Frankfurt/Main	458,731
Miami	33,621,273	19	Osaka	999,693	19	Washington	456,436
Madrid	32,893,190	20	Dallas/Ft.Worth	904,994	20	Charlotte	452,009
New York (JFK)	32,856,220	21	Atlanta	894,471	21	Newark	450,187
Hong Kong	32,752,359	22	San Francisco	869,839	22	Oakland	449,050
London (HKG)	32,065,685	23	Bangkok	867,942	23	Pittsburgh	448,785
Orlando	30,823,509	24	Dayton	832,246	24	Seattle	446,066
St.Louis	30,561,387	25	Beijing	774,207	25	Amsterdam	432,480
Bangkok	29,616,432	26	Tokyo (HND)	769,747	26	San Francisco	429,222
Toronto	28,930,036	27	Brussels	687,385	27	Toronto	426,506
Singapore	28,618,200	28	Oakland	685,425	28	Memphis	388,412
Seattle	28,408,553	29	Subic Bay	629,679	29	Santa Ana	387,862
Boston	27,412,926	30	Sydney	590,009	30	New York	384,554

Table 1: World's Busiest Airports for Passengers, Cargo and Operations, 2000

A fully loaded Boeing 747-400 weighs approximately 875,000 pounds. Runways must therefore be built to accommodate aircraft take-offs and landings, meaning that sufficient runway length must be provided for aircraft to accelerate, accounting for other factors that can degrade aircraft performance, such as ambient temperature, airfield elevation, runway gradient, and barometric pressure. For example, airports located in hot climates or at high elevations must have longer runways due to reduced air density. Aircraft require a specific amount of air to pass over and under the wings to ensure adequate lift is generated during the take-off roll. To compensate for reduced air density, a longer runway is necessary to allow an aircraft to accelerate to a higher take-off speed.

Other airside facilities that are important to airport functioning include taxiways and ramps. Taxiways are pavements that connect ramps and the runway(s), from which aircraft take-off and land. Taxiways are critical to maintaining efficient aircraft movement around an airfield. Taxiways provide pavement on which aircraft queue prior to take-off, as well as locations where landing aircraft can exit a runway. A ramp is a wide expanse of pavement where an airplane is parked at the concourse. The ramp is the location of many activities that support the departure or arrival of an aircraft including baggage loading and unloading, and airplane servicing. Larger airports will have ramps besides those located at the concourses. Aircraft that carry strictly air cargo will be parked at an air cargo ramp, adjacent to buildings where cargo is staged and sorted. General aviation aircraft also use air carrier airports; these aircraft will be parked at a general aviation ramp, away from the concourses and air carrier terminal.

Landside: The landside operations of an airport deal primarily with the handling of passengers. Passenger processing and waiting activities occur in terminal buildings. Airport owners continue to reevaluate and redevelop terminals because they are so vital to providing a quality experience to the traveler. Terminals of the past have often been uninteresting, unattractive, and confining to the passenger. In recent years, many terminals have either been refurbished or completely rebuilt, incorporating many design features that one sees in large public spaces, such as shopping malls, high quality office buildings, and art galleries. Examples include Pittsburgh International's AIRMALL, a collection of over 100 shops in the terminal; Amsterdam's Schipol Airport with extensive shops and markets; open space at Denver and Orlando International Airports; and art programs at the San Francisco and Atlanta airports. However, actual passenger-handling activities within terminals have been gradually changing with the advent of electronic ticketing, use of carry-on luggage, and security requirements.

Concourses are long, relatively narrow buildings containing a central corridor through which passengers walk to access or depart their aircraft. Thus, the concourse provides an important transitional area between the terminal and a passenger's aircraft. While airports have been re-developing and/or expanding terminal buildings, they have also been making similar improvements to concourses. Modern concourses are much wider than their predecessors, with newer concourses being up to 150 feet wide. Additionally, concourses are increasing in length. Some concourses exceed 2,000 feet (609 m) in length, thus requiring moving sidewalks to assist pedestrian movement. Current terminals have up to six concourses attached to the main building. Other airports are designed so that the concourses are isolated away from the building; passengers reach

the concourse(s) by riding a train or people mover.

Ground access: Ground access to airports is very important, especially if an airport is located a relatively long way from where passengers start their trips locally. Some airports are conveniently located near central business districts or local major destinations. However, even airports that are close to urban destinations often experience substantial congestion on the roads that connect them to the regional road network. Other airports are located at greater distances from local destinations. Some of these more distant airports have roadways that have been built primarily as airport access, but which have become sites for local development as well, for example, the access roads to Washington Dulles and Denver International airports.

In order to accommodate vehicles that are parked at an airport, most major airports in developed countries have large parking facilities. In the USA, numerous airports have over 20,000 automobile parking stalls located on the airport; Atlanta and Dallas/Ft. Worth have over 30,000 revenue producing parking stalls. Revenue generated from parking is often the largest revenue source for airport operators, and thus the reluctance of some to implement strategies to reduce the use of private vehicles for airport access.

European and Asian transportation planners have long recognized the need to provide other modes of access to airports, starting the transformation of the airport into a truly multimodal facility. Airports in Amsterdam, London, Munich, Rome, Tokyo, and Hong Kong have subway or train connections to their respective cities. High-speed rail connections are possible at airports such as Charles DeGaulle Airport in Paris and in Frankfurt. More airports in the USA have incorporated heavy rail access into their designs. Airports in Washington, D.C., Atlanta, Boston, and Chicago, for example, feature subway access to complement traditional vehicular access. It seems likely, however, that because airports are significant attractions to regional trips, transportation planners will have to examine more seriously how to handle airport access trips with modes other than the automobile.

Reducing Peak Demand for Airport Capacity: Flight delays have been increasing at major airports around the world because of increased airside congestion. For example, the level of non-weather related delay in the US air transportation system increased by 11 percent from July, 2000 to July 2001. The average delay time was almost 45 minutes. In 2000, one flight in six was delayed in Europe with an average delay of 22 minutes. Almost one-half of Europe's 50 largest airports have already reached or will soon reach capacity in handling aircraft at the airport.

The historical approach to dealing with increasing demand for air travel was to build new airports or expand existing ones. However, given the sheer size of a new airport, and the financial, social and environmental challenges in providing substantial increases of existing runway capacity, government agencies and airport managers have begun to consider operational strategies to reduce peak demand. Demand management strategies include such actions as limited hours of operation, a daily limit on operations or an annual passenger limitation, reallocation of flights to other nearby airports, increased landing fees during peak periods, mandatory use of larger aircraft, restricted use of national hub airports, and readjustments to airline schedules to better match with airport

capacity. Each of these strategies requires the cooperation of the airport manager, government agencies, and the airlines.

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Bibliography

Airport Councils International (1996) Airport Environmental Management Handbook, 2nd ed., Washington D.C. (An overview of all environmental aspects of airport operations and strategies for mitigation).

Ashford, N., Stanton, H.P., and Moore, C. (1997) Airport Operations, New York, McGraw Hill (Comprehensive text on airports, with very detailed discussion of every aspect of the design and operations of successful airport operations).

Harrison, J. (1996) Mastering the Sky, A History of Aviation from Ancient Times to the Present, New York, Sarpedon (A history of both civilian and military aviation, and the important implications to society).

Heppenheimer, T.A. (2001) A Brief History of Flight, New York, John Wiley & Sons (A readable history of aviation with an up-to-date discussion of possible future developments).

Morrison, S. and Winston, C. (1995) The Evolution of the Airline Industry, Washington D.C. The Brookings Institution (A comprehensive examination of the evolution of the airline industry with emphasis on market strategies and competitiveness, especially in light of deregulation).