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Understanding Flight Delays at U.S. Airports in 2010, Using Chicago O'Hare International Airport as a Case Study

Paul Blackwood

UNDERSTANDING FLIGHT DELAYS AT U.S. AIRPORTS IN 2010, USING CHICAGO O'HARE INTERNATIONAL AIRPORT AS A CASE STUDY

by

Paul Blackwood

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UNDERSTANDING FLIGHT DELAYS AT U.S. AIRPORTS IN 2010, USING CHICAGO O'HARE INTERNATIONAL AIRPORT AS A CASE STUDY

Paul Blackwood, M.A.

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Flight delays are economic, social, and environmental albatross to U.S. businesses and consumers. In 2007 alone, domestic flight delays cost the U.S. aviation industry $40.7 billion (Joint Economic Committee of the House and Senate Report, 2008). These delays involved inconveniences for airlines and passengers, and untold misery for local and state officials. In that same year, delays forced U.S. airlines to consume an extra 740 million gallons of jet fuel (Joint Economic Committee of the House and Senate Report, 2008). The purpose of this study is to understand flight delays at U.S. airports and to determine how key causal factors for delays can be mitigated. The Chicago O'Hare International Airport (ORD) is used as a case study for this research, and the year under review is 2010.

The thesis focuses on departure delays, using the Bureau of Transportation Statistics (BTS) on-time performance data. The data is divided into 5 delay-causing categories which forms the cornerstone of this study. Data are analyzed with SPSS 18.0, GIS ArcMap 10, and Microsoft Excel 2010. In 2010, ORD's combined delays were the equivalent of 15.59 years of continuous delays. Flight distances and destinations greatly influence delay durations. The study recommends introducing a taxation/bonus system to encourage efficiency and schedule compliance.

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CHAPTER I

INTRODUCTION

Background and Purpose

The Problem

Flight delays are economic, social, and environmental albatross to U.S. businesses and consumers. In 2007 alone, domestic flight delays cost the U.S. aviation industry $40.7 billion (Joint Economic Committee of the House and Senate Report, 2008). As expected, these delays involved inconveniences for airlines and passengers, and untold misery for local and state officials. In addition to these inconveniences, the report also found that in that year nationwide flight delays forced U.S. airlines to consume an extra 740 million gallons of jet fuel (Joint Economic Committee of the House and Senate Report, 2008). This waste occurred while airplanes sat unproductively on tarmacs with engines spooled as well as during airborne holding patterns. In terms of personal cost, these delays translated into "$37.60 per passenger, per delay hour" (DWS, 2008). The amount of fuel burned was equivalent to 5 percent of the industry's domestic fuel consumption for that year (DWS, 2008).

In spite of the huge sums of money invested in the aviation industry to better understand and overcome the issues of flight delays, the problem still persists. Research work devoted to understanding flight delays has attributed the causes of flight delays to several factors. These factors include the Airline Deregulation Act of 1978 and the growth of the hub-and-spoke network (Morrison 1997, Bryan &

O'Kelly 1999, FAA 1999, Flores-Fillol 2009, and Bayles), slot control (Morrison 1997, Daniel 1995, Fernandes & Pacheco 2000, Brueckner 2002, and Berardino 2009), gate assignment (Yan & Tang 2006, Haghani & Chen 1997, and Mangoubi & Mathaisel 1995), and runway and air space congestion (Schaefer & Millner 2001 and Schorr 2006).

These studies have provided some useful insights into the causes of flight delays in the U.S. In particular, they have shown how the current problems of flight delays have been caused by certain policies and measures which were initially put in place to promote the airline industry and presumably help consumers. However, most of them have focused on single factors. The result is that some of the solutions suggested or implied have also been single-targeted, rather than comprehensive. For example, Schaefer & Millner (2001) as well as Schorr (2006) suggest the need for additional airports to reduce flight delays. However, they fail to explain how many additional airports (over their 450 airport count), would be sufficient to satisfy current excesses in the system. They also fail to clarify what quantifiable impact such additions would have on the system's overall flight delay structure. Furthermore, there is no guarantee that building more airports will solve the problem. If anything at all experience with road transportation indicates that building more airports may actually increase the congestion problem.

Beginning 2003, the U.S. government developed and implemented an all-encompassing framework to document causes for domestic flight delays. These causes are divided into five major categories by the U.S. Bureau of Transportation Statistics (BTS) –an entity within the U.S. Department of Transportation (DOT). The categories include security, late aircraft, carrier, weather, and national airspace/aviation system (NAS) delays.

This categorization shows that the causes of flight delays are complex and could be better understood if all these complex factors were studied together. To date, no research work on flight delays has been conducted that takes into consideration all the five categories of causes identified by BTS. This thesis is of the view that we will not be able to mitigate the problem of flight delays until we understand fully what causes the delays. This requires a detailed study of all the factors that have been officially recognized as possible causes of delay.

Objectives

The purpose of this study is to explore the key causal factors for departure delays at U.S. airports in 2010, using Chicago O'Hare International Airport as a case study, and to identify how these factors can be mitigated. To accomplish this goal, this study will be guided by the following three questions:

1. What are the major factors behind departure delays at Chicago O'Hare International Airport?
2. What standards of delays are acceptable?
3. Can these variables be managed to bring delays within acceptable standards?

Methodology

According to BTS, flight delays consist of departure delays and arrival delays. From the viewpoint of a given local airport it is easier to examine the causes of departure delays over arrival delays since departure delays are solely ground based. Arrival delays on the other hand are airborne, but they may also be ground based as well. While it is possible to review both delays simultaneously, such a study would require significant resources. For this reason, this thesis chooses to examine departure delays. The Chicago O'Hare International Airport (ORD) was chosen as a case study for this thesis for several reasons. The first reason was its perceived significance in U.S. air transportation, in addition to its sizeable operation. According to the 2008 Joint Economic Committee of the House and Senate report, as at 2007, ORD was second only to Hartsfield-Jackson Atlanta International Airport (ATL) in flight delays nationally –with over 32 million departing passengers in 2007 alone. The second reason for choosing ORD is that it has extensive hub activities that will allow examination of the effect of the hub-and-spoke network. Third, ORD was one of only four airports initially assigned slot control. Finally, it was chosen because of convenience and accessibility to the author of the thesis.

This study utilized both primary and secondary data. To mobilize the quantitative aspects of the project, flight data warehoused by the U.S. Federal Bureau of Transportation Statistics Airline On-Time database were collected, parsed, and analyzed with Excel, GIS ArcMap 10 and various SPSS models.

Microsoft Excel was used to produce tables and charts while GIS ArcMap 10 and SPSS 18.0 was used to conduct ANOVA and other related tests. This effort was supplemented by depth interview with American Airlines –a major carrier that operate extensively in the ORD international airspace.

Project Significance

The result of this study is expected to be far-reaching for ORD as well as for neighboring U.S. airports. The study identifies some of the major causes for flight delays at ORD, and offers suggestions on how they might be reduced. While building off the work of previous scholars, the study lays the foundations for insightful discourse and action, moving forward. The project hopes to advance the efforts of re-organizing the O'Hare airspace into one that is characterized by the efficient movement in air traffic –and not by gridlock as is now the case. Improvements in this airspace will ultimately save U.S. tax payers money as well as serve as a model for future streamlining efforts at other airports.

Organization of Thesis

This thesis has six chapters. Chapter 2 provides a review of related literature and identifies previous scholarly work done on flight delays, and their limitations. Chapter 3 situates the problem in the case study area – describing the evolution and development of the Chicago O'Hare International Airport, its standing in the US airline industry and its flight delay problems. Chapter 4 discusses the methodology that was used in collecting and analyzing both the primary and secondary data that were used in the study. Chapter 5 presents the results of the study, while Chapter 6 summarizes and concludes the study with recommendations.

CHAPTER II

LITERATURE REVIEW

Much scholarly work has been done on airspace congestion and flight delays. The purpose of this chapter is to review this literature so as to place this thesis in appropriate context. The chapter has four main sections. The first section focuses on the definitions and effects of flight delays. The second section focuses on the causes and explanations of flight delays; the third evaluates the previous research; and the fourth section provides a summary and conclusion of the chapter.

Definition and Effects of Flight Delays

According to Wang et al (2001, p. 1), flight delay[s] [are] defined in many different ways, depending upon the context." For example, delays may be defined as how late scheduled flights depart or arrive, compared to an airline's schedule" (Wang et al 2001, p. 1). They may also be defined by upstream activities that have manifested themselves at the local airport level in the form of forestalled arrivals. Such delays, Wang asserts, are prorogated delays. For purposes of this review however, delays are recognized as the failure of any scheduled flight to maintain schedule within 15 minutes of scheduled time.

At the very basic level, there are generally two types of delays: arrival delays and departure delays –and since June 2003, both delays have been carefully monitored by the U.S. government (BTS, 2011). Arrival delays occur when a scheduled flight, that is already airborne, lands more than 15 minutes after its scheduled time of arrival. Arrival delays are calculated by subtracting scheduled arrival time from the actual time of arrival of a flight (BTS, 2011). Departure delays are delays experienced when a scheduled flight fails to depart more than 15 minutes after its schedule time of departure (BTS, 2011). Departure delays are calculated by determining the difference between the scheduled time of departure and a flight's actual time of departure. "A flight is considered on-time when it arrives less than 15 minutes after its published arrival time" (BTS, 2011). The total delay an airport experiences over a given time is found by adding total arrival delays for that period to the total departure delays for that period. Wang et al (2001) found that it is possible, at times, for both general types of delays to be impacted by propagated delays because of the interdependences between schedules flights within the National Airspace System. Propagated delays are delays that are manifested at the local level but were set in motion by "upstream events" in the national airspace system.

No matter how they are defined, flight delays continue to cost the U.S. economy a substantial amount of money. In 2007, for example, the U.S. Congress found that flight delays surcharged the U.S. economy $40.1 billion; burned an additional 740 million gallon of fuel; and released "7.1 million metric tons of carbon dioxide –or about 5 percent of the 142.1 million metric tons of carbon dioxide [produced] from domestic commercial aircraft in 2006" into the atmosphere (Joint Economic Committee of the House and Senate Report, 2008, p. 5). The report also showed that "almost 20 percent of total domestic flight time in 2007 was wasted in delay; seventy-eight percent of flight delays in 2007 occurred before take-off; and delays at the nation's largest airports disproportionately contributed to total passenger delays in 2007" (Joint Economic Committee of the House and Senate Report, 2008, p. 5).

Explanations of Flight Delays

Explanations of flight delays have pointed to several sources including the Airline Deregulation Act of 1978 –signed into law by President Jimmy Carter; the creation and use of hub-and-spoke model at U.S. airports; the design and implementation of slot control, gate assignment, and runway and air space congestion. Each is discussed in detail below.

Airline Deregulation

The Airline Deregulation Act of 1978 principal goal was to promote the "reliance on competition" among airline carriers (Morrison, 1997, p. 1). The Act was created to address the crippling effects of market protection, and to observe the requirements of the international theory of contestable markets that emerged during the mid-1970s (Stutz & de Souza, 1998, p. 190). The theory argued that competition was beneficial to consumers and for that reason there should be easy entry and exit in any given market, and this case the airline industry. Prior to this, the Civil Aeronautics Board (CAB) established in 1938, provided oversight to the U.S. airline industry, which protected the few major carriers in the industry from additional competition.

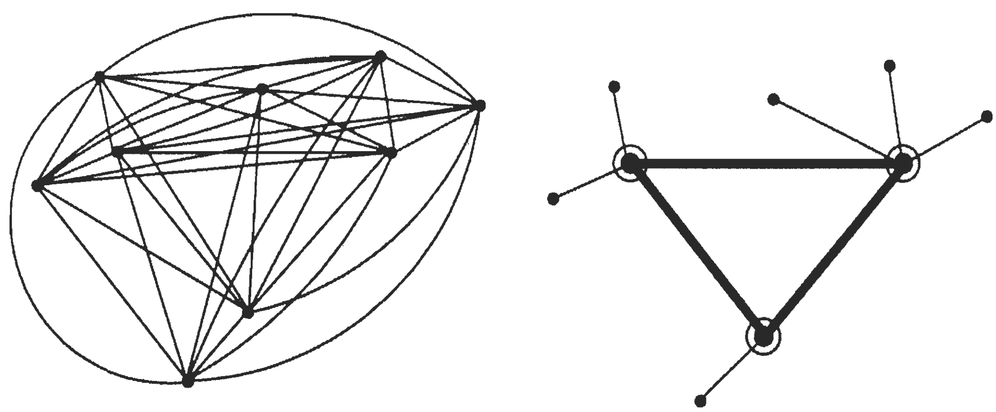
In 1979, the Ninety-Sixth U.S. Congress explained that the passage of the Airline Deregulation Act (as expected), was to set in motion a pattern of "an economic rationalization" which would improve the industry's economic performance (U.S. Congress, 1979, p. VI). Morrison (1997) contends, however, that the Deregulation Act of 1978 ushered an era of such fierce competition that it became the starting point of much of the industry's current problems. He notes that in the absence of government route entry control, airlines were left unchecked and could enter or exit markets at will (Morrison, 1997).

The Hub-and-Spoke Network

One of the earliest impacts of the 1978 Airline Deregulation Act was the growth of the hub-and-spoke network –a transportation model used to optimize routing capacity of passengers and goods between locations. Aviation experts vigorously argue that it was the airlines industry –and Delta Airlines, in particular, that first developed the hub-and-spoke concept in the 1950s (Delta, 2011). Kraus et al (2006) found that the idea later became very popular among carriers with scheduled operations in the 1970s.

As a transportation network, hub-and-spoke network has two basic components, namely links and nodes with every link in the system being sandwiched by a node or a hub. However, unlike the completely interconnected network system design (Figure 2.1) –where commuting is conducted between originating cities and destination cities in unbundled non-stop trips – hub-and-spoke networks optimize commute by concentrating resources and equipment at specific locations for the purpose of bundling traffic flow (Bryan & O'Kelly 1999). It was also noted that, "in a hub-and-spoke network … reduction in the number of links is made possible by the establishment of hubs or transshipment points" (Bryan & O'Kelly 1999 p. 276).

a. b.



Note: Panel a. has more direct routes than panel b. However, some direct routes in Panel a. could be grossly underutilized carrying "weak" payloads. In Panel b. weak or underutilized routes are eliminated and bundled to optimize movement of passenger and goods.

Source: Bryan & O'Kelly, 1999

Figure 2.1 A Completely-Interconnected 9-Node Network (Panel a) and A Hub-and-Spoke Network (Panel b)

As seen in the diagram above, the airline hub-and-spoke model is built around the idea of making a desired airport the center of flight connections for passengers. Hubs are designed to route passengers from flights originating out of other airports to a common point (usually another hub). Sometimes additional connections are required for passengers or goods arriving at a hub to get to their final destination.

According to Bryan & O'Kelly (1999, p. 276) there are two basic models of hub-and-spoke networks designs. These are "single assignment model" and the "multiple assignment model". The single assignment model is characterized by multiple cities connecting to a single hub, while the "multiple assignment model" is characterized by each city connecting to more than one hub.

In the single assignment model no sorting is necessary at the departing cities because all passengers and goods must journey to the same hub. However, in the "multiple assignment model" the sorting must be conducted at points of departure ahead of passengers of goods arriving at hub destinations, since multiple hubs are involved (Bryan & O'Kelly, 1999).

Hub-and-Spoke Benefits

Hub-and-spoke as a transportation network model has many benefits. In explaining the circumstances that drove the previously "market-sheltered" industry to develop new, out-of-the-box ways to contain cost and improve profits, Kraus et al (2006, p. 88) writes: the aviation industry "driven by [new] competitive pressure[s] on (formerly) protected national carriers … [adapted] to an increasingly competitive market environment, … [soon] the hub-and-spoke-system became a typical companion of the trend towards a liberalization of air transport". They note that airports with hubs activities saw increases in traffic. Bryan & O'Kelly (1999) believe this is due in part to the fact that airlines that subscribe to hub-and-spoke operations conscientiously reduce – and sometimes even eliminate – underutilized links or routes by bundling passenger-flow, as well as cargo into strategic hubs locations. Bryan et al (1999) also found that this strategy –while it reduces the number of direct routes between airports, even as it inversely increases travel time because of indirect passenger routings– it also improves carrier profitability because it eliminates wastes.

Experts note that air carriers, through "hubbing" and regulating passenger flow, are able to use larger airplanes to move greater volumes of payload each trip, and thus reduce passenger mile costs (Bryan & O'Kelly, 1999). Cessna Model 172R Handbook (2011) describes payload as "the occupants, cargo, and baggage" onboard a given flight.

In a study that compared conditions at three non-hub airports with three major hubs, Button & Taylor (2000 p. 215) found there were "significant, positive correlation between [the creation of] new economies, employment and hubbing." The study discovered that hub activities at the reviewed airports were compelling drivers for employment.

Hub-and-spoke activities also allow airlines to increase their visibility and improve their image at desired locales. In addition, local officials and airlines view hub operation as a significant marketing tool to promote increased flight options. In 2009, American Airlines issued a news release to market flights out of the carrier's largest hub based at Dallas/Fort Worth International Airport to General Mitchell International Airport located in Milwaukee, Wisconsin (American Airlines 2011, Mitchell International Airport 2009). The move was designed to market the carrier's newly scheduled flights in a manner that matched its passenger's travelling needs, and to improve shareholder profit. An excerpt of this release is provided as Appendix A. At the same time the FAA (1999) believes the hub-and-spoke network design allows airlines to optimize their resources –fewer planes serving maximum number of paired-cities and routes.

Hub-and-Spoke Drawbacks

While the hub-and-spoke model has brought some clear benefits to transportation systems in general, it also has some drawbacks. In 1999, the FAA set up the Office of the Secretary (OST) Task Force and found that after two decades, deregulation had generated significant benefits for the public (FAA, 1999). But the Task Force also found that "in response to deregulation" airlines greatly expanded their use of hub-and-spoke in the U.S. (FAA, 1999, p. 1). However, the "efficiency gains" from hub-and-spoke operations allow carriers to erect giant-sized operations at local hubs, which make it harder for new carriers to enter those locations, and as a consequence, higher fare prices are sustained (FAA, 1999, p. 1).

Flores-Fillol (2009) questions the rosy picture espoused by advocates of hub-and-spoke operations arguing that the full impact of hub-and-spoke operations on air traffic congestion and flight delays in the U.S. national airspace system, are telling. He explains that because "airport congestion [also] depends on the number of [carrier] operations, in the current competitive environment, congestion problems are exacerbated when airlines increase flight frequency into hub operations (so as to reduce passengers' schedule delays) [by] using [multiple] smaller capacity aircrafts (such as regional jets or even turboprops)" to shuttle more passengers to their connection points or destination (Flores-Fillol, 2009, p. 358). He notes that "these smaller planes utilize the same resources as larger planes in terms of landing slots and air traffic control, while carrying [relatively] fewer passengers" and creating unnecessary congestion and delays in the process (Flores-Fillol, 2009, p. 358). Bayles

(2007) describes hub operations as self-starters of flight delays, and explains that they attract more flights that results in overcrowded airspaces. Fredrick Piccolo, chief executive officer of Sarasota-Bradenton International Airport (SRQ) recounted that delays at his local airport were the result of upstream hub activity (Bayles, 2007).

While Button (2002) concedes that periodic congestion was among the most frequent problems facing passengers at hub airports, he insists congestion should not be entirely discouraged, however. He explains that optimal levels of congestion translate into good economics for airports and carriers alike. Button (2002, p. 182) appealed for moderation on the issue of congestion noting: "it would simply be wasteful of airline resources and airport capacity if congestion was zero, but rather of what is an optimal level of congestion. In economic terms, an optimal level of congestion is derived at that point where the benefits of an additional user just balance with the costs that the user imposes on the system (including those on other users)."

Another disadvantage of the hub-and-spoke is that passengers are sometimes routed counter-intuitively through distant hub locations. This technique may increase passenger anxiety. Bor (2007, p. 209) found that "physical effects of air travel, in particular, have psychological consequences and these apply especially to trans-meridian long-haul flights, which may produce irritability, sleep disturbance, boredom and restlessness". Also, increased travel time incurred as a result of indirect routes, has the potential for additional waiting, if connections are delayed. Under these circumstances passengers are forced to spend more to keep themselves refreshed on such indirect routes. For example, on Sunday, September 4, 2011, Delta Airlines' flight from Grand Rapids, Michigan (GRR) to New York, New York (JFK), was routed through Memphis, Tennessee (MEM) –with a change of plane in Memphis, and then to Orlando, Florida (MCO), before finally arriving at New York, New York (JFK) (Delta, 2011). The flight which could have taken an average of 2 hours, or less, by direct flights out of Detroit, Michigan (DTW), instead took 9 hours, 55 minutes –layovers included (Delta, 2011). Passengers' anxiety and financial distress, under such circumstance are further amplified if upstream flights, before connection, experience delays.

Passengers and aviation officials agree that they often feel unfairly punished by hub operations. Buffalo News business news reporter, Matt Glynn, disclosed that, William Vanecek, "director of aviation for the Niagara Frontier Transportation Authority" raised objections to hub connections in these words: "business travelers cannot afford to spend hours reaching their destination, … so nonstop service is crucial … It's not only fare price [that matters], but [also] the time your people spend in an airport or getting to an airport, and then it's making sure your flight times to your final destinations are not eight, nine hours' worth of connection" (Glynn, 2011).

Slot Control

Another cause of flight delays that has been discussed in the literature is slot control. According Morrison (1997, p. 4), slots are control and regulatory tools used to determine "the number of takeoffs and landings that air carriers" –and other general aviation users – may conduct each hour at an airport." In 1997, only four

U.S. airports were subject to slot control. The four were Chicago O'Hare International, New York LaGuardia International, New York John F. Kennedy International, and Washington Dulles International (Morrison, 1997). Morrison explains these airports were selected to participate in slot control by Federal Aviation Administration (FAA) because of their sheer size, and because of their location. Within this regulatory framework, carriers operating at these airports are required to buy slots from the government at the desired slot-controlled airports, for operation.

Slot distribution assignment varies among carriers, and the assignment process is sometimes subjective. Berardino (2009) found that "methods for distributing slots among operators have ranged from simply giving them to airlines recorded as operating at a certain date; withdrawing then redistributing them, creating exemptions for favored operations (including, on one occasion, the redistribution of seventy-one slots to JetBlue at JFK); or relying on the secondary market where holders of record could sell or lease slots or use them as collateral on loans from financial intermediaries, some of whom became holders of record" (Berardino, 2009, p. 282 – 283).

The U.S. government has made it clear that airlines do not possess proprietary right to slots (Berardino, 2009). Nevertheless, in the past, these slots have been considered as properties and have been sold by cash-starved carriers to raise capital (Rassenti et al, 1982, Coursey 2008, Berradino 2009). Indeed, Coursey (2008) found that slots are customarily sold to the highest bidders. Berardino (2009) also found that in 2008, Southwest Airlines paid as much as $7.5 million for fourteen slots at

LaGuardia International Airport (LGA). He noted that this level of financial investment is akin to scarcity of access to these airports (Berardino, 2009). To this end, the U.S. government, in its "final guidelines [proposed] for New York's J. F. Kennedy International Airport (JFK) [clarified] … slot ownership rights by explicitly replacing temporary holdings with slots leases of up to ten years, and placing ownership, and the right to redistribute, firmly in the hands of the FAA" (Berardino 2009, p. 283).

Berardino (2009 p. 280) also found that "physical land limitations define the capacity of any given runway as well as its associated airspace system, and [argues that] such limitations are used to establish the number of slots per time period at an airport". His study points out that such limitation are crucial when calculating estimated delays at various time of the day (Berardino, 2009). Fernandes & Pacheco (2000) also discovered that passenger terminals, among other things, determined airport capacities. If an airport critical capacity is breached, slot operations are adversely affected, and airspace congestion and flight delays increase –spiraling out of control. Other variables used to define airport capacity include: the number of runways an airports has; airport technology and equipment available for operation; airport size –whether it is small, medium, or large; human capital; weather; ambient ecology; and the layout of the physical plant, e.g. airports bordered by mountainous terrain, huge water bodies, and cities (Pavlin, 2006).

Morrison (1997) explains that slot control (and its distribution) was commissioned, in part, to curb flight delays and carriers are expected to operate within the terms of their contractual agreements. However, the link between airport congestion and the sale of slots cannot be contested. Brueckner (2002) found that airports that sold and operated slot control were subject to higher levels of congestion. Basing on Daniel's (1995) study of regression analysis of three alternate airport-concentration measures, Brueckner, 2002 found that flight delays increased with increased activities, but more so for slot-controlled airports.

Because slots are major revenue earners for airports, sometimes airports sell more slots than are available (Donohue, 2004). In such instances, it may be argued that authorities sell slots based on what that slot-controlled airport should be able to handle under very ideal circumstances, instead of recognizing the airport's actual operational limitations. Brueckner (2002) suggests the problem of overselling slots may be addressed by increasing the capacity of congested airports with new runways and improvements in the nation's current air traffic control technologies.

Gate Assignment

"Flight gate assignment is an essential feature of an airport's operation" (Yan & Tang, 2006, p. 547.). However, seamless gate assignment is not always attainable, and the effects of unplanned events at major airports sometime set in motion negative cascading effects on various gates and flights downstream (Yan & Tang, 2006). Surmising the reality of these delays Yan & Tang (2006 p. 547) reports the "the reality is that stochastic flight delays (such as early or late arrivals and late departures) often occur, and these cause real-time stochastic disturbances on previously made gate assignments." Preparing for such eventualities clearly adds unique layers of difficulty to the process of designing gate assignment plans. Because it is difficult to see into the future – in addition to other related constraints – gate planner must design for stochastic flight delays to avoid certain frustration (Yan & Tang 2006).

Yan & Tang (2006) contend that gate assignment plans do not possess the capacity for "real-time *reassignment"* and suggest that they often fold under the weight of unexpected disturbances since planners are usually unable to make reasonable and timely corrections for such disturbance. To frame this idea Yan & Tang (2006 p. 548) explain that "if the two planned *time windows* – a period of time for a flight assigned to a gate – for two consecutive flights, overlap due to stochastic flight delays, then the airport authority needs to reassign the two conflicting flights. [However] such a reassignment will probably impact on downstream flights … [and] such downstream disturbances are affected by many complicated factors, including the location of the original gate assignments, the time of the actual flight delays, and constraints related to reassigning two conflicting flights, all of which are difficult to estimate ahead of time." As such, the ability to accommodate unforeseen system wide occurrences requires a nimble gate planning system that is capable of offsetting further stochastic delays in the system. Yan & Tang insist that if planners are able to use a self-interrogate system between planned assignments and potential reassignments, such a system would yield useful results (Yan & Tang, 2006).

This problem as discussed by Yan & Tang (2006) not only illustrates the complexities involved in aligning the arrivals and departures of carriers with their assigned gates in planned-for-events, but it also reveals the haphazard strategies gate schedulers are forced to employ in stochastic circumstances. However, there are a number of smart gate flight models in use today including "zero-one integer programs, mixed integer programs, or network flow programs … and their objective functions usually include the minimization of the total passenger waiting time, the total passenger walking distance, the number of off-gate events, the range of unutilized time periods for gates, the variance of idle times at the gates, or a combination of the above" (Yan & Tang, 2006 p. 548).

Pedestrian traffic inside the terminal itself also impacts gate operations (Haghani & Chen, 1997). Basing themselves on the work of Mangoubi & Mathaisel (1985), Haghani & Chen (1997 p. 437) found that "the distances a passenger is required to walk in an airport to reach his departure gate, the baggage claim area, or his connecting flight are an important consideration in the effective utilization of aircraft gates at an airport terminal". As such, the physical plant layout of airports terminals may also impact flight delays. Haghani & Chen (1997 p. 437) recalls an example, where "the mean walking distance per passenger at Terminal No. 2 of Toronto International Airport in Canada, was reduced from 923 ft. in 1973, to 800 ft. in 1975 … [and found] the improvement was a direct result of a change in gate assignment policy by Air Canada, the terminal's sole user." This decision saved each passenger as much 100 ft. in walk distances within its terminal (Haghani & Chen, 1997).

Runway and Airspace Congestion

Runway and air space congestion have also been identified as causes of flight delays (Schaefer and Millner 2001, Schorr 2006). Schaefer and Millner (2001) found that the primary cause of flight delays is overcrowding within the national airspace system, which they attributed to insufficient airports. They explained that 450 airports handled all commercial flights in the U.S., but 94 percent of these were processed by only 60 of the top tier U.S. airport. More crucially, they discovered that as few as 20 airports of those 60 airports controlled more than half of that traffic. Schaefer & Millner (2001) believe this situation is responsible for much of the chaos and lengthy flight delays experienced the U.S. Schorr (2006) makes similar arguments insisting that runway and airspace congestions are the cornerstone for domestic delays.

U.S. Government's 2003 Regulatory Intervention

Beginning 2003, the U.S. government developed and implemented an all-encompassing framework to document causes for domestic flight delays. These causes are divided into five major categories by the U.S. Bureau of Transportation Statistics (BTS) –an entity within the U.S. Department of Transportation (DOT). These categories are: 1). Security Delays, 2). Late Aircraft Delays, 3). Carrier Delays, 4). Weather Delays, and 5). National Airspace/Aviation System (NAS) Delays.

Security delays refer to events that trigger the evacuation of an airplane, an airport terminal, or any other airport area. Among other things, BTS lists "inoperative screening equipment and/or long lines in excess of 29 minutes at screening areas" as events that cause security delays (BTS, 2011).

Late aircraft delays refer to any prior flight that arrives late and in turn causes another flight to be late for departure, or arrival (BTS, 2011). Carrier delays are any carrier based action that results in cancellations or delays. Examples include: "maintenance or crew problems, staffing, aircraft cleaning, baggage loading, fueling, etc.," (BTS, 2011).

Weather delays are any severe meteorological event carriers deemed adverse to flight safety, which results in delays or cancellations (BTS, 2011). Examples severe weather includes freezing rain, severe thunderstorms, ice storms, and twisters.

National aviation system (NAS) delays also called National Airspace System delays are any variety of circumstances – including events that are "non-extreme weather" – that occur in the U.S. domestic airspace and compromises the separation and safe operation of aircraft. These may include: airport operations, e.g. runway construction; faulty runway or directional lightings or equipment, excessive air traffic, or problems stemming from air traffic control (ATC), and some weather event (BTS, 2011).

Evaluation

These studies have provided some useful insights into the causes of flight delays in the U.S. In particular, they have shown how the current flight delays have been caused by certain policies and measures which were initially put in place to promote the airline industry and presumably help consumers. However, most of these studies have focused on single factors. Thus, it has either been hub-and-spoke, slot control, or gate assignment. The result is that some of the solutions suggested or implied have also been single-targeted, rather than comprehensive. For example, while Schaefer & Millner (2001)'s study raises some important questions, they fail to explain how many additional airports (over their 450 airport count), would be sufficient to reduce current delays in the system. They also fail to clarify what quantifiable impact such additions would have on the system's overall flight delay structure. Furthermore, there is no guarantee that building more airports will solve the problem. If anything at all experience with road transportation indicates that building more airports may actually increase the congestion problem.

Similarly using Schorr's (2006) reasoning, the industry's woes may simply be solved by building new airports. Clearly, this idea is neither practical nor advisable since the government does not have infinite resources to build new runways or airports. As already mentioned, carriers will simply continue to overschedule flights to meet demand.

As indicated by the BTS categorization of flight delay causes, flight delays are indeed caused by a complex set of factors that needed to be studied as such. To date, no research work on flight delays has been conducted that takes into consideration all the five categories of causes identified by BTS. This, in part, could be due to the difficulty of categorizing the many factors that might cause flight delays under these five headings. For example, BTS (2011) even cautions, that "there are some categories of weather [that gets reported] within the NAS category". These kinds of weather events are non-severe and manageable, and the DOT insists that the FAA, carriers and airports, for the most part, should be able mitigate their impact on flight operations. Examples of these kinds of weather event are: headwinds, crosswinds, rain, and moderate to heavy snow. In 2009, non-severe weather was responsible for more than 60 percent of NAS delays, and in that same year, NAS delays totaled 30 percent of overall delays (BTS, 2011).

However, a careful analysis of the factors that have been identified in the literature can lead one to closely link those factors to BTS' five categories of causes. For example, other kinds of natural events that are clustered into NAS delays include obstacles on runways and collision of birds with aircraft. On June 29, 2011, for instance, the diamondback terrapins turtles crossing Runway 4 at John F. Kennedy International Airport (JFK), forced a partial shutdown of the airport operations at the airport (Ossad, 2011). The "stampede" was so protracted that it featured every major news network bulletin. In the end, the U.S. Department of Agriculture assisted the turtles across the runway to their nesting area across the bay. Again, on January 15, 2009, US Airways Flight 1549, departed LaGuardia International for Charlotte/Douglas International and collided with at least two Canadian geese. The impact flamed out both engines –effectively converting the jetliner into a virtual glider. Captain Sullenberger landed the crippled passenger plane in New York's Hudson River, and all 155 souls onboard miraculously made safe exists. Ultimately, Flight 1549 was not only delayed, it was permanently disabled. Although incidences and incursion with wild life are very common within the industry, they do not always make the evening news and their cumulative impact on delays are no less significant.

Finally, delays caused by the hub- and-spoke networks can be assigned as to late aircraft delays, NAS delays, or carrier delays categories. Delays generated from slot control may be primarily grouped as NAS delays as well as late aircraft delays. This is because slots operations have been found to encourage clogged airspaces. As discussed, clogged airspaces inhibit the timely arrival and departure of flights with connection. On the other hand, since airport terminal gates are leased by airlines, the delays generated from gate assignments are generally the result of carriers themselves. Note however, that gate assignments may also result in late aircraft delays for downstream flight activities as well as extended weather delays and security delays. Weather delays and security are especially likely if slot or hub activities cause overload in the national airspace system.

Summary and Conclusion

Flight delays constitute a major problem in the U.S. airline industry. In 2007, it was estimated that flight delays cost the U.S. a total of $40.1 billion. Apart from this, domestic flight burned an additional 740 million gallon of fuel; released "7.1 million metric tons of carbon dioxide –or about 5 percent of the 142.1 million metric tons of carbon dioxide [produced] from domestic commercial aircraft in 2006" into the atmosphere delays; and levied disproportionate levels of delays at the nation's largest airports in 2007" – among other things (Joint Economic Committee of the House and Senate Report, 2008). Needless to say, the causes of flight delays have attracted a lot of research work. Most of this work has attributed the causes of delays to the deregulation of the U.S. airline industry in 1978 and the resulting growth of the hub-and-spoke system of network, slot control, and gate assignment. While all these studies have highlighted the cause of flight delays, the problem still persists and our understanding of the problem is still incomplete.

In 2003, BTS introduced a new category of causes of flight delays and began collecting statistics about them. These categories are security delays, late aircraft delays, carrier delays, weather delays, and national airspace system delays or NAS delays. As of 2010, academic studies on the causes of flight delays at U.S. airports using the government's 5 designated causes of delays were hard to come by. Admittedly, this could in part be due to the fact that it is not easy to classify all the many causes of flight delays under these five categories. However, given the importance of flight delays and given the fact that they continue to occur, it will be important to understand these causes so as to determine the best cause of action to take to mitigate the effects of delays. This thesis examines the causes of flight delays within the context of the government's 5 categories for the causes of delays, using Chicago O'Hare International Airport (ORD) as a case study. In the next chapter, the background information of ORD and the problems of flight delays at that airport will be provided.

CHAPTER III

THE CITY OF CHICAGO AND THE O'HARE INTERNATIONAL AIRPORT (ORD)

The purpose of this chapter is to provide background information on the Chicago O'Hare International Airport (ORD) –the case study airport for this research. The chapter has three sections and a summary. The first section deals with the City of Chicago –home of the Chicago O'Hare International Airport. The second deals with the O'Hare International Airport, while the third provides a summary of the chapter.

The City of Chicago, Illinois

The City of Chicago, Illinois, affectionately called the "Windy City" is home to the Chicago O'Hare International Airport. The city is located at latitude 41° 88' N, and longitude 87° 63' W (World Atlas, 2011), on the southwestern shores of Lake Michigan (Figure 3.1). With a core population of 2.8 million and metropolitan area population of 9.5 million residents, Chicago is the third largest city in the U.S., as well as the third largest metropolitan area in the nation, after New York and Los Angeles (U.S. Census Bureau 2011, U.S. Census Briefs 2010). The Chicago metropolitan area, commonly called Chicago-Joliet-Naperville, IL-IN-WI, or Chicagoland is some 25 miles (40 km) from north to south, and 15 miles (25 km) from east to west," at its greatest extent (U.S. Census Briefs 2010, Chicago, 2011). The city is considered an ethnic melting pot with 44 percent white, 32 percent African American, and 24 percent of residents reporting as some of other ethnicity (Table

3.1). Between 2006 and 2010 median household income was $46,877, and the median age for residents was 32.9 years (U.S. Census Bureau, 2011).

Table 3.1 Chicago Ethic Profile (2010)

Demographic Detail	
White	1,212,835
Black or African American	887,608
American Indian and Alaska Native	13,337
Asian	147,164
Asian Indian	29,948
Chinese	43,228
Filipino	29,664
Japanese	4,347
Korean	11,422
Vietnamese	8,930
Other Asian [1]	19,625
Native Hawaiian and Other Pacific Islander	1,013
Native Hawaiian	242
Guamanian or Chamorro	361
Samoan	94
Other Pacific Islander [2]	316
Some Other Race	360,493
Total	**2,770,627**

Source: U.S. Census Bureau 2010

The City of Chicago was incorporated in 1837 with little over 4,000 residents (Chicago, 2011). The city "was ideally situated to take advantage of the trading possibilities created by the nation's westward expansion" (City of Chicago, 2010). The city's urge to improve trading was so fierce that an agreement was reached to connect the waterways of the Great Lakes to the Mississippi River. This project was completed in 1848, "but the canal [waterway] was … rendered [soon after], obsolete by railroads" (City of Chicago, 2010). The railroad thrived in Chicago, and the “young city became the country’s railroad hub, which helped diversify the city’s rapidly growing industrial base” (Chicago, 2011).

As the city grew in national importance, so did its boundaries. By the 1850s the city had begun to attract people in droves. Because of the population boom, residents were forced to improve the city’s limited infrastructure by installing “a sewer system” among other things (Chicago, 2011). However, much of the infrastructural improvements were made of wood, and in 1871 a vast portion of city was consumed “in the Great Chicago Fire” (City of Chicago, 2010). This did not deter the city’s resilience and it thereafter embarked on an ambitious program to rebuild. In fact, by 1884 Chicago was home to the nation’s first skyscraper (City of Chicago, 2010). Historians romanticize that that skyscraper –the “10-story, steel-framed Home Insurance Building, [located] at LaSalle and Adams streets …was demolished … [as recently as] 1931 (City of Chicago, 2010).

Chicago’s prominence came into full force when in 1890 it competed against New York, Washington DC, and St. Louis and won to become the site of the 1893 World Fair: Colombian Exposition (Applebaum, 1980). The success of the fair had profound impact on architecture, city planning, the arts, American industrial optimism and Chicago’s self-image as a great American city (Applebaum, 1980). By the end of World War I however, Chicago was caught, yet again, in another love affair with transportation –but this time with air transportation. The love affair flourished even further after the city was paired with San Francisco, and New York, in the 1920s by U.S. Post Office Department as part of the government’s new transcontinental airmail routes strategy (Wensveen, 2007). Wensveen explains that these new airmail partnerships legitimized air transportation as a viable means, and placed "the airmail service in the same relationship with the Post Office Department as mail service provided by the railroads, steamship, and other mail contractors" (Wensveen, 2007, p.33). Wensveen also argues that these airmail contracts have evolved into several modern-day airlines.

Chicago also "became a major radio and electronics [manufacturing] center during the 1920s," but manufacturing as a whole collapsed during the Great Depression (Chicago, 2011). "In 1931, Chicago's overall unemployment rate stood at 30 percent –much higher than the national rate, which would hit 25 percent in 1932-33 –the worst years of the Depression (Pacyga, 2009, p. 253). Pacyga explains that the devastation was so deep that "Chicagoans largely relied on charity to attempt to deal with poverty." However, by late 1950's the city had fully recovered. By some estimates, this period marks the "high point of Chicago's role as an industrial city" (Hudson 2006 p. 135). Hudson also found that by 1958 "the metropolitan area had more than 13,000 manufacturing plants – three-fourths of which were …in the city itself" (Hudson 2006 p. 135).

The federal government's economic contribution was also considerable in the city after the Interstate Act of 1956 was passed. Then "Governor William G. Stratton pointed out …that [the] highway construction in Chicago … [totaling] $137,679,000, [represented] the largest public works program in the history of the area, and surpassed all other metropolitan road programs in the nation" (Pacyga, 2009, p. 336).

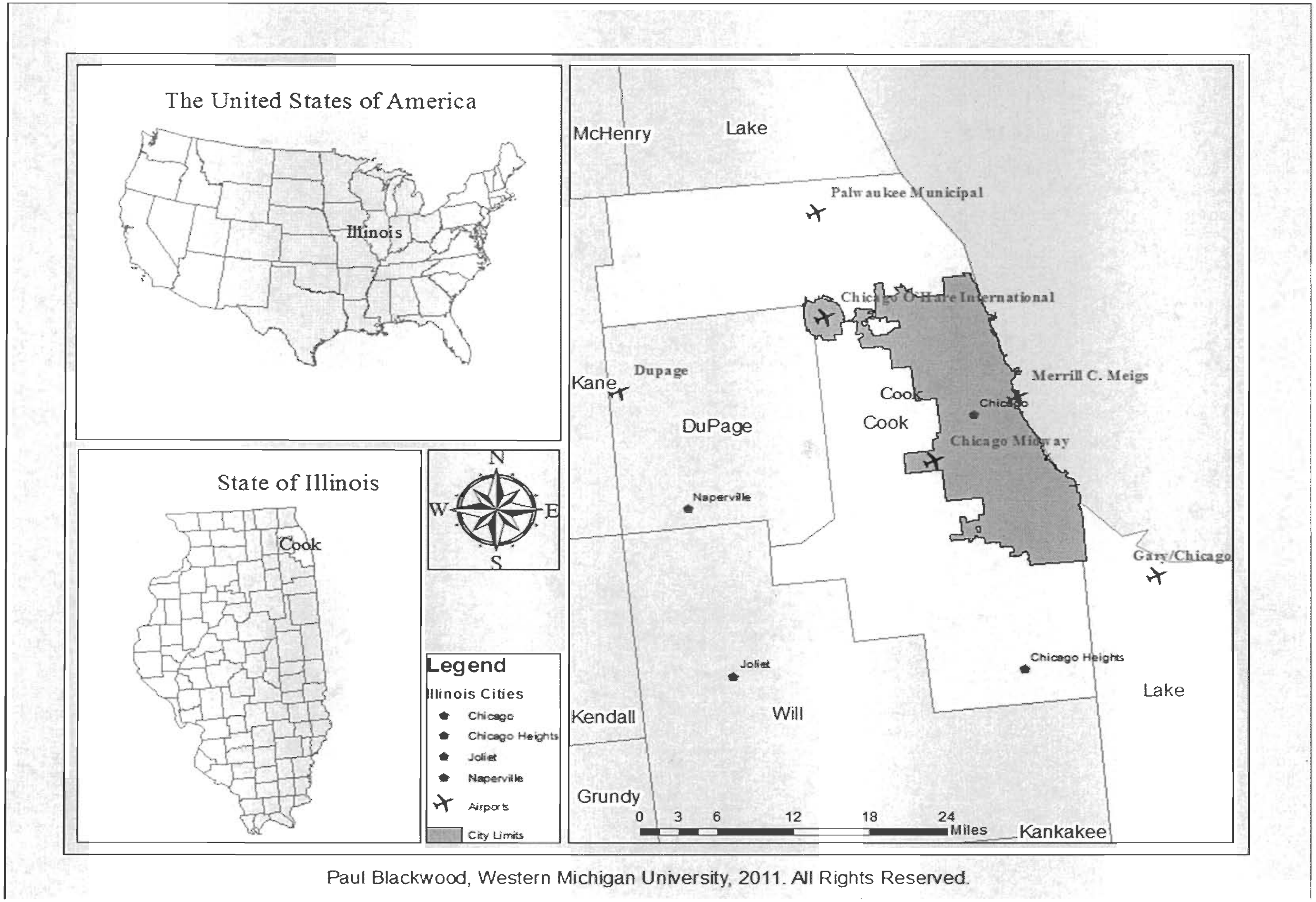


Figure 3.1 The City of Chicago and Chicago O'Hare International Airport

As the city transitioned into the 1960's, 70s, and 80s, they city experienced anemic economic growth, and increased signs of poverty became evident. Pacyga (2009, p. 397) explains that in the 1980s Chicago was home to "ten of the nation's sixteen poorest neighborhood." According to Palmer, Wheeler & Mitchelson (1997, p. 1), "between 1980 and 1985 … [the region] lost a total of 187,000 jobs … 184,000 of which were in manufacturing alone." However, by "the 1990s the city … [rebooted and] experienced renewed residential and commercial investment … [and gained] population for the first time since the 1940-50 census period" (Bennett, 2006).

Today, modern Chicago is among the top economic centers in the U.S. According to World Business Chicago (2012), "Chicago has one of the world's largest and most diversified economies, with nearly 4.3 million employees and a gross regional product (GRP) of more than $500 billion."

The Chicago O'Hare International Airport (ORD)

Located about 14 miles northwest of the City of Chicago, the O'Hare International Airport sits about 672 feet above sea level on a 7,627 acres of land (AirNav 2011, FAA 2008). According to "The Airports Council International, which governs roughly 1,650 airports worldwide," Chicago O'Hare International Airport was ranked the third busiest airport worldwide in 2010 (Huffington Post, 2011). The Council ranked Atlanta-Hartsfield International Airport first and Beijing Airport second in that report (Huffington Post, 2011).

The origin of the O'Hare International Airport however, goes back to 1945, when, a Site Selection Committee appointed by Chicago Mayor Edward Kelly chose

Orchard Field, the location of a Douglas aircraft assembly plant located on the northwest side of Chicago, as the site for a new Chicago airport. "The site had four concrete runways" (Chicago Department of Aviation, 2011). The concrete runways were fitted with temporary runway lights the following year to accommodate dusk operations (Chicago Department of Aviation, 2011). In 1949, the city "renamed Orchid Field as Chicago-O'Hare International Airport to honor naval aviator … [Lieutenant Commander] Edward H. "Butch" O'Hare –a Medal of Honor recipient from Chicago, who died in World War II" (Chicago Department of Aviation, 2011). However, it was not until 1955 –six years after receiving its current name –that the airport accepted its first commercial air traffic (Chicago Department of Aviation, 2011). In that first year, the airport "served 176,902 passengers" (Chicago Department of Aviation, 2011).

Operation during the airport's infant years was fairly intense. As a consequence, the airport embarked on year-to-year changes to address its growth trajectory. In 1956, 13 airlines flew out of O'Hare (Chicago Department of Aviation, 2011). This demand forced the city to add one more runway to the airport's existing four concrete runways, the following year (Chicago Department of Aviation, 2011). In 1958, O'Hare dedicated the airport's first international terminal into operation "with non-stop flight[s] from Paris to Chicago," and processed 22,498 international passengers that year (Chicago Department of Aviation, 2011). That following year, the city's mayor, Richard J. Daley, agreed to expand the airport's limited land territory to 7,200 acres of land (Chicago Department of Aviation, 2011).

Figure 3.2 Aerial Photograph of O'Hare International Airport
Photo Source: Seita, 2012. http://www.flickr.com/photos/jseita/5457379097/

Between 1960 and 1969 O'Hare was declared the world's busiest airport, processing almost 20 million passengers in 1965 (Chicago Department of Aviation, 2011). The airport added its sixth runway in 1968, and by 1971 a seventh was added (Chicago Department of Aviation, 2011). In 1978, the U.S. Congress passed the Airline Deregulation Act. The Act had enormous impact on the airport's operation.

Robson (1998) found that the consequences of deregulation forced some carriers to flee to neighboring airports to escape O'Hare's expanding hub operations. The Act was also responsible for the implementation of slot control at the airport in 1986 (Robson, 1998). The Chicago Department of Aviation (2011) recounts that "over 50 million passengers passed through … [the airport], for the first time, in 1986. This level of passenger throughput came at a heavy price as flight delays and congestion became common features at O'Hare.

In 2000 –almost 30 years after O'Hare was first designated the world's busiest airport –the airport was still considered one of the busiest in the world (Dempsey, 2000). Since then it has been competing with Atlanta Hartsfield Airport for this top honor, until 2011 when the international Airport Council reported that it was third behind Atlanta Hartsfield and Beijing International Airports. This frontrunner status has allowed the airport to continue to attract lofty investments over the years. Dempsey (2000) shows that between 1998 and 2000, the airport secured at least $60 million to improve parking infrastructure alone. The staggering throughput has also been good for the local economy. Ashford, Stanton, and Moore (1998, p.3) found that O'Hare (because of the size of its present operations) along with counterparts such as "Los Angeles, London Heathrow, and Atlanta, all have total site employment levels of more than 50,000."

Presently, major capacity constraints exist at O'Hare (FAA, 2005). As at 2010, O'Hare still had only 7 runways in operation, despite servicing an average of

2360 flights per day (AirNav, 2011). That runway-to-flight ratio is equivalent to each runway handling approximately 340 each day.

Specifically, the perpetually high levels of throughput have placed enormous pressure on O'Hare every year since the 1960s. According to the FAA, "delays and congestion have plagued Chicago O'Hare International Airport [ORD] for more than 30 years, in spite of regulatory intervention" (FAA, 2005. p. 2). The FAA found that between 2002 and 2004 alone, arrival delays at O'Hare grew from 19 percent to 27.9 percent, while departure delays –over the same period –jumped from 18.4 percent to 28.2 percent.

Concerned that O'Hare's airspace is mistakenly headed for grid lock, the government engaged industry experts to devise an appropriate regulatory response. That response: slot control. However, in 2000 the U.S. Congress conceded the response produced limited results in curbing congestion and alleviating delays, and ordered slots at O'Hare obsolete after 2002 (FAA, 2005).

In 2008, the U.S. Congress' Joint Economic Committee of the House and Senate report revealed that the airport was a significant contributor to the nation's domestic flight delays, and that it was second only to Atlanta Hartsfield-Jackson International Airport (ATL) in passenger-delay times (Joint Economic Committee of the House and Senate Report, 2008). In 2007, O'Hare's combined departure and arrival passenger delay time was 17,749,859 hours (Joint Economic Committee of the House and Senate Report, 2008). The FAA anticipates "that U.S. air travelers will grow from more than 689 million passengers in 2007 to more than 1.1 billion in

2025" (Joint Economic Committee of the House and Senate Report, 2008, press release).

Over the last few years, however, the City of Chicago has refocused its effort to forcefully address O'Hare's congestion and delay problems through the Chicago O'Hare Modernization program. The Chicago O'Hare Modernization program (OMP) is a massive multi-billion dollar project designed to ease O'Hare's overcapacity and reduce flight delays (FAA, 2005). The plan, drafted with inputs from airlines, local and federal authorities, and various interest groups, was concluded in 2001 and is to be executed in two phases. According to the FAA (2005), phase 1 was scheduled to conclude in 2009, while phase 2 is expected to be finished in 2013. Improvements to O'Hare will include: "a new runway, [relocation of 3] runways, extension to 2 existing runways, [as well as] …additional infrastructural improvements designed to increase the efficiency and capacity of O'Hare" (FAA, 2005, p. 2). Part of the OMP plan is to reconstruct the airport's intersecting runways into parallel runways (City of Chicago, 2010). The move is expected to substantially reduce flight delays. In fact, city officials and the FAA forecast that as a direct consequence of the OMP investment, flight delays will be dramatically scaled back from approximately "19.2 minutes" per flight to about "5 minutes" per flight by 2013 (FAA, 2011, p. 2). These 19.2 minutes represents the average delay experienced per flight in 2004. Authorities anticipate that O'Hare will handle about 3,170 flights per day by 2013. In simple terms, the newly constructed runway (alone) is expected to accommodate an additional 52,300 operations per annum, while lowering current flight delay numbers by one-third (FAA, 2008). The report showed that it will be necessary to effect calculated changes within 40 -400 miles of O'Hare (at minimum) if full OMP benefits are to be fully realized (FAA, 2005).

Summary and Conclusion

Through the years the City of Chicago and the O'Hare International Airport have witnessed many changes. However, both the city and the airport infrastructure continue to be outpaced by the rate of growth by the city's residents and the airport's users. Because of this, both the city's and the airport's revinvention and repositioning efforts are riding heavily on the success of the Modernization program. Simply put, it is impossible to see how the city and the airport will move forward without acquiring new physical space, as well as improving present infrastructure to absorb current growth projections. In the meantime, flight delays, the topic of this thesis continue to be a major problem that needs to be investigated and addressed. The methodology used for investigating this perennial problem is the topic of the next chapter.

CHAPTER IV

METHODOLOGY

As indicated in Chapter 1, the purpose of this thesis is to identify the key causal factors for flight delays at U.S. airports, and how these factors could be mitigated to more acceptable standards, using Chicago O'Hare International (ORD) as a case study. This requires the acquisition of data on flight delays at ORD and other relevant information pertaining to the causes of the delays. This chapter discusses the types of data, methods of data collection, and analysis employed in this study. The chapter has three sections. The first section describes the data types and methods of data collection. The second section describes some concerns about the data, while the third section discusses the methods of data analysis, summary and conclusion.

Types of Data and Methods of Data Collection

Both primary and secondary data are used in the study. Table 4.1 provides a schematic of the various types of data, data sources, and instruments that were used to collect and analyze the data. Primary data, consisting mainly of airline perspectives on flight delays, were obtained by depth interview with airline officials. Initially, the plan was to interview United Airlines and American Airlines (AA), two airlines very prominent airlines operating at ORD. However, officials at United Airlines were not willing to talk, so only AA was interviewed. The AA interview was held with the Managing Director of System Operations Control, and the Manager of Operations

Analysts, at their Fort Worth, Texas, headquarters. Interview questions focused on a range of issues including: the reasons behind AA's delays at ORD; the impact of slot operations at ORD; concerns surrounding gate operations; and the relevance of ORD to AA's operation. The full set of these questions can be found as Appendix B.

Table 4.1 Research Data Type and Source

Data Type	**Data Classification**			
	Qualitative Variables		**Quantitative Variables**	
Primary Data	Source	Instruments	Source	Instruments
	American Airlines	Questionnaire/ Depth Interview	N/A	N/A
Secondary Data	Source	Instruments	Source	Instruments
	U.S. Department of Transportation, Bureau of Transportation Statistics (BTS)	Citations, Quotes, etc.	U.S. Department of Transportation, Bureau of Transportation Statistics (BTS)	Excel, CVS, SPSS
	Journals, Articles, Dissertations	Citations, Quotes, etc.	Journals, Articles, Dissertations, U.S. Census	Citations, Quotes, etc.

However, most of the data were secondary and quantitative in nature and were derived from two sources. The first and the largest source was the TranStats database located on the U.S. Bureau of Transportation Statistics (BTS)' website at: http://www.transtats.bts.gov/DL_SelectFields.asp?Table_ID=236&DB_Short_Name =On-Time. Data in the TranStats database are organized by year and individual months, and stored as zipped files. The data base can only be described as "huge" and consisted of109 variables as of February 2011, with literally millions of entries. The data date as far back as 1987, but the variables related to "cause of delay" came on stream only in 2003 –with each year recording about a million entries per year for ORD alone. Because of this overwhelming quantity of data, I decided to focus on a single year: 2010. This year was the latest year of full data entry available at the commencement of this research. Choosing 2010 also ensured that the study reflected the current state of the industry. The data extraction process was very tedious and time consuming, suggesting better methods of database management are in order.

The following variables were extracted for each delay: year, calendar quarter, month, day of month, day of week, flight date, unique carrier code, airline flight identification number, tail number, origin airport, origin airport city name, origin airport state code, origin airport state FIPS, origin airport state name, destination airport, destination airport city name, destination state code, destination airport state FIPS, destination state name, departure delay minutes, departure delay indicator (where 1 = yes, there was a 15 minutes or more delay; and 0 = no delay), departure delay groups carrier-caused delay, weather-caused delay, national airspace (NAS) delay, security-caused delay, and late aircraft delay. A full description for these variables is provided as Table 4.2.

Table 4.2 U.S. Bureau of Transportation Statistics On-Time Performance Data

Description of Data	
Field Name	**Description**
Time Period	
Year	Year
Quarter	Quarter (1-4)
Month	Month
Day of Month	Day of Month
Day of Week	Day of Week
Flight Date	Flight Date in (yyyy/mm/dd) format
Airline	
Unique Carrier	Unique Carrier Code. When the same code has been used by multiple carriers, a numeric suffix is used for earlier users, for example, PA, PA (1), PA (2). Use this field for analysis across a range of years.
Airline ID	An identification number assigned by U.S. DOT to identify a unique airline (carrier). A unique airline (carrier) is defined as one holding and reporting under the same DOT certificate regardless of its Code, Name, or holding company/corporation.
Carrier	Code assigned by IATA and commonly used to identify a carrier. As the same code may have been assigned to different carriers over time, the code is not always unique. For analysis, use the Unique Carrier Code.
Tail Number	Tail Number
Flight Number	Flight Number
Origin	
Origin Airport ID	Origin Airport, Airport ID. An identification number assigned by U.S. DOT to identify a unique airport. Use this field for airport analysis across a range of years because an airport can change its airport code and airport codes can be reused.
Origin Airport Sequence ID	Origin Airport, Airport Sequence ID. An identification number assigned by U.S. DOT to identify a unique airport at a given point of time. Airport attributes, such as airport name or coordinates, may change over time.
Origin City Market ID	Origin Airport, City Market ID. City Market ID is an identification number assigned by U.S. DOT to identify a city market. Use this field to consolidate airports serving the same city market.
Origin	Origin Airport
Origin City Name	Origin Airport, City Name
Origin State	Origin Airport, State Code

Source: BTS 2011

Table 4.2 Continued

Description of Data	
Field Name	**Description**
Origin	
Origin State	Origin Airport, State Code
Origin State Fips	Origin Airport, State Fips
Origin State Name	Origin Airport, State Fips
Destination	
Destination Airport ID	Destination Airport, Airport ID. An identification number assigned by U.S. DOT to identify a unique airport. Use this field for airport analysis across a range of years because an airport can change its airport code and airport codes can be reused.
Destination Airport Sequence ID	Destination Airport, Airport Sequence ID. An identification number assigned by U.S. DOT to identify a unique airport at a given point of time. Airport attributes, such as airport name or coordinates, may change over time.
Destination City Market ID	Destination Airport, City Market ID. City Market ID is an identification number assigned by U.S. DOT to identify a city market. Use this field to consolidate airports serving the same city market.
Destination	Destination Airport
Destination State	Destination Airport, State Code
Destination State Fips	Destination Airport, State Fips
Destination State Name	Destination Airport, State Name
Departure Performance	
CRS (Computer Reservation System) Departure Time	CRS Departure Time (local time: hhmm)
Departure Time	Actual Departure Time (local time: hhmm)
Departure Delays	Difference in minutes between scheduled and actual departure time. Early departures show negative numbers.
Departure Delays Minutes	Difference in minutes between scheduled and actual departure time. Early departures set to 0.
Departure Delays (15 Minutes)	Departure Delay Indicator, 15 Minutes or More (1=Yes)
Departure Delay Groups	Departure Delay intervals, every (15 minutes from <-15 to >180)
Departure Time Blocked	CRS Departure Time Block, Hourly Intervals
Taxi Out	Taxi Out Time, in Minutes
Wheels Off	Wheels Off Time (local time: hhmm)
Arrival Performance	
Wheels On	Wheels On Time (local time: hhmm)
Taxi In	Taxi In Time, in Minutes
CRS Arrival Time	CRS Arrival Time (local time: hhmm)

Source: BTS 2011

Table 4.2 Continued

Description of Data	
Field Name	**Description**
Arrival Performance	
Arrival Time	Actual Arrival Time (local time: hhmm)
Arrival Delay	Difference in minutes between scheduled and actual arrival time. Early arrivals show negative numbers.
Arrival Delay Minutes	Difference in minutes between scheduled and actual arrival time. Early arrivals set to 0.
Arrival Delay (15 Minutes)	Arrival Delay Indicator, 15 Minutes or More (1=Yes)
Arrival Delays Groups	Arrival Delay intervals, every (15-minutes from <-15 to >180)
Arrival Time Blocked	CRS Arrival Time Block, Hourly Intervals
Cause of Delay (Data Starts 6/2003)	
Carrier Delay	Carrier Delay, in Minutes
Weather Delay	Weather Delay, in Minutes
NAS Delay	National Air System Delay, in Minutes
Security	Security Delay, in Minutes
Late Aircraft Delay	Late Aircraft Delay, in Minutes

Source: BTS 2011

Other secondary data collected were on the historical growth of the City of Chicago, the evolution and development of the Chicago O'Hare International Airport, as well as airport's prominence in the U.S. airline industry. These sources included published articles and reports as well as data from the U.S. Census Bureau.

Data Problems and Issues

There were several concerns and problems with the data. The fact that airlines report their causes of delays in broad categories (as mentioned by BTS, 2011), presented some unique challenges. Among them were questions of whether all causes of delays, as reported by airlines, were, or could be accurately grouped as reported. For example, interviewing airline officials showed that there were differences in opinion as to what the meaning of some of the categories for causes of delays considered, or included. Another example is how weather delays were accounted for. In particular, because only extreme weather is accounted for in the weather delay category, weather termed other-than-extreme is reported in the NAS category. This made it difficult to determine the full impact of weather or other NAS elements, on delays in an independent way.

Other problems stemmed from the 14 Code of Federal Regulations (CFR) Part 234 DOT regulations. As stated before, 14 CFR Part 234 requires "airlines that account for at least one percent of the domestic scheduled passenger revenues, to submit monthly service quality performance reports" (BTS, 2011). But since this regulation has no binding effect on individual carriers accounting for less than "1 percent of domestic scheduled passenger revenue", many carriers –potentially contributing to delays –go unreported. While at face value these unreported delays may seem insignificant, there is a good chance they are not. Cumulatively, carriers that account for less than 1 percent of scheduled passenger revenue may account for significant delays when combined. In 2010, only 16 carriers fit the Department of Transportation's profile of at least 1 percent. These carriers were: AirTran Airways (FL), Alaska Airlines (AS), American Airlines (AA), American Eagle (MQ), Atlantic Coast Airlines (DH), Atlantic Southeast Airlines (EV), Comair (OH), Continental Airlines (CO), Delta Air Lines (DL), Hawaiian Airlines, JetBlue Airways (B6), Mesa Airlines (YV), SkyWest Airlines (OO), Southwest Airlines (WN), United Airlines (UA), and US Airways (US) (BTS, 2011). Currently Pinnacle Airlines (9E) and ExpressJet Airlines (XE) do not fall into this category and report voluntarily to the

BTS (BTS, 2011). As a result of this, departure delays contributed by other carriers, but not listed, are neither reported nor considered. Also, as a major player at ORD, United Airlines' refusal to contribute to this study was significant and very disappointing.

Methods of Data Analysis

The secondary data extracted were analyzed using SPSS 18.0, Microsoft 2010 Excel, and GIS ArcMap 10. The departure delay distant groups, departure delay minute, NAS delays, carrier delays, and late arrival aircraft variables, as well as various elements of time were imported into SPSS 18.0. Microsoft Excel 2010 was used to plot simple representational percentage charts to highlight flight delay profile for ORD, while SPSS 18.0 was used to create complex charts featuring various variables. SPSS 18.0 was also used to perform analysis of variance (ANOVA) tests on the categories of causes in the BTS data set, and to determine the individual impact among the various casual factors of delays. Finally, GIS ArcMap 10 was used to create various maps of Cook County, IL featuring the City of Chicago, as well as maps of the continental U.S., and territories, and various distance groups measured from ORD.

Summary and Conclusion

This chapter provides information about the types of data used in this study, and how these data were collected and analyzed. As mentioned, both primary and secondary data were used in this study. The primary data were obtained from interviews held with officials from AA, while most of the secondary data came from

U.S. Bureau of Transportation Statistics (BTS) database. The principal tools used in the analyses of these data were Microsoft Excel 2010, SPSS 18.0, and GIS ArcMap 10. In spite of the data problems itemized above, the data obtained from the U.S. Bureau Transportation Statistics is the best data currently available. The next chapter discusses the analysis and findings of the study.

CHAPTER V

ANALYSIS, RESULTS AND DISCUSSION

This chapter concentrates on the Chicago O'Hare International Airport (ORD), as noted in chapter 4, and contains the analyses, results, and discussion for this study. The chapter is divided into 3 sections. Section 1 begins with an overview of ORD's flight delay profile for 2010. Section 2 contains detailed analyses of ORD's departure delays for that same year, and focuses on the breakdown of the causes by months, days of months, and carriers using length of average departure delays, comparison of differences between the means of the causes of departure delays and analysis of variance of within and between distance groups. Section 3 wraps up this chapter by covering the study's discussion and recommendations.

Overview of All Delays at O'Hare International Airport (ORD) in 2010

The culture of lateness and the resignation to same is deeply entrenched in U.S. air travel. In 2010, flight delays at the O'Hare International Airport totaled 8,191,297 minutes (Table 5.1). This total is the equivalent of 15.59 years of continuous delays. The causes of these delays are also listed in Table 5.1 –which shows late aircraft delay, at 37 percent, as the leading cause of delays for arrival and departure delays, combined. This 37 percent represents 5.78 years of continuous delays. NAS delays were also significant component of all delays at ORD at 34 percent. Carrier delay (or delays incurred from carrier actions) accounted for 24 percent of ORD's total delays while weather delays and security delays accounted for

5 percent and less than 1 percent, respectively. The proportions of these sources of delay at ORD appear comparable with those of the U.S. as a whole (Figure 5.1).

Table 5.1 Chicago O'Hare International Delay Profile in 2010

Arrival & Departure Delays				
Causes of Delay	Total Delay in Minutes {Arrival & Departure}	Delay Time		Delay Percentage
		Days	Years	
Late Aircraft Delay	3,038,862	2110.32	5.78	37
NAS	2,780,375	1930.82	5.29	34
Carrier	2,000,996	1389.58	3.81	24
Weather	365,864	254.10	$\frac{7}{10}$ or 8.4 months	5
Security	5,200	3.6	< 1 week	0
Total	**8,191,297**	**5688.42**	**15.59**	**100**

On the national scale, in 2010, late aircraft delay, at 39.4 percent, was also the leading cause for flight delays among the nation's airports (see Figure 5.1). Observe that late aircraft delay ranks first in both comparisons. However, unlike ORD –where the government controlled National Airspace System (NAS) was the second leading cause for that airport's delay problems, across U.S. skies, privately operated airline carriers were responsible for about one third of the nation's combined arrival and departure delays during 2010. Security delays and weather delays, combined, accounted for less than 5 percent of all delays, nationally.

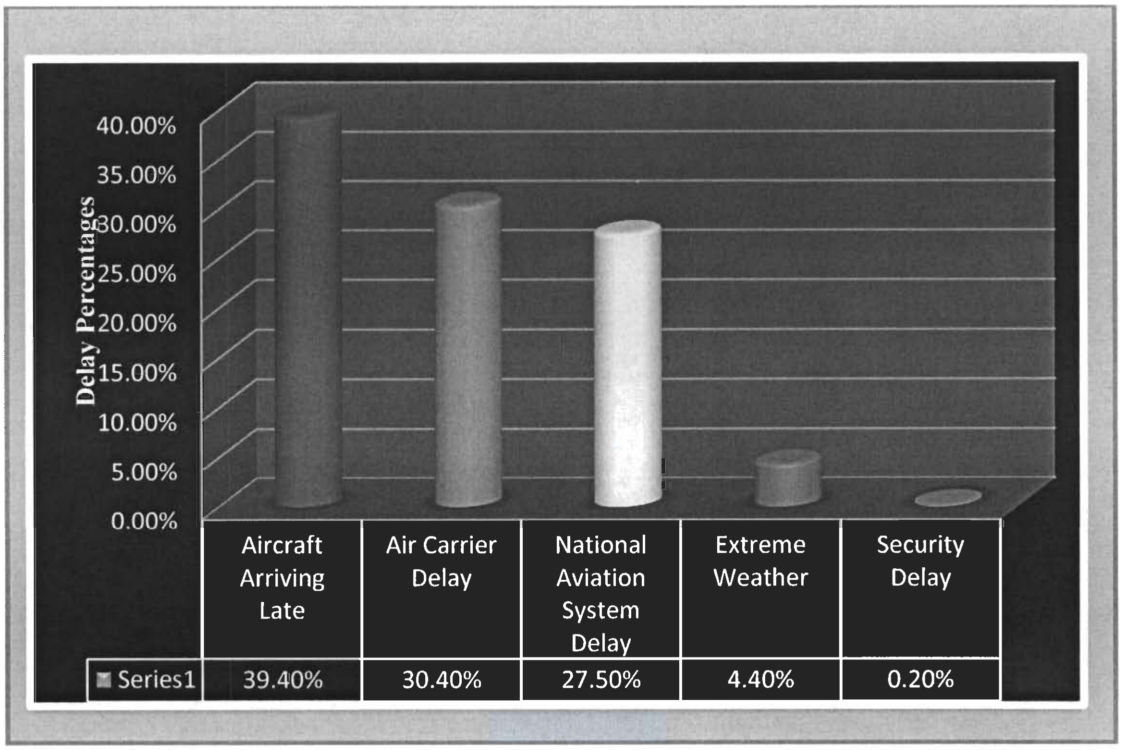


Figure 5.1 U.S. Delay Profile, 2010. Source: U.S. Bureau of Transportation Statistics

Departure Delays at the O'Hare International Airport (ORD)

Departure delays caused 43 percent of ORD's delay problem in 2010 (see Figure 5.2A). This represented a total of 3,521,982 minutes in actual delays for this period –or the equivalent of 7.08 years of continuous delays. Like ORD's combined delay profile, ORD's departure delays were also spread across 5 major causes. In 2010, these categories were late aircraft delay, carrier delay, NAS delay, weather delay, and security delay, in order of importance (Figure 5.2B). The breakdown in minutes and days of these causes are also given by Table 5.2.

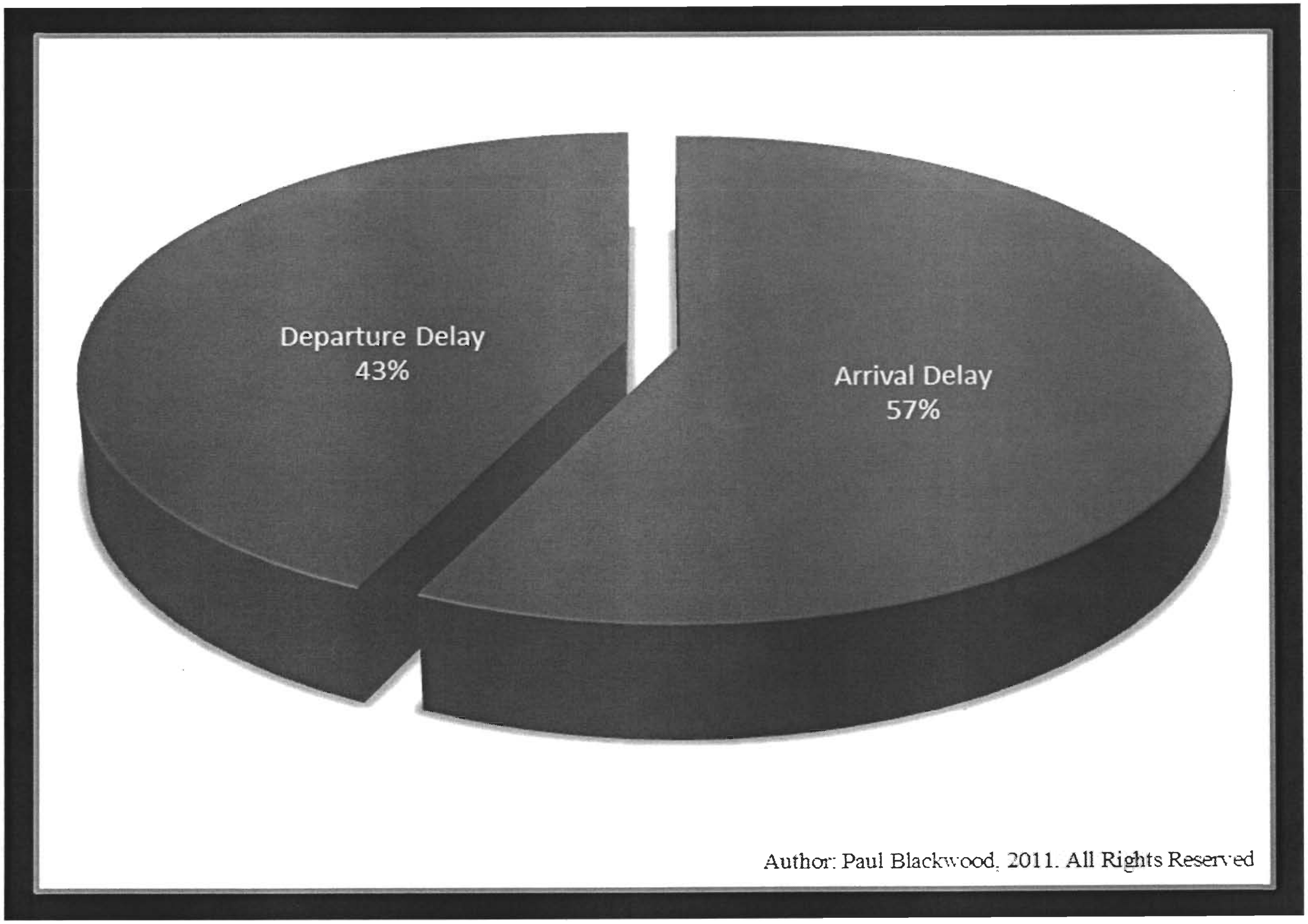


Figure 5.2A Delay Profile for Chicago O'Hare International Airport (2010)

capacity. It is also believed that airlines –armed with better travel demand expectations for return flights at the end of the season –make better demand forecast, and ultimately, better connection schedules. This reduces the risk of second spike at the end of this season.

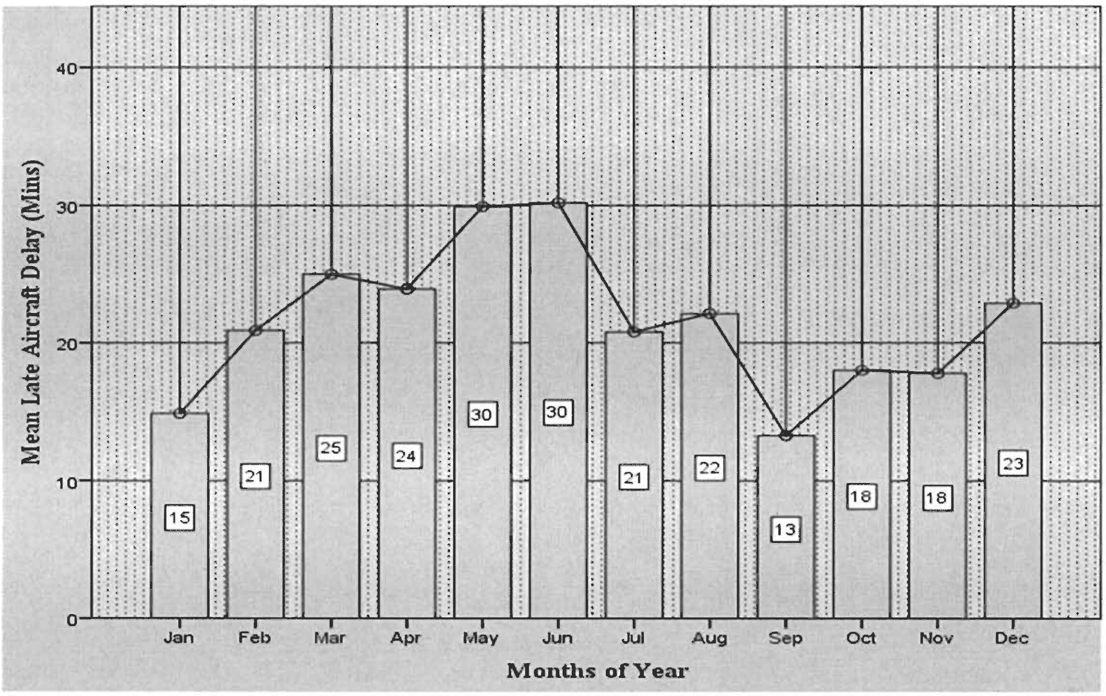


Figure 5.3 Mean Late Aircraft Delays at ORD in 2010 vs. Months of Year

As seen in figure 5.3, during the month of January, average delay for "late aircraft" was 15 minutes. This is contrary to expectations, since experts have long argued that weather –and in particular the seasonal wintery weather of the Midwest – are among the chief culprits for extended flight delays for flights headed into, or out of, airports located in the high latitudes of the U.S. It is easy to envision how wintery weather delays (if they did occur) would impact flight connections and result in substantial late aircraft delays. The facts ascertained from the results of this study however, does not support this popular belief held by many. By industry standards, the month of January would have been collectively uneventful for carriers, except that this category of delay did not affect all carriers at ORD evenly (percentage-wise) for that month, or 2010 for that matter. More carrier analyses for this delay category are documented later as the study progresses.

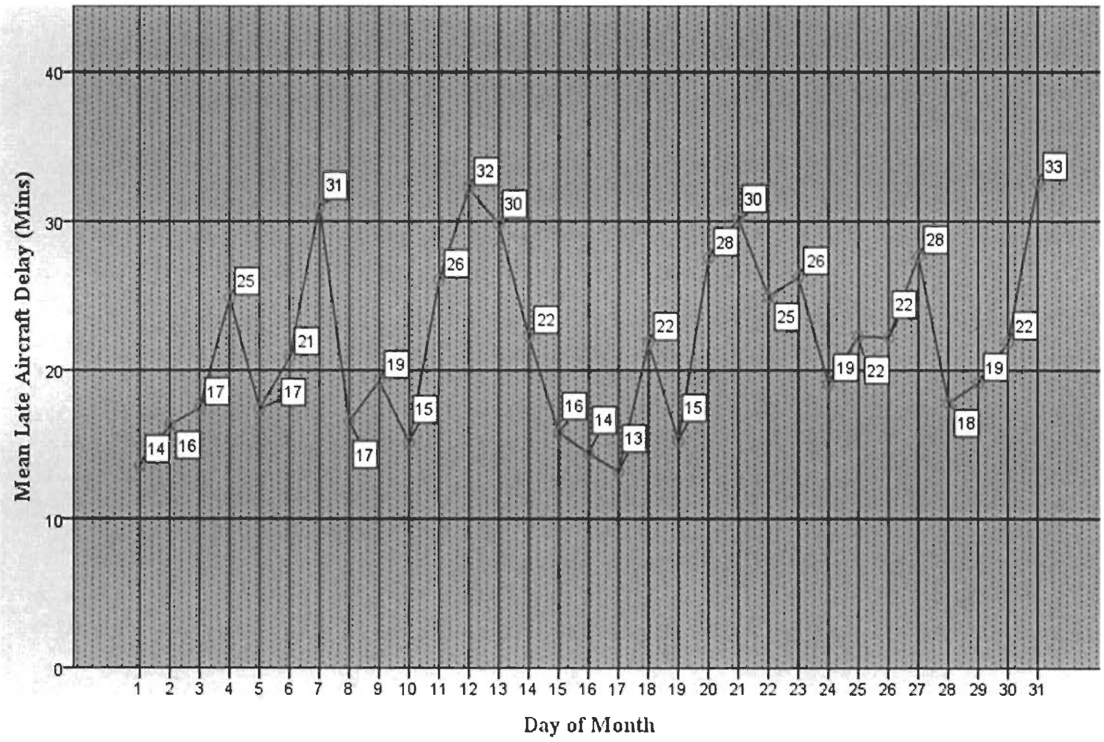


Figure 5.4 Mean Late Aircraft Delays at ORD in 2010 vs. Day of Month

Passengers were also delayed at different rates over the course of a typical month in 2010 – on individual days of the month – because of late aircraft delay (see Figure 5.4). The range for these daily gyrations is 13 minutes to 32 minutes. On average, late aircraft delays peaked above 29 minutes as many as 5 times within a given 31 day period. By comparison, only 3 days reported late aircraft delays of 14 minutes or less within a similar period. When evaluated by a 20 minute threshold, at least17 days of each month reported late aircraft delays of 20 minutes or more. Days with highest late aircraft delays occurred on the 7th, 11th, 12th, 21st, and 31st day of each month. American Airlines Operations Analyst Manager explained that while poor flight connections schedules between the major and regional carriers played an important role in late aircraft delays, experts were unclear of what deeper issues and yet-to-be determined reasons trigger the daily gyrations observed in Figure 5.4, in addition to the specific peak days of late aircraft delay during this period. He proposed that the answer to this question could be the key that unlocks critical components of the nation's late aircraft delay problems.

The range for delays over the typical days of the week in 2010 at ORD was 19 minutes to 26 minutes (Figure 5.5). When examined over individual days of a typical week –with the exception of Wednesdays, which averages 19 minutes in late aircraft delays (the lowest ebb) –ORD's passengers were hammered every day by upwards of 20 minutes in late aircraft delays (see Figure 5.5). These delays generally crested on Tuesdays and Fridays at 26 minutes. Interestingly, weekend days, namely, Saturday and Sunday, were not immune to this problem and registered an average of 22 minutes late aircraft delay each, for this category. It is necessary to frame the results of this day-of-the-week analysis into proper context, by explaining that it would be inaccurate to suggest that on any given day of the week, all flights departing ORD in 2010 experienced 19 minutes (or more) in late aircraft delays. Instead, what the results of the analysis is indicating, is that on any given day of the week in 2010, at

ORD, if a departing flight is delayed as a result of flight connections - i.e. late aircraft delay, one may expect his or her departing flight to be delayed by at least 19 minutes.

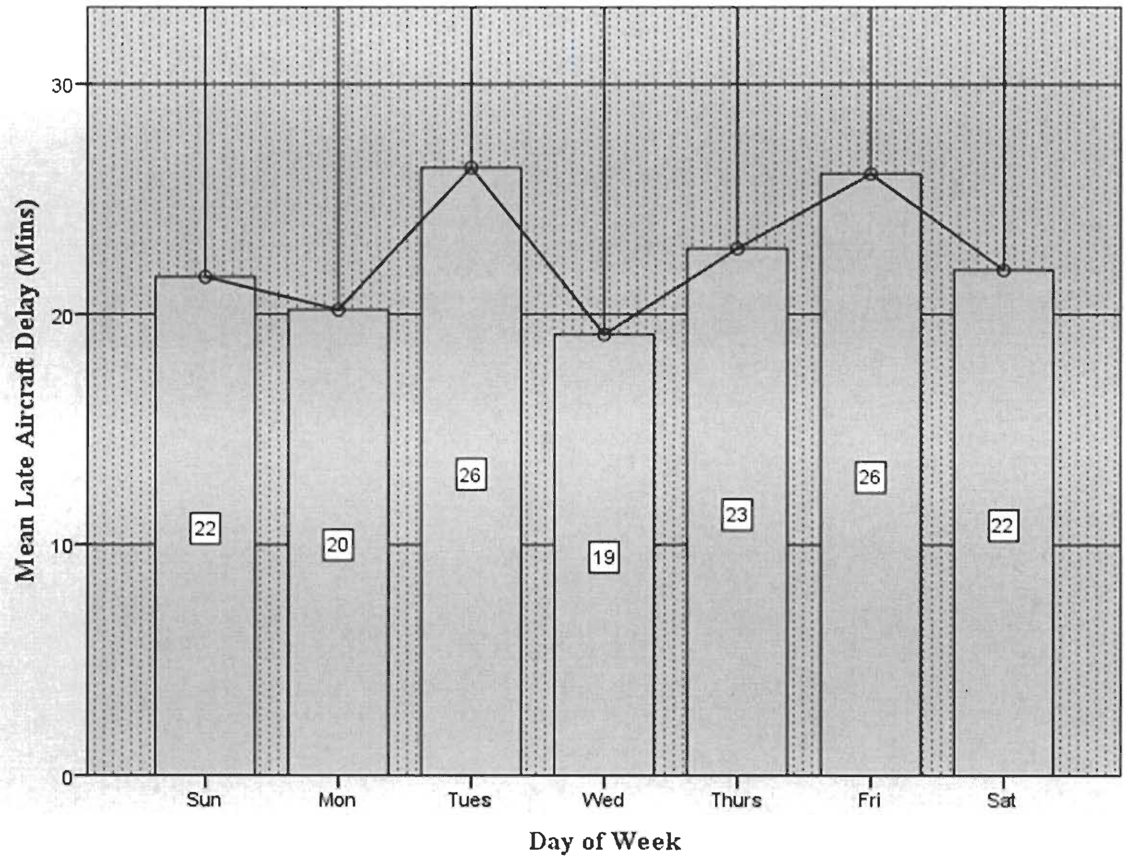


Figure 5.5 Mean Late Aircraft Delay vs. Day of Week

This clarification may be refined even further by making the case that such delays will vary across carriers and specific days of month (see Figure 5.6). As Figure 5.5 confirms, the following carriers (when delayed) typically waited at least 20 minutes for departure on any given day of the week. These carriers are: Pinnacle Airlines (9E), Alaska Airlines (AS), JetBlue (B6), Continental Airlines (CO), Delta Airlines (DL), Atlantic Southeast Airlines (EV), SkyWest Airlines (OO), United Airlines (UA), US Airways (US), ExpressJet Airlines (XE), and Mesa Airlines (YV).

Of this group, 9E, AS, B6, DL, EV, and XE reported mean late aircraft delays of 30 minutes or more (see Figure, 5.6). Moreover, the propensity for any of these carriers to experience late aircraft delays of 20 minutes or more intensified during the months of February through August, as well as December (Figure 5.3). Remarkably, Comair (OH) mean late aircraft delay value over this period is a mere 5 minutes.

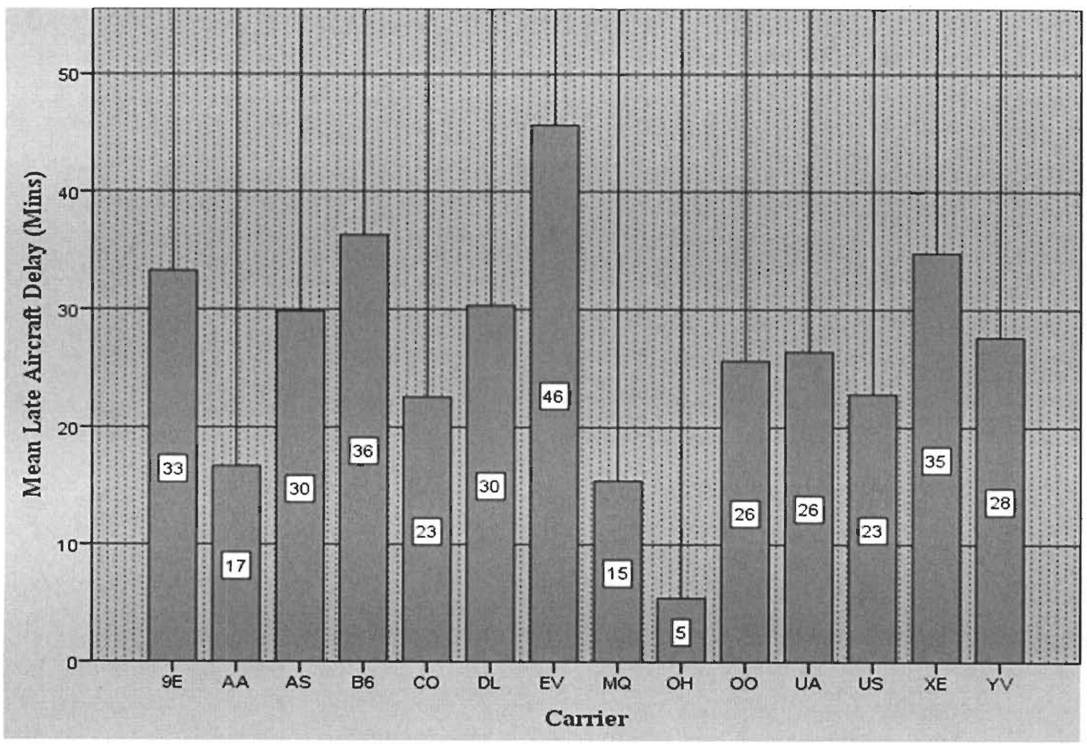


Figure 5.6 Mean Late Aircraft Delay vs. Carrier

Figure 5.7 illustrates summary values for late aircraft delays for carriers operating out of ORD in 2010. This facilitates a better discussion of how carriers really performed in this category. As seen, American Airlines (AA) accumulated 202,753 minutes in late aircraft delays. But as also seen in Figure 5.6, AA's average delay was only 17 minutes. This means in 2010, 17 minutes delays were spread across 11926 flights. Similarly, American Eagle Airlines (MQ) accumulated 272,562 minutes in late aircraft delay in this period. Again, because MQ averaged 15 minutes delay for this category, this was spread across 18,170 flights over a 12 month period. When contrasted with Atlantic Southeast Airlines' (EV) 40,411 minutes in annual late aircraft delay time, the results are informative. In 2010, EV averaged 46 minutes for these delays, and these were distributed across only 395 flights. Since EV's operation is significantly smaller than AA and MQ (individually or combined), EV performed very poorly in late aircraft delay as a category.

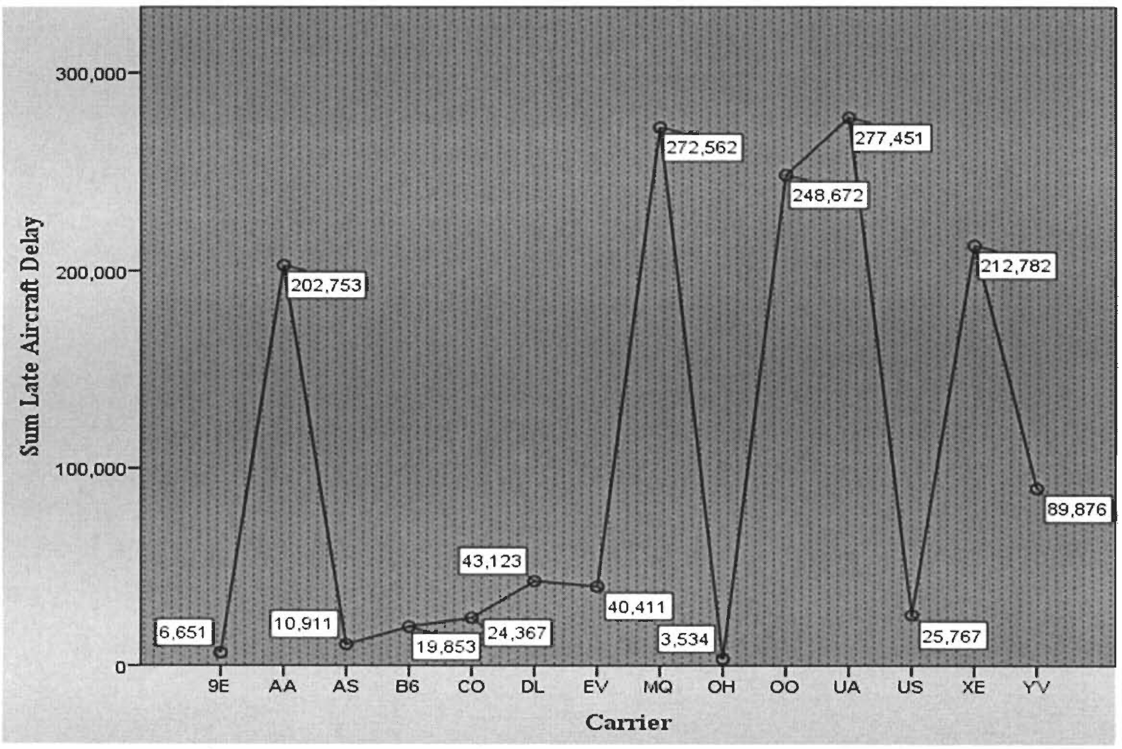


Figure 5.7 Summary of Late Aircraft Delays vs. Carrier

Carrier Delays

Carrier delays are an important delay component at ORD; specifically because these delays are totally under the control of privately owned airline carriers. The range for this category of delay over a typical month in 2010 was 15 minutes to 19 minutes. As described earlier, in 2010, carrier-caused delays accounted for 29 percent of ORD's departure delays. There were little differences between mean carrier delay values for each month (Figure 5.8). These negligible fluctuations over the 12 month period for 2010 suggest industry culture –across carriers –accounts for a significant portion of the industry's current delay problems. As already mentioned, except in January where difference in mean delay was just 2 minutes above the average value of 17 minutes, all mean delays hovered about a 16 minutes threshold by no more than a single minute.

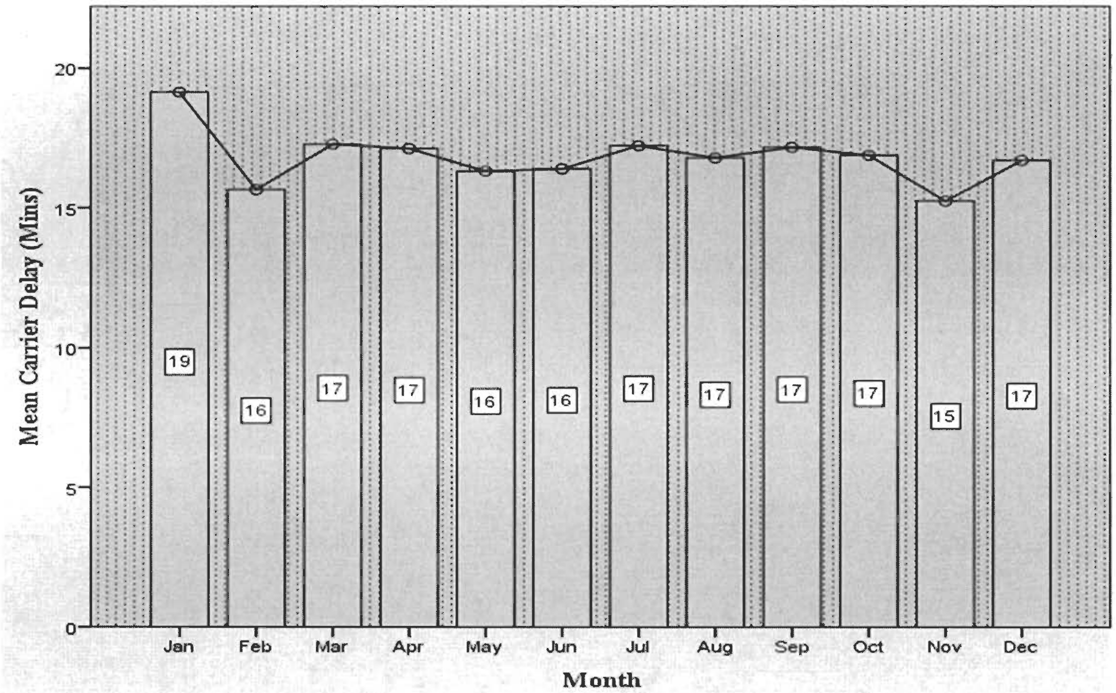


Figure 5.8 Mean Carrier-Caused Departure Delays at ORD in 2010 vs. Month

This reveals that ORD's 2010 carrier departure delays problems were not due in large part to the unexpected occurrences of atypical events. Instead, it communicates systemic cultural laxity against such delays. Symptoms of this lax culture are sometimes quite visible even to untrained eyes. For example, as recent as December 2011, Delta Airlines via its webpage explains: “Every major airline accepts more reservations for flights than it has seats available. This practice is known as overbooking. Flights are overbooked because a certain percentage of passengers are expected to be "no-shows" (Delta, 2011). Industry officials reason that, “if airlines only booked reservations according to the number of seats on a plane, then flights would leave with empty seats, and people who would have wanted those seats, would be left having to find other options. [As such], the airline industry monitors no-show trends and books reservations to meet the expected passenger load. But even with the best forecasting techniques, sometimes more customers show up than were expected. The result is an oversold flight … [and] passengers [subsequently] asked if there are anyone who are interested in voluntarily giving up their seats in exchange for compensation and a seat on a later flight” (Delta, 2011). During these frequent occurrences, a flight must wait indefinitely on the uncertain and voluntary resolution reached between passengers and the carrier, or until the carrier is forced to arbitrarily rebook one or more passengers on another flight (Delta, 2011). In instances where the latter is employed, there are Department of Transportation guidelines that must be observed by the relevant carrier so as to protect the interests of the affected passenger(s). Delays deriving from such practices are examples of carrier delays, because they are delays caused by the activities of respective carriers.

In addition to these industry practices, carriers are frequently delayed because of the tardiness of food concessionaire, slow resolution of weight-and-balance issues, and refueling. It is important to note that there are legitimate cancelations or delays that are caused by unplanned-for events such as unexpected mechanical failures or last-minute staffing emergencies, that are not always tied to carrier cultural indiscretions. Nonetheless, these also contribute to carrier delays.

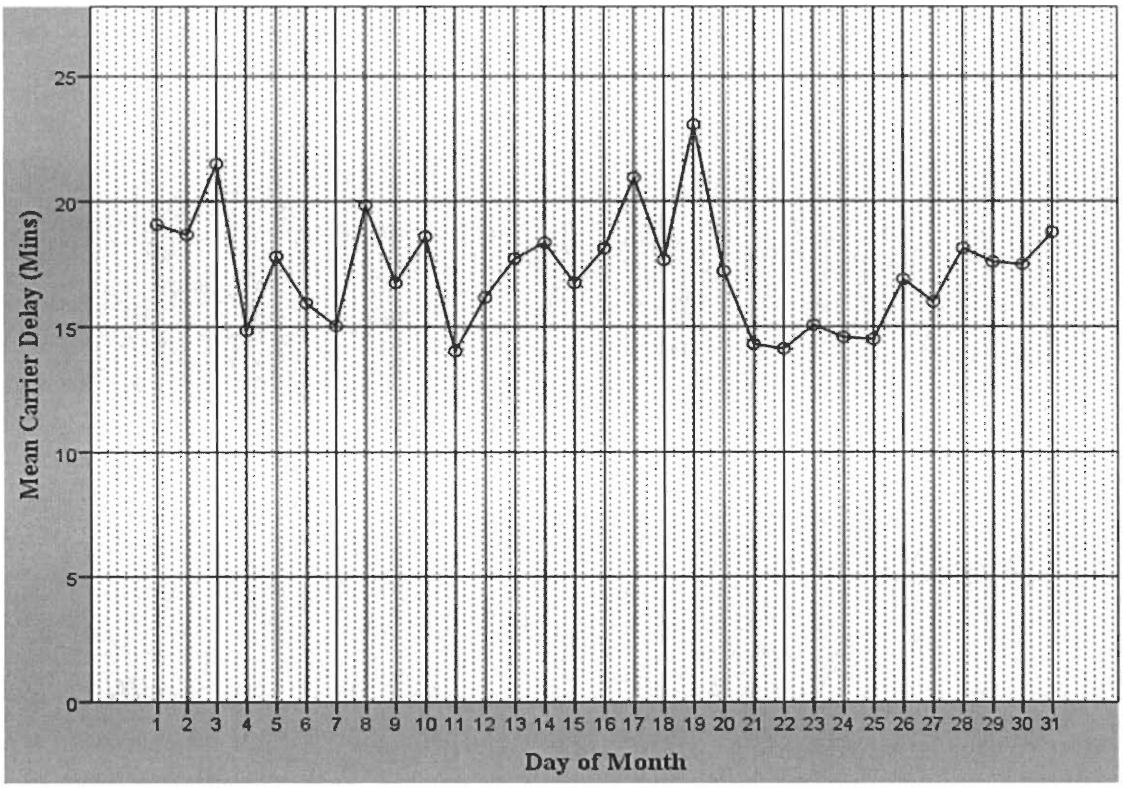


Figure 5.9 Mean Departure Carrier-Caused Delays at ORD in 2010 vs. Day of Month

Unlike the average monthly distribution of carrier delays which remained very much constant during 2010, the day-to-day distributions of carrier delays in a given month were uneven and less predictable. However, as seen in Figure 5.9 these delays also fell between a 15 to 20 minutes threshold. Worst delays for this category generally occurred on the 3rd, 16th, and 19th days of a typical month. After carrier delays reached peak levels on the 19th they fell off rapidly and settled at the lower limits for at least 5 consecutive days. When examined over days of a typical week, Mondays appears to be the least affected (see Figure 5.10). However, delays gradually build up for subsequent weekdays with each day averaging just about a minute more than the day before. On average, passengers at ORD experienced peak carrier delays on Fridays. These delays usually run about 20 minutes.

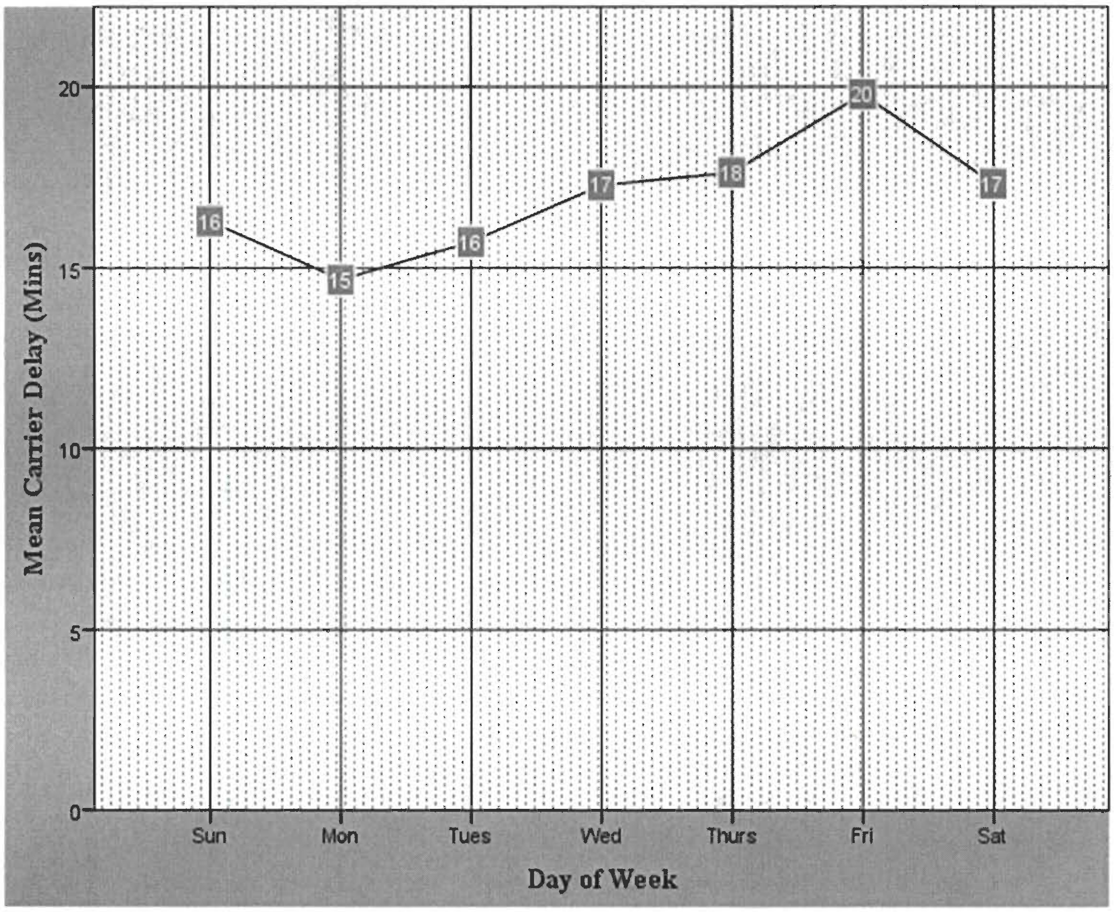


Figure 5.10 Mean Departure Carrier-Caused Delays at ORD in 2010 vs. Day of Week

Individual airline carriers contributed to ORD's overall carrier-caused delays in different proportions. From analyses, it was found that Comair's (OH) had significant problems when compared to Alaskan Airlines (AS), Continental Airlines

(CO), JetBlue (B6), American Airlines (AA), American Eagle Airlines (MQ), and United Airlines (UA) –just to name a few (see Figure 5.11).

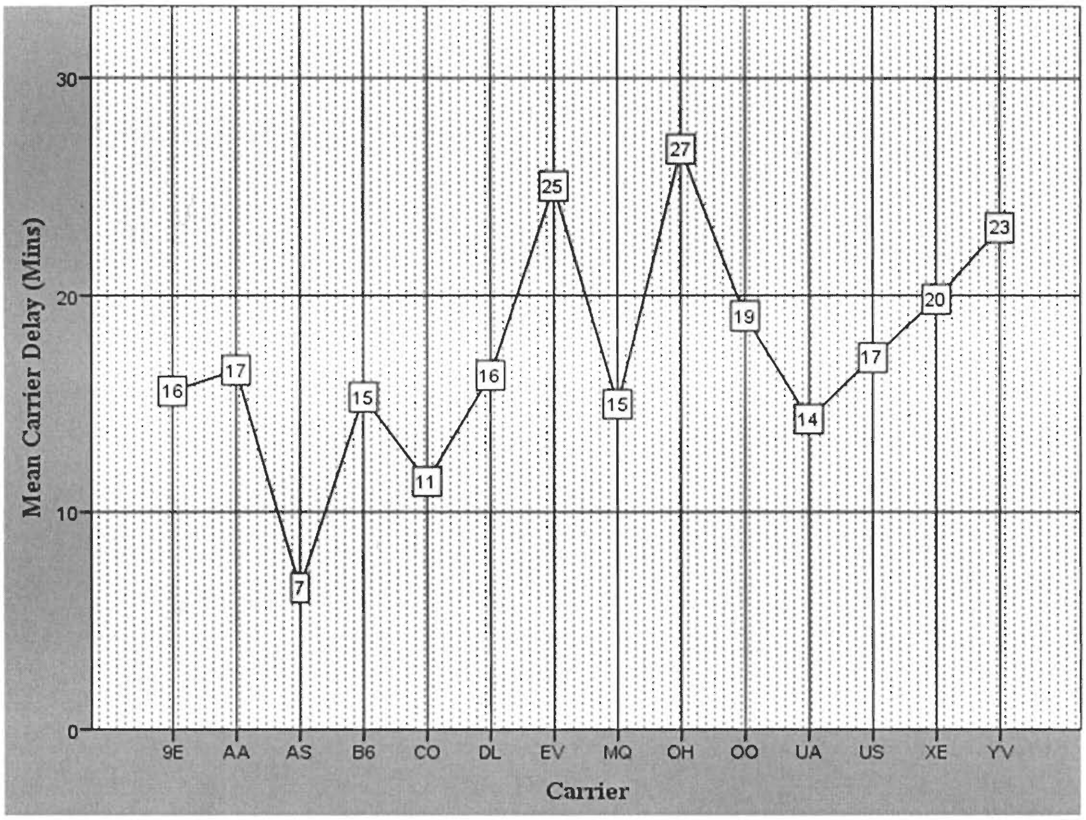


Figure 5.11 Mean Departure Carrier-Caused Delays at ORD in 2010 vs. Carrier

The figure shows that OH's average carrier delay out of ORD in 2010 was almost half an hour when they did occur. In addition to this, the delays occurred appeared to be erratic. Recall in that in Figures 5.9 and 5.10, carrier delays were not specific to any numeric day of the month, but clearly intensified in length if they did occur on Fridays. On average OH's 642 annual carrier delays were 4 times longer than AS's 340 annual carrier delays (Figure 5.11). Interestingly too, MQ's 17665 annual carrier delayed flights were likely to be airborne at least 12 minutes sooner than similarly delays OH flights. The annual numbers of carrier-delayed flights are found by dividing summary carrier-delay values in Figure 5.12 by mean carrier delay values in Figure 5.11.

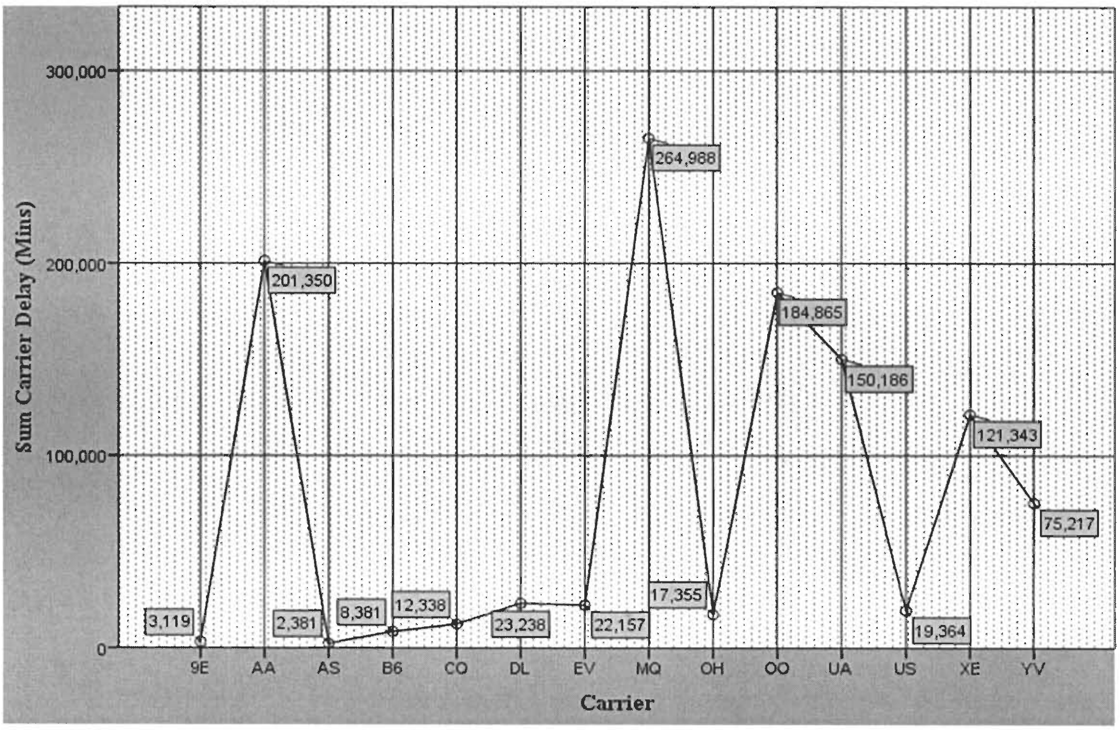


Figure 5.12 (Summary) Departure Carrier-Caused Delays at ORD in 2010 vs. Carrier

National Airspace System (NAS) Delay

NAS delays are delays set in motion by unresolved issues in the U.S. national airspace system. These issues range from, but are not limited to: air traffic control (ATC) resources –manpower and/or equipment; airspace congestion –caused from the number of aircraft permitted into a physical airspace; airspace availability or accessibility –which is sometimes constrained by wild life; and finally, the resources and technology and available at U.S. airports. On average, the monthly NAS delays at ORD in 2010 ranged from 12 to 17 minutes in duration (Figure 5.13). June recorded the highest mean delays for this category. Interestingly, the monthly mode for NAS delays in 2010 is 13 minutes. It is also important to note that NAS delays are largely within the control of the government. When compared to departure carrier delays nationwide –delays caused by privately operated carriers –the government fared better than the private sector operations at ORD in 2010. Again, in 2010, NAS delays were responsible for 25 percent of ORD's delay.

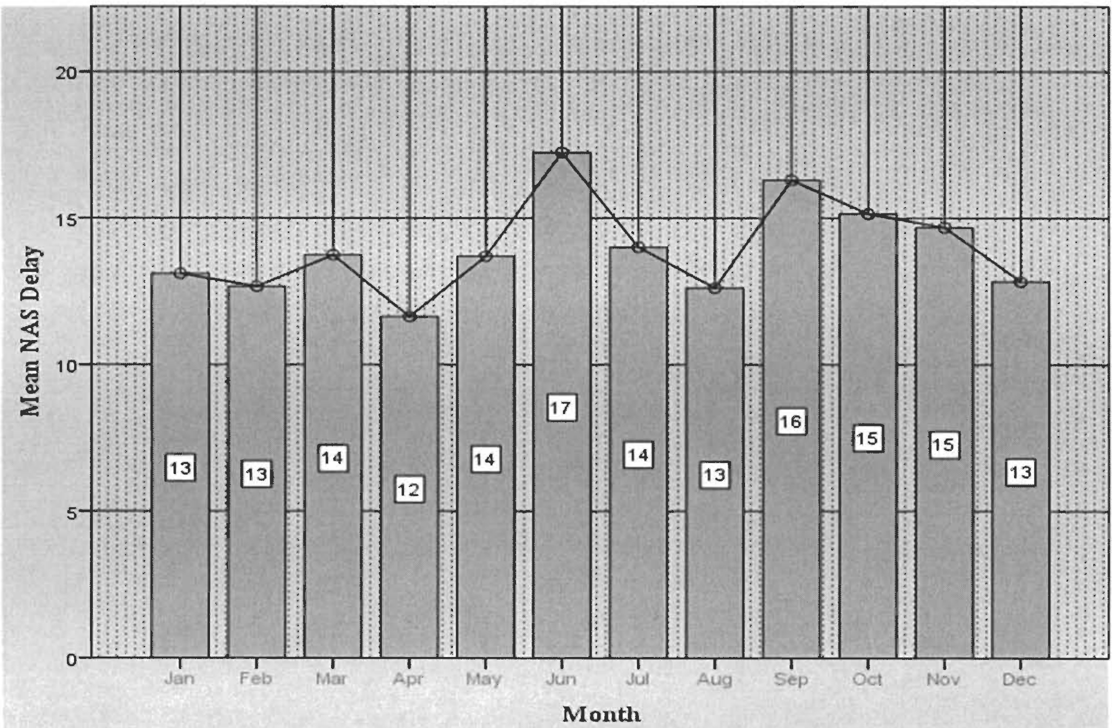


Figure 5.13 Mean NAS Delays at ORD in 2010 vs. Months of the Year

During a typical month, day-to-day variations are sometimes considerable (Figure 5.14). Although most NAS delays within a regular 31 day period in 2010 averaged between 10 to 15 minutes, flights experiencing departure delays related to the national airspace system tended to worsen on the 18th and 23rd days of the typical month, with 20 minutes or more in NAS delays. However, when compared over a 52 week period on a day of the week basis, NAS delay averaged between 11 to 16 minutes with Mondays accounting for highest NAS delays (Figure 5.15).

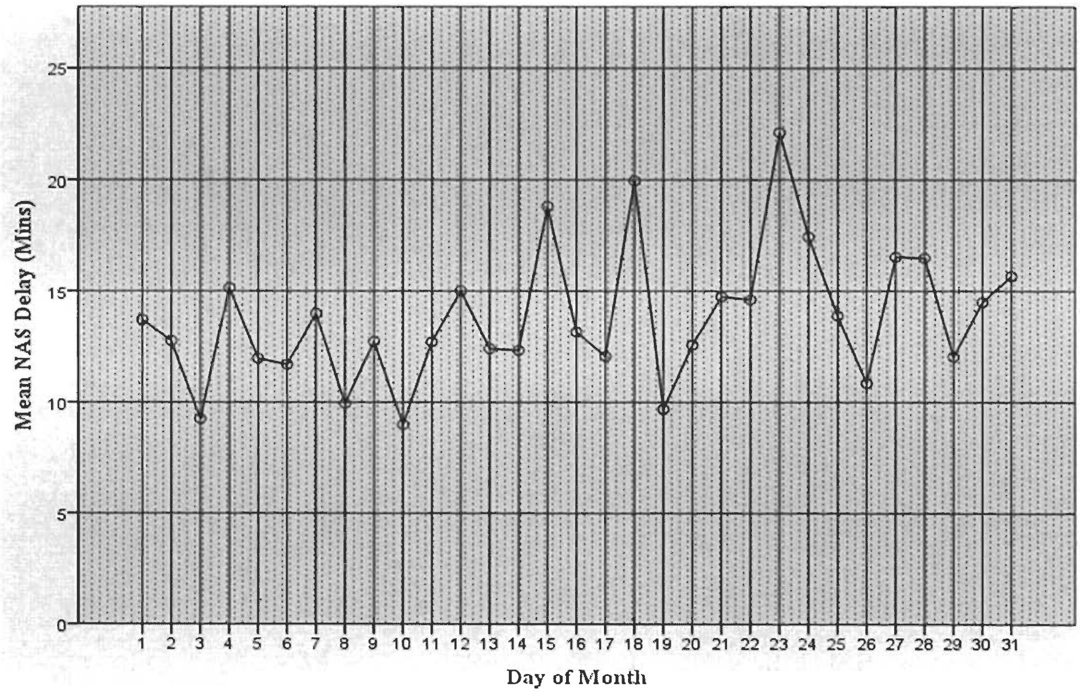


Figure 5.14 Mean Departure NAS Delays at ORD in 2010 vs. Day of Month

Similarly, least NAS delays were recorded on Fridays. The average NAS delays on Fridays were 11 minutes. To fully understand the description above, it is important to note that these values represent the average of total NAS delays on these respective days versus the number of flights that recorded such delays. Observe that NAS delays have a double mode of 14 and 15 minutes. Compared to late aircraft delays and carrier delays categories, NAS delays on Fridays fared better at 11 minutes. Late aircraft delays on Fridays were 26 minutes (Figure 5.5), while carrier delays for that same day were 20 minutes (Figure 5.10). This reality for Fridays may be the result of a number of factors occurring on Fridays, but two likely possibilities are: better air traffic control (ATC) coverage –due to anticipated increases in weekend travel, as well as less congested airspace of Fridays. Either or both possibilities mitigate departure delays associated with the national airspace system located in this region.

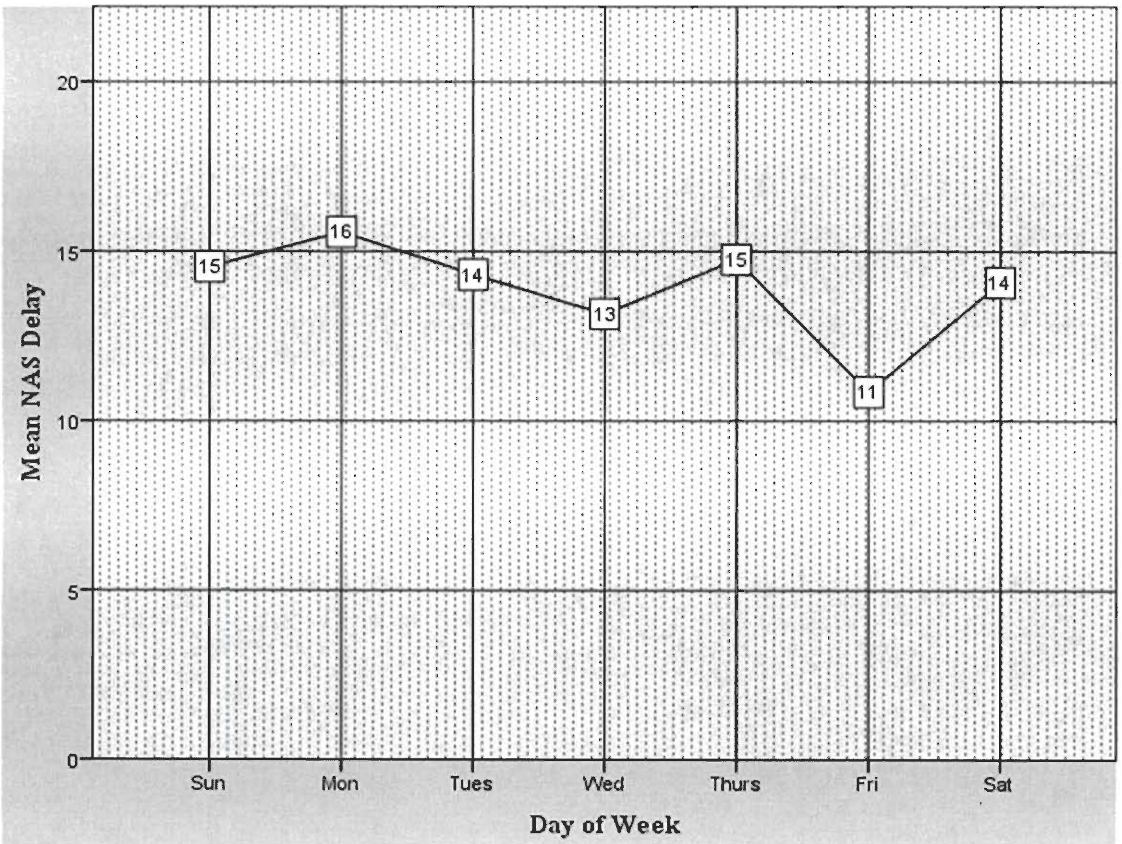


Figure 5.15 Mean Departure NAS Delays at ORD in 2010 vs. Day of Week

The U.S. national airspace system is non-preferential toward carriers, and the system treats all carriers alike –except in cases of emergencies scenarios described in the Code of Federal Regulation (CFR). Interestingly however, in 2010 carriers were impacted differently by NAS delays (Figure 5.16). Continental Airlines' (CO) annual NAS delays averaged almost 30 minutes for this period. Moreover, only two other airlines accompanied CO above the 20 minute threshold. These carriers were JetBlue (B6) at 31 minutes, and Comair (OH) at 23 minutes. American Airlines (AA) and American Eagle Airlines (MQ) with respect to the carrier's operation (cumulatively), performed better than expected at means of 18 minutes and 15 minutes respectively.

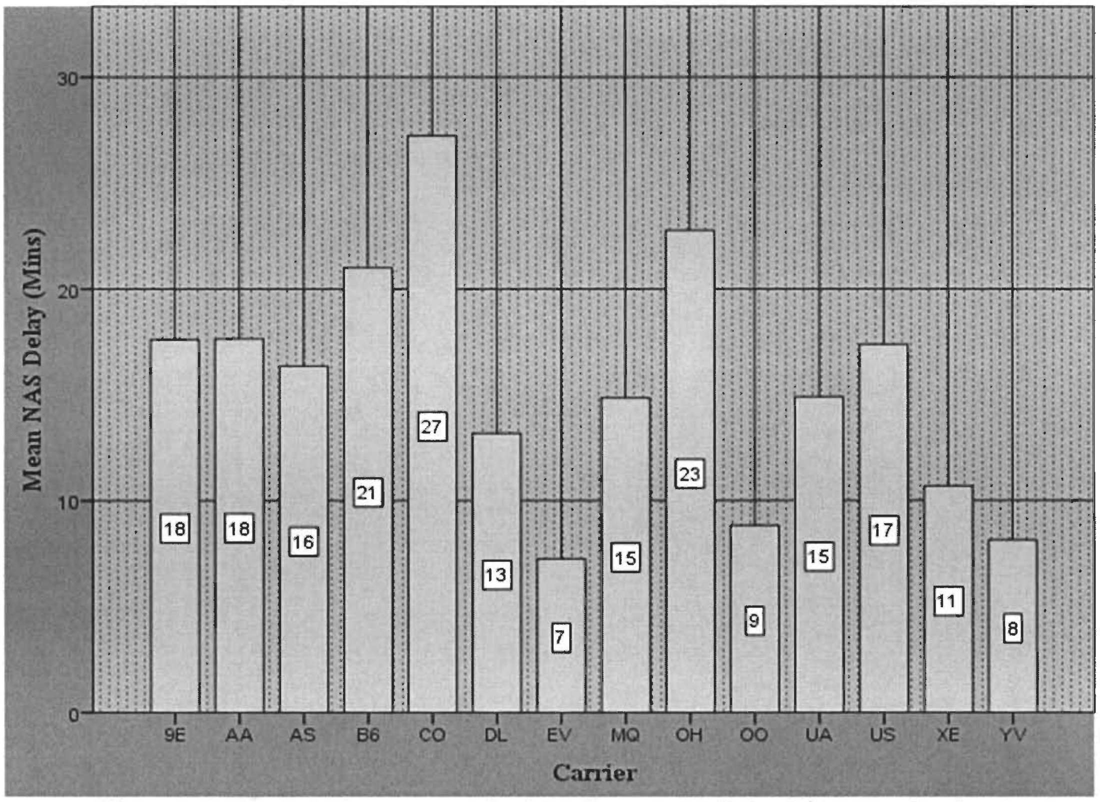


Figure 5.16 Mean Departure NAS Delays at ORD in 2010 vs. Carrier

It is possible that the results of this performance chart are an indicator to deeper issues among carriers –such as crew proficiencies, or the lack thereof. For example, some of the newer airlines are inclined to have younger less experience crews compared to some of the more established carriers. Wide variations in NAS departure delays among carriers may also be related to less than ideal gate locations for some carriers which could see some carriers making it to takeoff locations behind others carriers with “premium” gate locations. Expectations for AA and MQ were less because of the herculean size of that airlines’ combined operation.

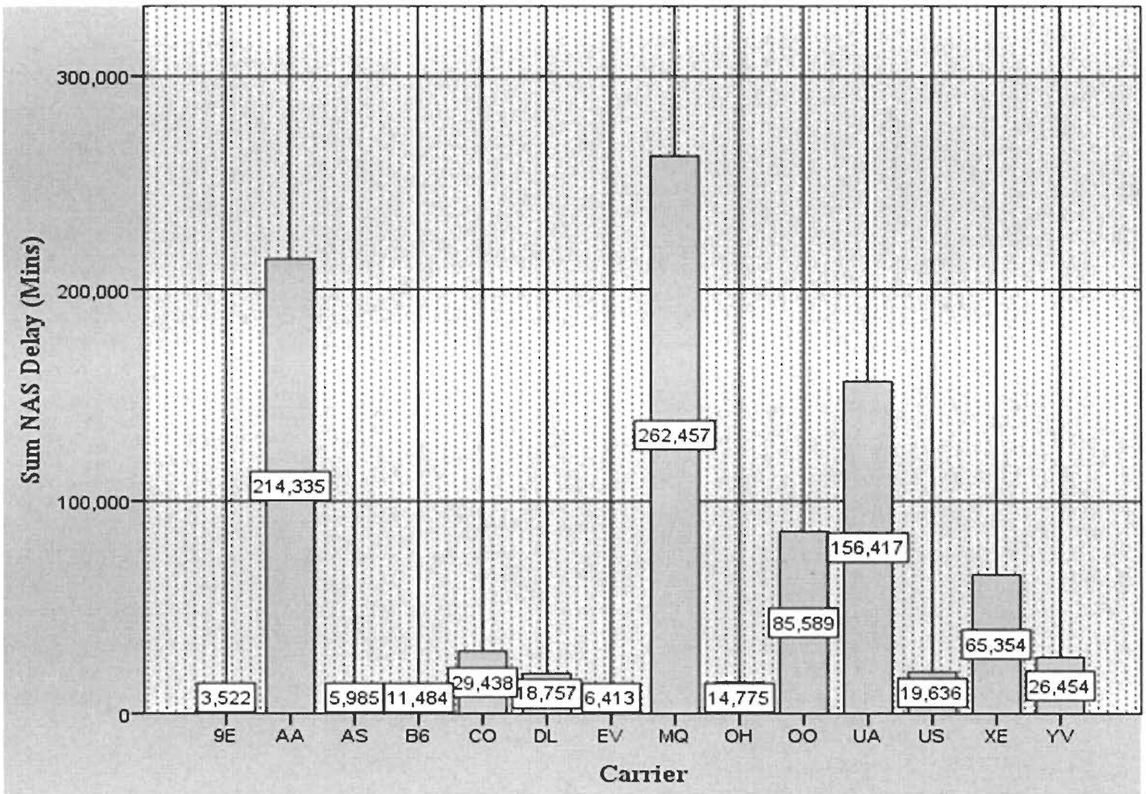


Figure 5.17 (Summary) Annual Departure NAS Delays at ORD in 2010 vs. Carrier

By comparison, Pinnacle Airlines (9E), in 2010, recorded a summary of 3,522 minutes in NAS delays (Figure 5.17). Over the same period, American Airlines (AA) recorded a summary of 214,335 minutes in NAS delays. Astonishingly however, both carriers performed equally with mean values of 18 minutes in NAS delays. After crunching summary values in Figure 5.17 against mean values in Figure 5.16 it is discovered that it took 196 delays from 9E, but 11,908 AA delayed flights from AA to produce 18 minutes means delays in the national airspace system at ORD. This finding signals greater efficiency on the part of AA over 9E. At the same time CO’s summary values were 29,438 minutes, or 184,897 minutes less than AA summary values. Astonishingly, CO's mean NAS delays were a staggering 27 minutes. CO's MAS mean values are 9 minutes worse than AA's performance values. CO's NAS delays were spread among only 1090 flights. The discovery should raise performance concerns for CO.

Weather Delays

In 2010 only 6 percent of ORD's departure delays were caused by weather. Interestingly however, people very often blame local weather and airport security for the nation's delay woes. This month-to-month review of weather delay reveals that mean weather delay, for any month in 2010, did not exceed 6 minutes (Figure 5.18). The range for mean weather delays across months as 2 minutes to 5 minutes.

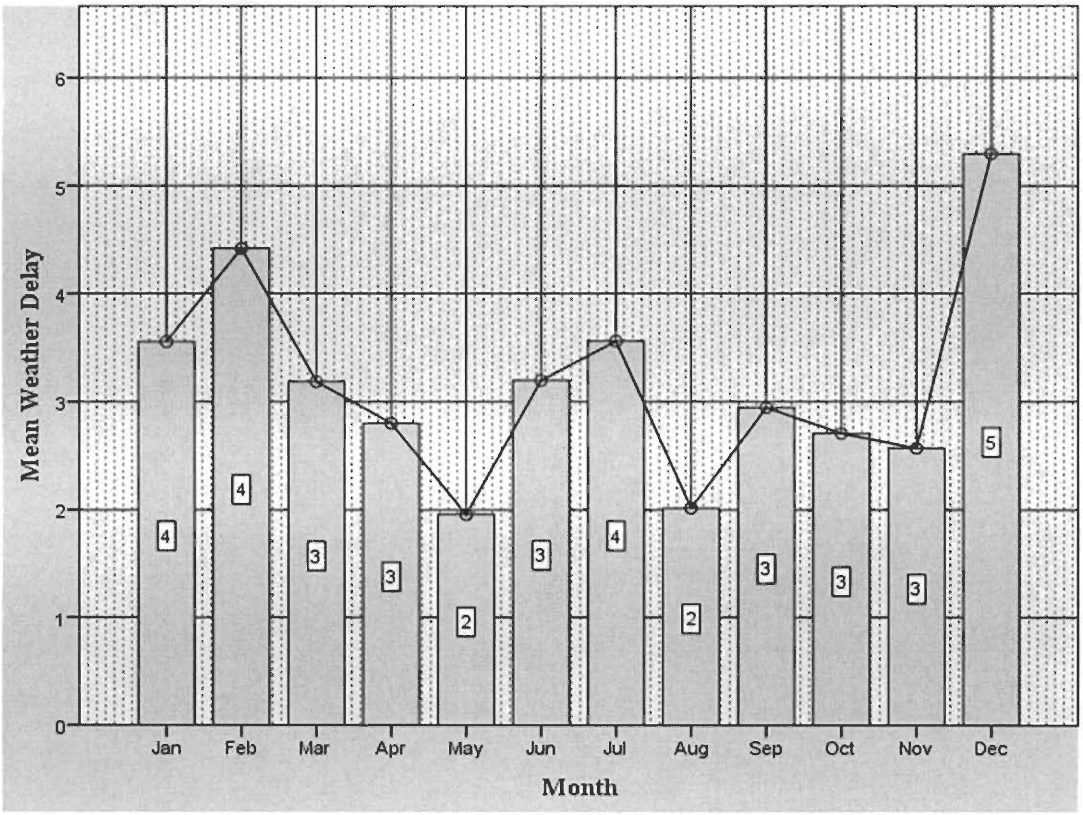


Figure 5.18 Mean Weather Departure Delays at ORD in 2010 vs. Month

December recorded the highest average weather delay at 5 minutes. May and August recorded lowest mean weather delays of 2 minutes. It must be underscored that even within the dreaded wintery months of December through March weather delays remained relatively inconsequential to ORD's operation in 2010. The day-to-day analysis of mean weather delay also reveals similar uneventful results (Figure 5.19). These will be explored below.

To understand weather delays, it is important to recall that weather events on any specific days are Acts of God. As such, unlike seasons or months of the year where predictable weather patterns are common, no substantive arguments can be made about the quantity of weather experience on a particular day of the month or day of the week. Instead, what may be correctly deduced from the increased weather delays seen in Figure 5.19 and Figure 5.20 on specific days of the month and week (though minimal they are), is ORD's ability or inability to respond to weather on such days by applying appropriate fixes that resume flight departures. On average, during 2010, related departure weather delays peaked on Fridays at an average of 5 minutes. It is useful to recall that late aircraft delay and carrier delays also peaked on Fridays (see Figure 5.5 and Figure 5.10). Going back to Figure 5.18, minimum weather delays occurred on Wednesdays, and the mode for day-to-day weather delays is 3 minutes. Without national enplanement distribution data, it is impossible to determine how passenger ridership demands impact the preparedness of weather-staffing crew, or the deployment of defensive weather equipment.

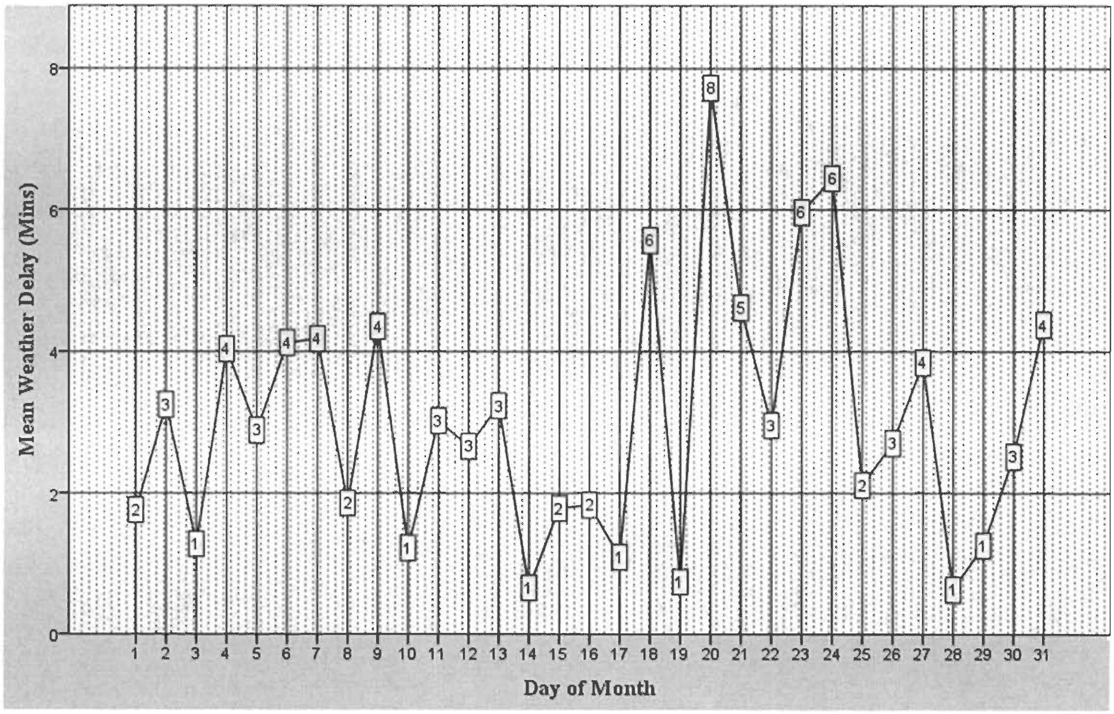


Figure 5.19 Mean Weather Delays at ORD in 2010 vs. Day of Month

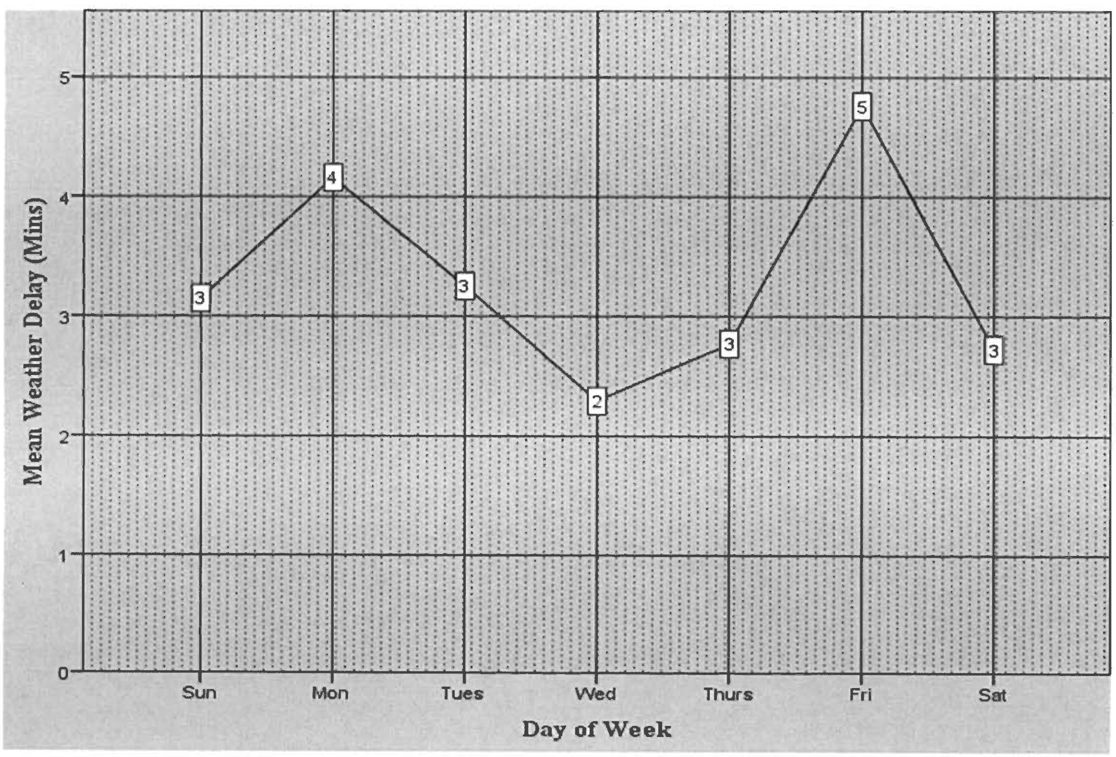


Figure 5.20 Mean Weather Delays at ORD in 2010 vs. Day of Week

As disclosed earlier, in 2010 weather impacted carriers at different rates. Below, Comair (OH) sustained highest weather delays on average, but was responsible for only 3 percent of ORD's weather delays for that period (Figure 5.21A, Figure 5.21B). American Airlines (AA) and American Eagle Airlines (MQ) both recorded similar mean values of 5 minutes delays brought on by weather. However, both airlines were responsible for a staggering 67 percent of all weather related delays at ORD in 2010. This obvious disproportion is due to both carriers' overwhelming presence at ORD. This claim is also supported by findings seen in Figure 5.22. Here, AA summary delay values for 2010 were 87,587 minutes while MQ's were 55,330 minutes.

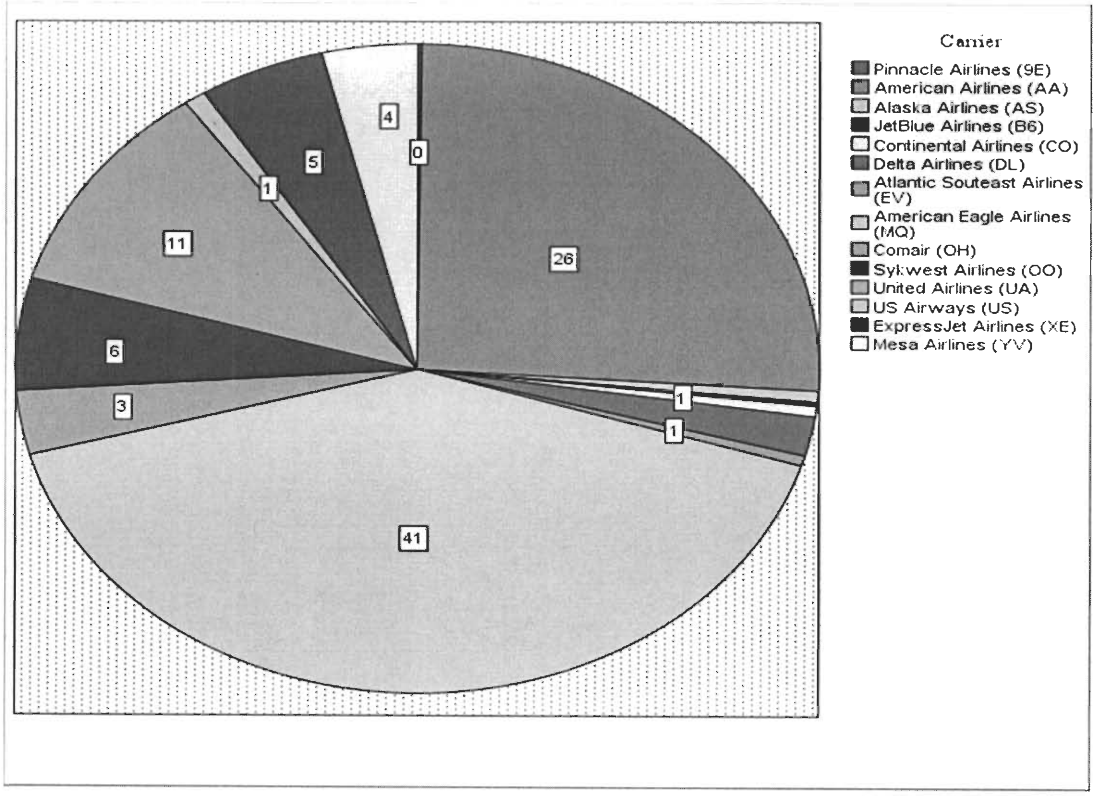


Figure 5.21A (Percentage Summary) Weather Delays at ORD in 2010 vs. Carrier

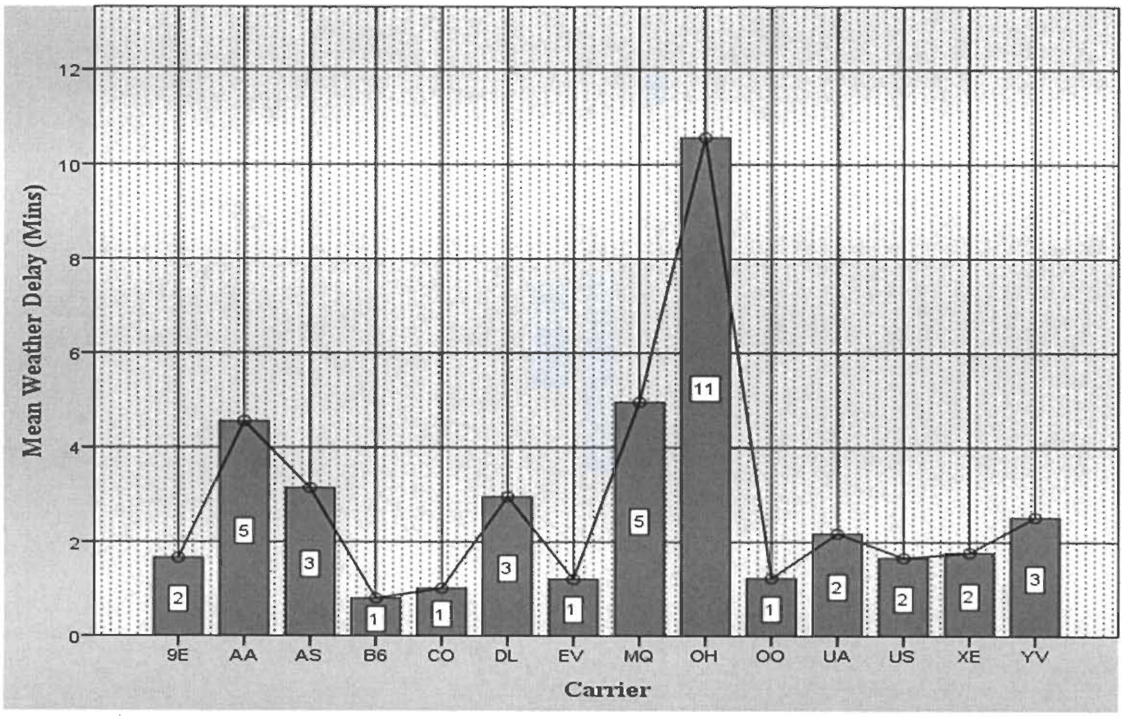


Figure 5.21B Mean Weather Delays at ORD in 2010 vs. Carrier

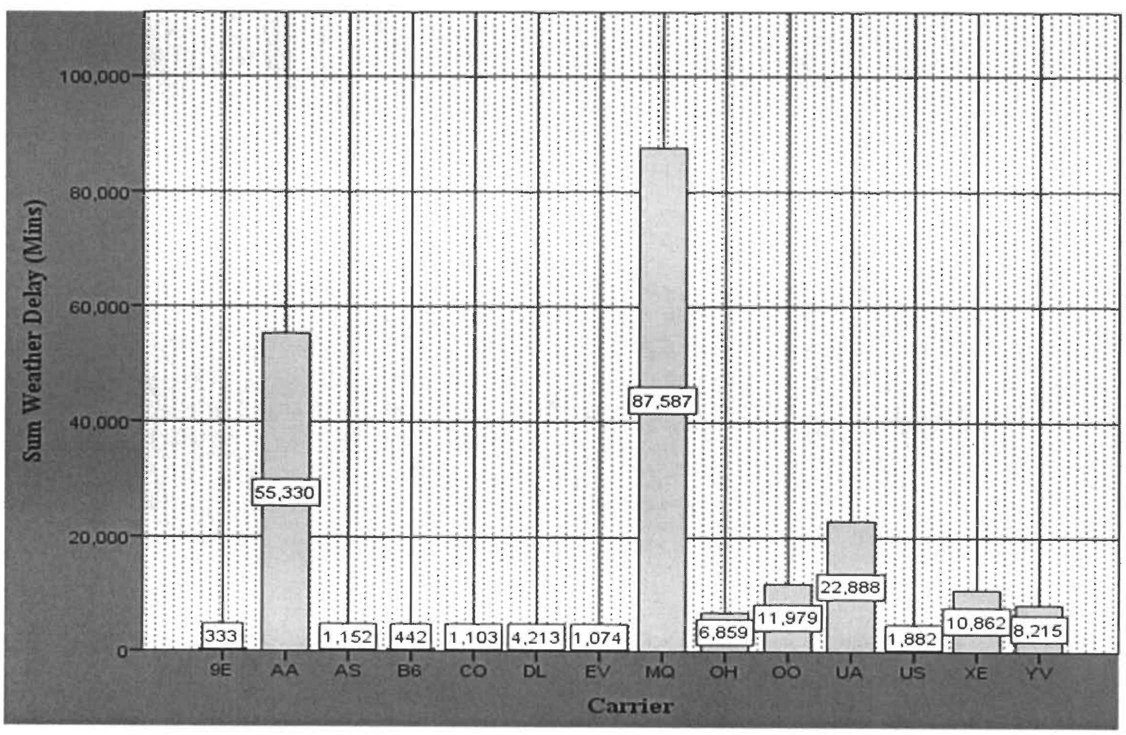


Figure 5.22 (Summary) Weather Delays at ORD in 2010 vs. Carrier

By contrast, OH's summary values for the same period was 6,859 minutes. Lowest summary values were assigened to Pinnacle (9E) at 333 minutes. These numbers suggest AA and MQ have been better prepared to deal with weather –even with such significant fleet, compared to OH. Such preparedness may have resulted from AA and MQ's use of an aircraft fleet better equipped deal with adverse weather. These numbers could also be a revelation of pilot proficiencies for airlines, with more proficient pilots incurring less delays.

Security Delays

Security delays were never a factor for departure flights at ORD in 2010. However, when they did occur, this is how it happened (see Figures 5.23, 5.24, and 5.25). Of the overall less-than-1-percent security delays recorded for all the various causes of delays at ORD, August recorded the highest average occurrences.

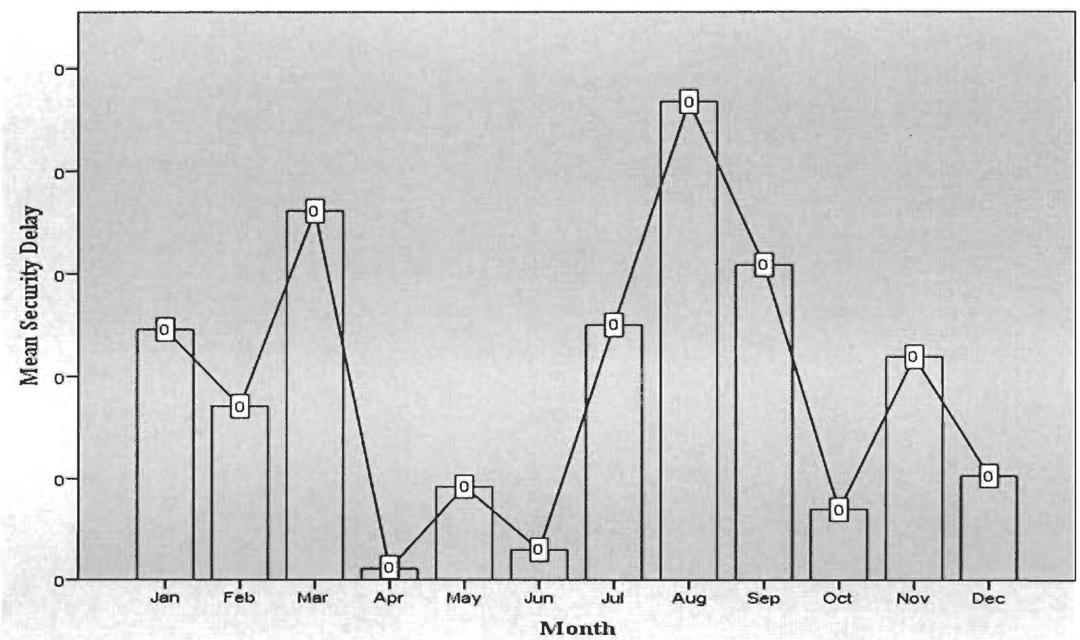


Figure 5.23 Mean Security Delays at ORD in 2010 vs. Month

It is important to note that in Figures 5.23 and 5.24, all mean values are represented by the numerical value zero for each month, as well as for carriers.

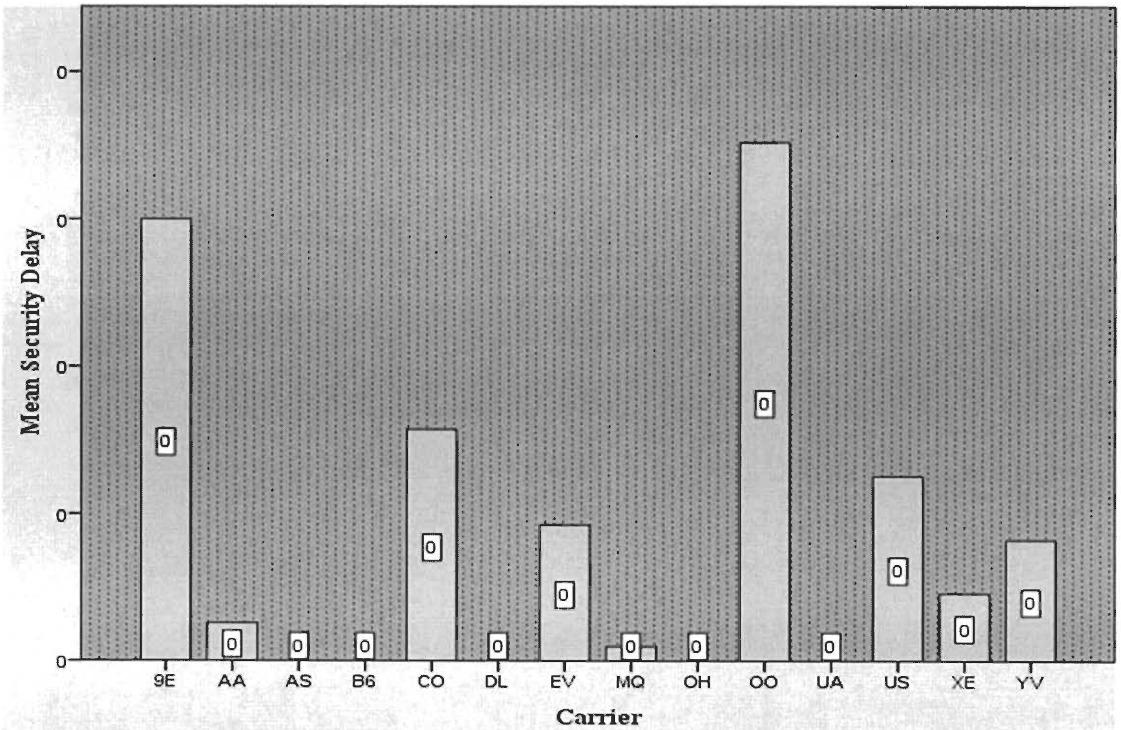


Figure 5.24 Mean Security Delays at ORD in 2010 vs. Carrier

Interestingly, SkyWest Airlines (OO) had outlier characteristics for departure security delays at ORD in 2010 (See Figure 5.25). In 2010, OO was the only carrier to record an annual security departure delay value above the 160 minutes high watermark, for any carrier. For that period OO registered 1,708 minutes. Even though this delay value is relatively high, when contrasted over a 12 month period, OO's delay is the equivalent of 1.18 consecutive days of security delay. However, even at level OO's combined 1.18 days of delay is not significant, and the numeric value fails to make the any rational argument for further exploratory efforts.

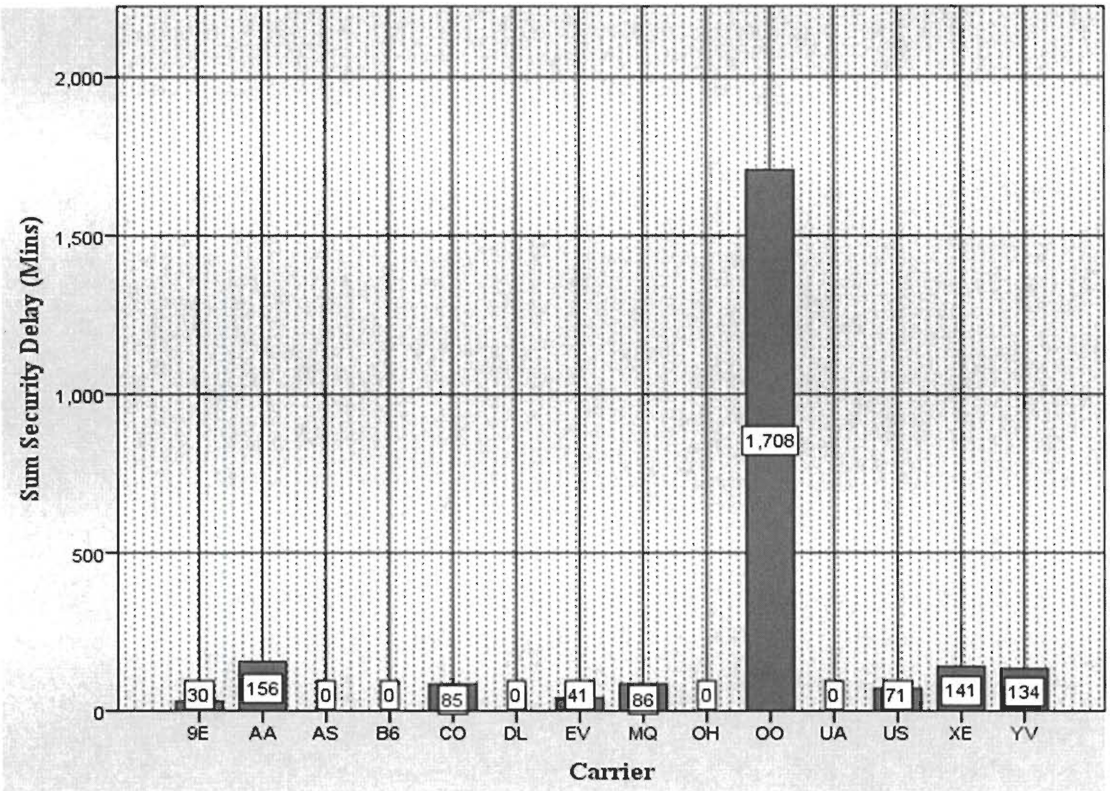


Figure 5.25 (Summary) Security Delays at ORD in 2010 vs. Carrier

Distance Group

The distance a flight travels between departure point A, and its intended destination point B, influences the kinds of delays encountered as well as the duration of such delays. Against this background it is important to analyze how flight distances affect departure delays at ORD. In 2010, the U.S. DOT established 11 distance-groups to cover all domestic destinations –each separated by 250 miles (Figure 5.27, Figure 5.28). Also reference Appendix C for full description of distance group. It is critical to observe that since ORD is being used as a case study for this research, all distance limits are measured radially outward from ORD and includes U.S. States and territories outside of the continental U.S. as well. As such, all distance group discoveries which follow are with respect to ORD –and specifically for 2010. Figure 5.26 below shows how each distance group was affected by overall departure delays.

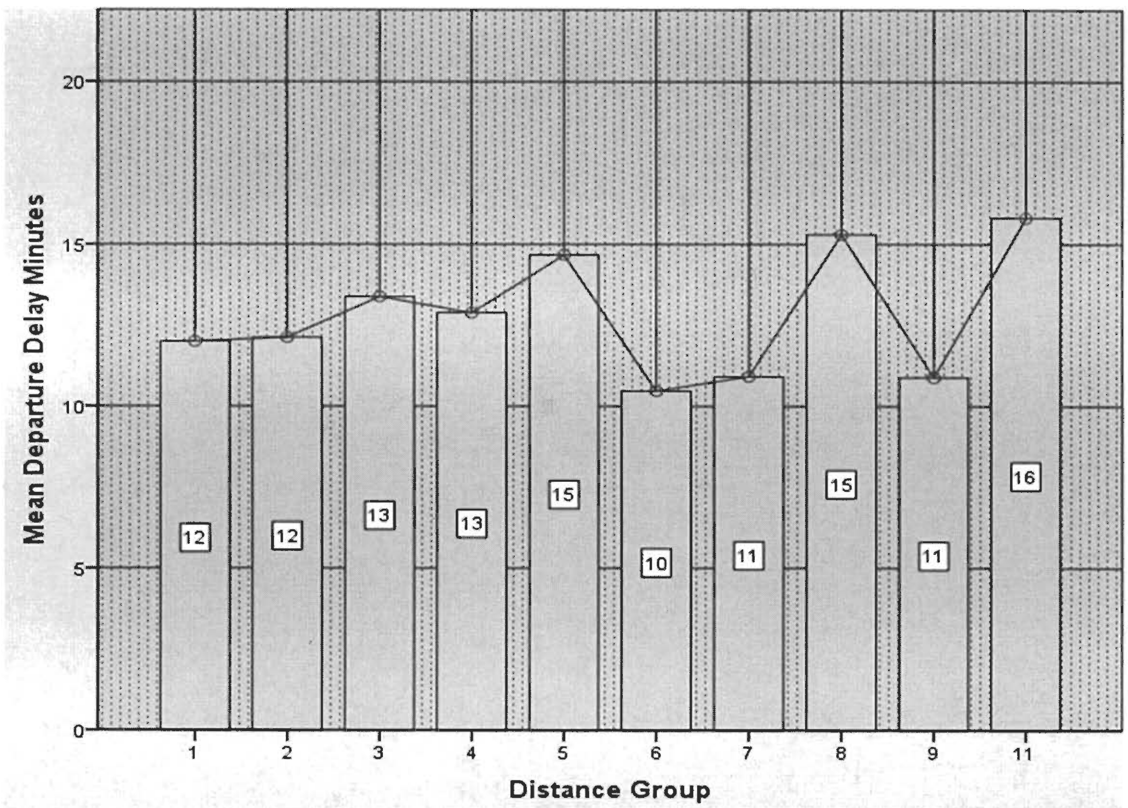


Figure 5.26 Distance Groups From ORD vs. Departure Delay (Minutes)

As seen in Figure 5.26, there is a largely a positive relationship between increases in distance from ORD and duration in departure delay times. Exceptions to this pattern are observed in Groups 6, 7, and 9. Interestingly, these distance groups cover western U.S. destinations only and include: western Montana, Idaho, eastern Washington, eastern Oregon, eastern California, Nevada, western Utah, Arizona, and southeastern Alaska. There are two working theory behind these exceptions. Firstly, these locations –group distance 6 and 7 –span vastly under-populated areas. This observation is supported by the relatively fewer airports in these locations (refer to Figure 5.27 and Figure 5.28). The idea is, with fewer airports, these airspaces will generally be less congested and allow for easier access and exits of carriers. Secondly, relatively fewer passengers are expected to departure ORD for destinations in groups 6 and 7 because of the lower population densities in these areas. This significant fall off in passenger volume impacts the overall quantities of baggage processed for boarding. The net result of this is reduced demands for customer service assistances, faster passenger processing, and subsequently less carrier-caused delays.

It is useful to understand, however, that passengers generally take more luggage as they travel further away from home. Moreover, the likelihood of travel from ORD to the destinations contained in these distance group is less likely to be business trips, and more leisure in nature. This is because of relatively less commercial activities in these under populated areas. American Airlines explains that under normal circumstances passengers are inclined to take increased pieces of luggage on leisure trips, and fewer pieces for business. This situation results in a unique mix of fewer passengers, smaller scheduled aircraft, but more baggage and more potential for hiccups and carrier delays –even as comparably fewer bags are taken onboard. This situation results in carrier delays for distance groups 6 and 7 being artificially higher than expected. The theory is supported by the modestly higher carrier delay mean values of 15 to 17 minutes when compared to NAS delays also in distance groups 6 and 7 (Table 5.4). More will be said about the impact of distance group on each specific delay category from the ANOVA descriptive results provided in Table 5.4. The discussion will beginning with late aircraft delay category and followed by similar discussions on carrier delays, NAS delays, weather delays, and finally, security delays.

Table 5.3 ANOVA (Analysis of Variance)

Results for Causes of Departure Delays over Distance Group at Chicago O'Hare International in 2010						
		Sum of Squares	d.f.	Mean Square	F	Sig.
Carrier Delay	Between Groups	180887.390	9	20098.599	17.588	.000
	Within Groups	7.505E7	65675	1142.761		
	Total	7.523E7	65684			
Weather Delay	Between Groups	10552.251	9	1172.472	4.326	.000
	Within Groups	1.780E7	65675	271.057		
	Total	1.781E7	65684			
NAS Delay	Between Groups	705321.024	9	78369.003	132.136	.000
	Within Groups	3.895E7	65675	593.095		
	Total	3.966E7	65684			
Security Delay	Between Groups	25.961	9	2.885	2.002	.035
	Within Groups	94606.506	65675	1.441		
	Total	94632.468	65684			
Late Aircraft Delay	Between Groups	212817.540	9	23646.393	16.136	.000
	Within Groups	9.624E7	65675	1465.446		
	Total	9.646E7	65684			
Departure Delay Minutes	Between Groups	336454.819	9	37383.869	37.646	.000
	Within Groups	3.038E8	305954	993.043		
	Total	3.042E8	305963			

Computations of a one-way ANOVA comparing causes of delays at ORD in 2010 against 10 distance groups featured at ORD (seen in Table 5.3) indicates that there are significant differences between all causes of delays and each distance group under review. Recall that "if the significance value is greater than 0.05 (found in the **Sig.** column) then you have homogeneity of variances", and no differences exist among variances (Laerd Statistics, 2012, p. 1). That the significance value of each cause of delay, displayed below in Table 5.3, is less than 0.05 and confirms that there is significant difference between all causes of delays and each distance group under review. Range for significance value is 0.0001 to 0.035, while the range for F is 2.002 to 132.136. These specific differences are further explained using some basic descriptive statistics.

Distance Group vs. Late Aircraft Delays

There is an interesting revelation in this category. Although departure delays caused by late aircraft arrivals average highest among all five categories at 22.51 minutes, counter to expectations late aircraft delays generally decreased as destination distance away from ORD increased (Table 5.4). This important finding cannot be readily explained without further review of these specific flights and their actual points of origin. However, it is reasonable to assume that flight connections originating from destinations further away from ORD, will terminate closer to ORD after hub connections are made at ORD. During such long haul flights the possibilities for more mishaps and subsequent delays are greater during the long range portions of these flights. An actual flight route on American Airlines in 2006, may serve as an example in this case. The domestic leg of this flight began at Miami International Airport (MIA) (Florida). The flight's next leg was destined for ORD –at which point passengers deplaned as well as enplaned. The flight's final destination is

Kalamazoo, MI at the Kalamazoo/Battle Creek International Airport (AZO). The approximate flight-leg distribution for this flight is as follow: MIA to ORD, 1041.5 nautical miles; ORD to AZO, 105.9 nautical miles (AirNav, 2011). The flight's first domestic leg between MIA to ORD covered more distance than the last domestic, and as a consequence was exposed to more hazards en route delay that may have resulted in delays. Potential hazards include (and are not limited to): weather, mechanic, crew emergencies, mechanical breakdowns, and passenger illness. The potential for such hazards increases as time and distance increase.

Highest average delays for late aircraft occurred in distance group 2 at 24.11 minutes, while distance group 11 recorded lowest late aircraft delays at 11.9 minutes. Similarly, this reverse phenomenon (in the late aircraft delay category) of lower delays times with increasing distance away from ORD, is counter to the general trend discovered in Figure 5.26A (which features the overall averages of all 5 delay-causing categories). This important finding can be explained by recognizing that distance group 11 includes destinations to Alaska and Hawaii. These destinations are better accessed from western United States. ORD is located in the Midwest and would logically support flight connections from neighboring airports –and more so than those located east of ORD, and rarely those located west and further away from ORD. In these instances the reasons listed above are applicable. The mode for late aircraft delays is 20 minutes.

Distance Group vs. Carrier Delays

Carrier delays averaged at 16.84 minutes, and distance group 4 and 8 were closest to the group's overall average of 16.84 minutes (Table 5.3). As expected in this delay category, distance groups 9 and 11 –the furthest distance groups from ORD –recorded highest levels of carrier delays. This discovery reveals the close relationship between intensity of crew and carrier preparations involved for these longer distance flights. These areas of preparation include, but are not limited to: fueling, staffing, food catering and baggage handling. It can be readily appreciated that more food, more fuel, more staffing, and more detailed and thorough maintenance are required for flight destined for distant locations. All these increase the likelihood that something will not be done according to schedule and consequently result in carrier delays. Significantly, distance group 11 recorded the highest average carrier delay of 27.81 minutes, for any distance group, in any category.

Importantly, distance group 5 ranked second in average delay for this category. This observation is substantial because this distance group represents the furthest distance group for the southern and eastern boundaries of the contiguous U.S. and includes destinations to northern Maine, Florida, southeast Texas, central New Mexico, as well as sections of Colorado, Utah, Wyoming, Idaho, and Montana. From these destinations, Florida and Texas alone represents an important flying demographic group affectionately called "snowbirds." Van Den Hoonaard (2002, p. 53) explains that "snowbird[s] … [are] person[s] who spend a significant amount of time living "up north" each year" but migrate to warmer southern regions during winter months. Van Den Hoonaard further explains that their migration patterns resemble migratory birds that head north for cooler summers, and return south for milder winter. Moreover, "some retirement communities in south Florida are [even] known as "snowbird communities" (Van Den Hoonaard, 2002, p.53). This demographic group tends to include retired seniors, which potentially amplifies the general need for additional customer service and baggage assistance, and increases carrier delays to above average delays levels.

Interestingly, the mean carrier delay for distance group 5 is almost the same as the overall average of late aircraft delay –which accounted of 40 percent of all departure delays at ORD in 2010. Distance group 5 mean carrier delay is 20.94 minutes and the mean of the overall late aircraft delay is 22.51 minutes.

Distance Group vs. National Airspace System (NAS) Delays

As disclosed in Chapter 2, NAS delays are believed to be spawned from congested airspaces. However, departures impacted by NAS activities within ORD's immediate environs (distance group 1) experienced relatively modest delay averages of 10.50 minutes. This is complicit to Figure 5.1 representation of ORD's arrival and departure delays which suggest that it was reasonably easier to exit ORD's airspace than it was to gain access to this airspace. This observation is noteworthy because apart from weather and security delays, no other distance group in any other category recorded lower mean values.

On the other extreme, flights destined for distance group 8 faced enormous NAS delays of almost 25 minutes on average. Distance group 8 constitutes the furthest western parameters of the contiguous U.S., and includes destinations in western California, western Oregon, and western Washington. Again, more information is required to fully interpret these results. However, the argument could be made that because of the popularity of West Coast destinations in the U.S., passenger enplanement numbers for are especially high. These higher passenger demands in turn require bigger aircrafts to shuttle passengers to their destinations located approximately 2000 miles away. These bigger longer range aircraft are limited on runways that can use for departures. AirNav (2011) reveal that only 3 runways –Runway 10/28, Runway 14L/32R, and Runway 14R/32L –at ORD were more than 9000ft in length. At face value, when tested against distance group 5 – another popular destination region –this theory appears somewhat challenged by mean NAS delay values of only 11.26 minutes. However, when examined closer, it becomes evident that distance group 5 destinations are on average 1250 miles away from ORD –almost 750 miles less than similarly sought-after West Coast destinations. This significant difference in distance gives distance group 5 more leverage in the size and types of aircraft that may be used to shuttle large volume of passengers, which in turn increases runways options to these aircrafts.

Distance group 11, which includes destinations to Alaska, Hawaii, recorded mean NAS delays of 18.39 minutes. This delay duration, although significant, is less than that of distance group 8. The argument of passenger enplanement versus aircraft range may also be used to explain these performance figures. Relatively fewer passengers are expected to ply these destinations as oppose to these within distance group 5. As such, difference in the size and range of aircrafts used to service distance group 8 markets, will experience less NAS departure delays because of increased runway options.

In summarizing NAS delays, it is important to understand that while NAS delays are impacted by airspace congestion, it is also affected by aircraft size and types, as size and types of aircraft determine the runways that are available. This problem is conceivably compounded depending on carrier gate locations. The further carriers requiring specific runways for operation are located from such runways, the more frequently and lengthy will be their NAS departure delays.

Distance Group vs. Weather Delays

Weather delays were not impacted significantly by distance groups. In fact, the overall mean value for weather delays at ORD in 2010 was a mere 3.26 minutes. Additionally, every distance group recorded fewer than 5 minutes departure delays out of ORD for any distance group destinations. The lowest mean values occurred in distance group 11 at 2.31 minutes, while distance group 9 recorded 4.41 minutes departure weather delays on average. This level of success of remarkably low levels of weather delays should be fairly credited to aviation interests across the industry to continuously improve the technology of aircraft, ATC, and airport equipment (software and hardware) to deal with the onslaught of weather in the Midwest. This revelation also signals that pilots operating in the ORD airspace during some of the harshest weather in the Midwest, have proficiency levels that among the best in the world.

Distance Group vs. Security Delays

Security delays averaged an overall 0.04 minutes when measured across all distance groups. This was an important discovery because invariably people express that potential security delays are highest among their concerns. However, the highest security delay reported for any distance group was 0.11 minutes. These levels of success is a remarkable testimony of the U.S. government, airline carriers, and passengers working together to ensure security delays are kept extremely low. This is also largely due to the highly efficient communication circuit used to advise passengers to arrival (in some instances up to 3 hours) ahead of time for security processing and screening.

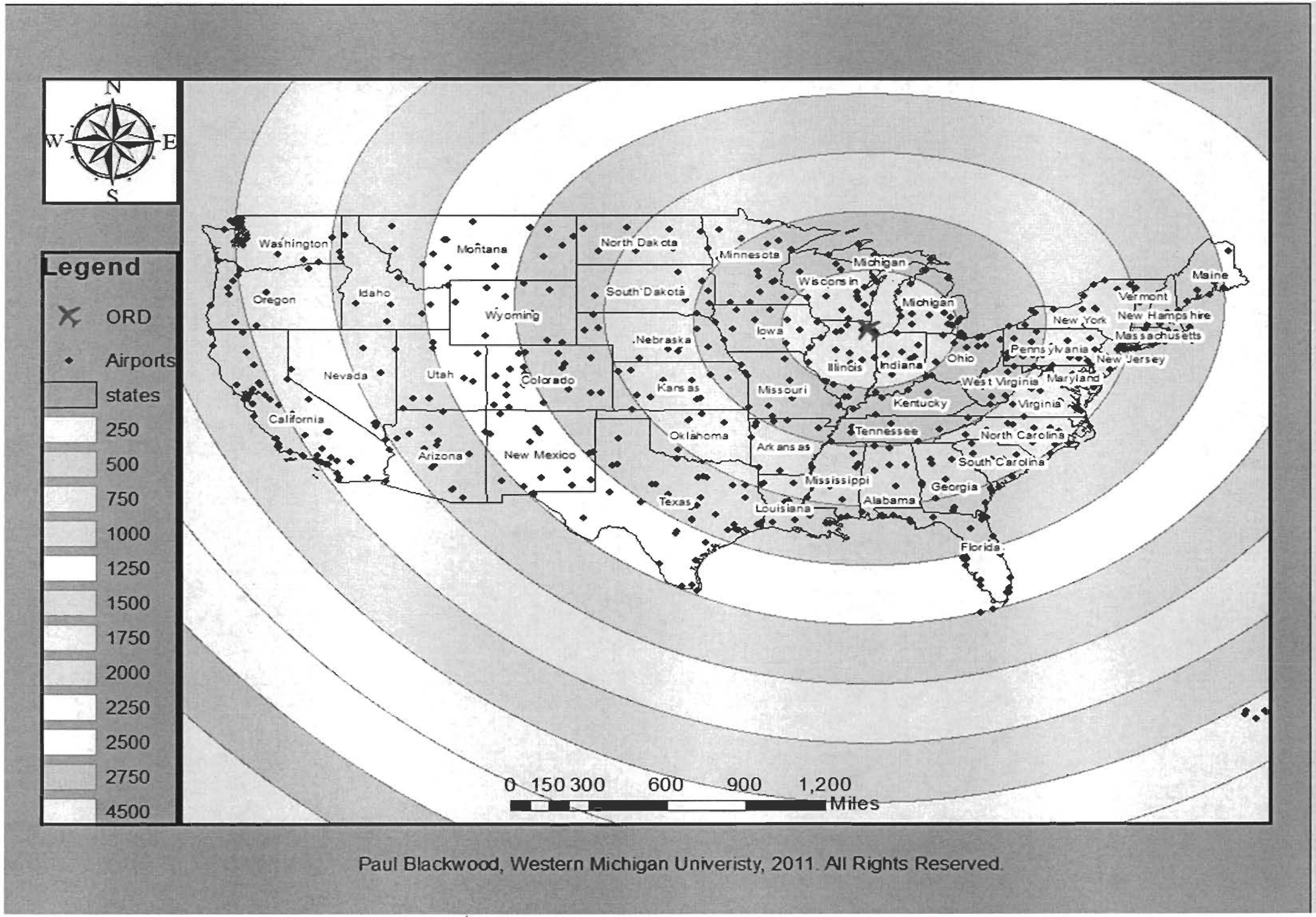


Figure 5.27 Distance Groups Measured Outward From O'Hare International Airport (Contiguous U.S. Only)

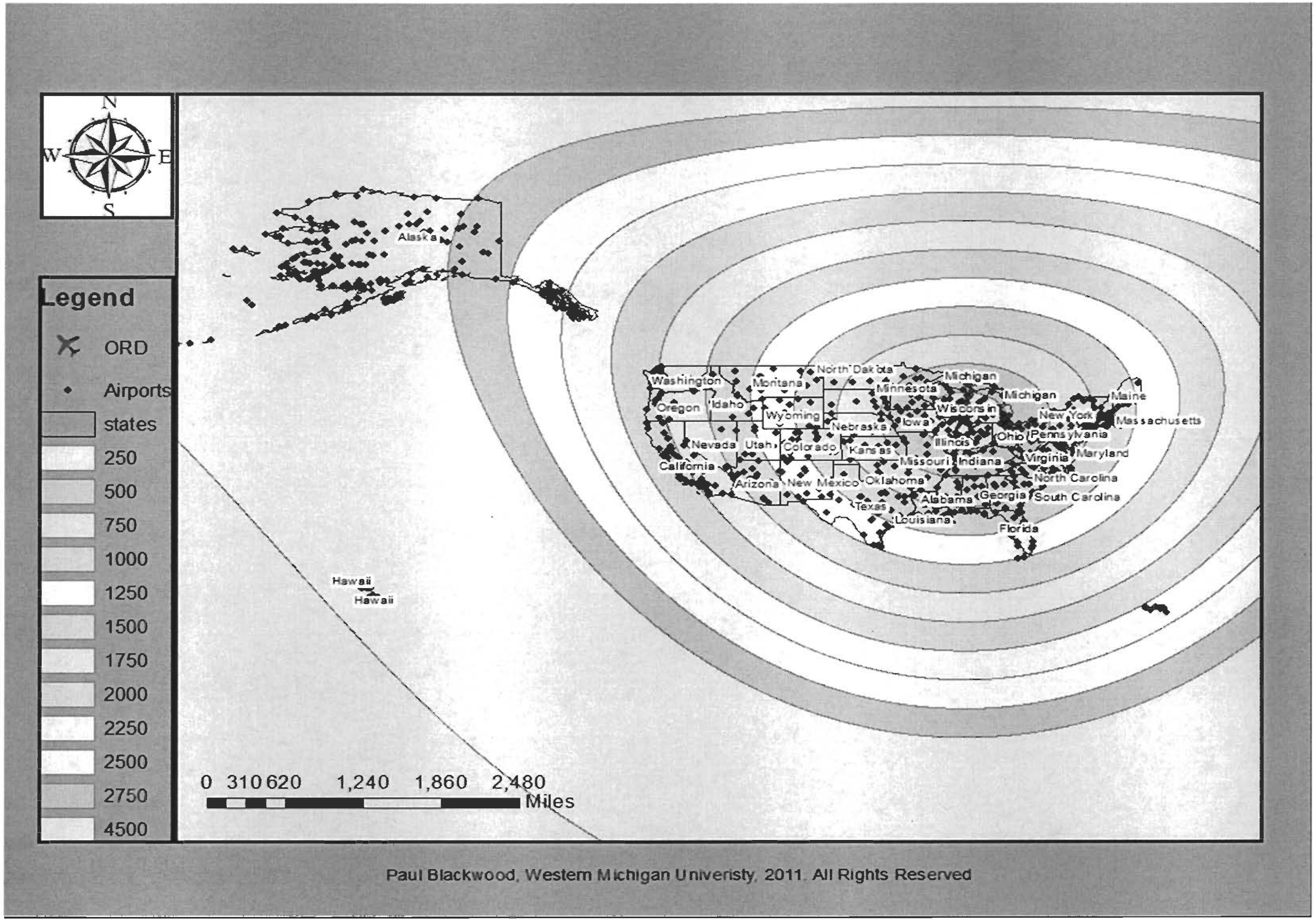


Figure 5.28 Distance Groups Measured Outward From O'Hare International Airport for All U.S. States and Territories

Table 5.4 Descriptive of Statistics on Causes of Departure Delays at ORD (2010)

Causes of Departure Delays Per Distance Group							
Cause of Delay and Distance Group		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
Late Aircraft Delay	1	10104	23.31	37.936	.377	22.57	24.05
	2	14488	24.11	38.022	.316	23.49	24.73
	3	20456	22.39	39.218	.274	21.86	22.93
	4	8653	23.14	39.389	.423	22.31	23.97
	5	4426	20.56	36.499	.549	19.49	21.64
	6	1145	20.93	37.713	1.115	18.75	23.12
	7	4154	20.93	36.818	.571	19.81	22.05
	8	1672	15.81	34.363	.840	14.16	17.45
	9	180	13.44	25.605	1.909	9.68	17.21
	11	407	11.90	39.489	1.957	8.06	15.75
	Total	65685	22.51	38.321	.150	22.22	22.81
Carrier Delay	1	10104	17.91	32.066	.319	17.28	18.54
	2	14488	17.01	31.177	.259	16.51	17.52
	3	20456	15.47	32.090	.224	15.03	15.91
	4	8653	16.37	33.891	.364	15.65	17.08
	5	4426	20.94	39.389	.592	19.78	22.10
	6	1145	17.18	35.162	1.039	15.14	19.22
	7	4154	15.84	34.698	.538	14.78	16.90
	8	1672	16.68	45.064	1.102	14.52	18.84
	9	180	19.01	35.008	2.609	13.86	24.15
	11	407	27.81	81.361	4.033	19.88	35.73
	Total	65685	16.84	33.843	.132	16.58	17.10
NAS Delay	1	10104	10.50	18.271	.182	10.15	10.86
	2	14488	11.30	20.611	.171	10.96	11.64
	3	20456	17.78	30.838	.216	17.35	18.20
	4	8653	13.82	22.948	.247	13.33	14.30
	5	4426	11.26	17.287	.260	10.75	11.77
	6	1145	13.33	20.526	.607	12.14	14.52

Table 5.4 Descriptive of Statistics Continued

Causes of Departure Delays Per Distance Group							
Cause of Delay and Distance Group		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
NAS Delay (continued)	7	4154	12.98	20.095	.312	12.37	13.59
	8	1672	23.09	31.669	.774	21.57	24.61
	9	180	13.80	24.148	1.800	10.25	17.35
	11	407	18.39	19.489	.966	16.49	20.29
	Total	65685	14.02	24.571	.096	13.83	14.20
Weather Delay	1	10104	3.13	18.538	.184	2.77	3.49
	2	14488	3.74	17.772	.148	3.45	4.03
	3	20456	2.96	15.671	.110	2.74	3.17
	4	8653	2.96	13.804	.148	2.67	3.25
	5	4426	3.93	19.501	.293	3.36	4.51
	6	1145	3.18	12.530	.370	2.46	3.91
	7	4154	3.63	15.004	.233	3.18	4.09
	8	1672	2.42	10.841	.265	1.90	2.94
	9	180	4.41	15.518	1.157	2.13	6.69
	11	407	2.31	10.545	.523	1.28	3.34
	Total	65685	3.26	16.468	.064	3.13	3.38
Security Delay	1	10104	.08	1.998	.020	.04	.12
	2	14488	.03	.869	.007	.02	.05
	3	20456	.03	1.119	.008	.01	.04
	4	8653	.04	1.229	.013	.02	.07
	5	4426	.03	.825	.012	.01	.05
	6	1145	.04	.774	.023	.00	.09
	7	4154	.01	.384	.006	.00	.02
	8	1672	.00	.000	.000	.00	.00
	9	180	.11	1.416	.106	-.10	.31
	11	407	.00	.000	.000	.00	.00
	Total	65685	.04	1.200	.005	.03	.05

Table 5.4 Descriptive of Statistics Continued

Causes of Departure Delays Per Distance Group							
Cause of Delay						95% Confidence Interval for Mean	
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound
Departure Delay Minutes	1	45833	12.00	30.226	.141	11.72	12.28
	2	68665	12.13	30.066	.115	11.91	12.36
	3	92328	13.39	32.538	.107	13.18	13.60
	4	40008	12.89	31.468	.157	12.58	13.20
	5	18976	14.67	34.329	.249	14.19	15.16
	6	6611	10.47	28.467	.350	9.79	11.16
	7	24240	10.92	29.053	.187	10.55	11.28
	8	6874	15.30	36.888	.445	14.42	16.17
	9	1045	10.89	26.880	.832	9.26	12.52
	11	1384	15.80	55.324	1.487	12.89	18.72
	Total	305964	12.70	31.530	.057	12.59	12.81

Summary of Causes of Flight Delays

The driving forces behind delays at ORD, and indeed, the U.S. are complex, at minimum. Although proportionate values reveal that late aircraft delays was ranked highest cause of delays –followed by carrier delays, and NAS delays; with weather and security equating to less than a blip on the proverbial screen –it would be an over simplification the industry's problems to instruct all carriers operating in ORD's airspace to arrive early and thereby solve this airport problems. The reason for this is that aircrafts arriving at ORD late for flight connections are also affected by upstream activities which also caused them to be late. These initial activities or reasons may span any of the 5 major causes of delays, or a combination of such causes.

To illustrate, consider an example of three aircrafts A, B, and C, alongside three airports 1, 2, and 3. In this scenario aircraft A destined for airport 2, departs airport 1. Aircraft A is delayed because of NAS events as well as carrier misjudgments. Upon arriving at airport 2 (behind schedule), aircraft A document it reasons for arriving late as NAS and carrier delays. Note that this chain of event has already caused aircraft B off to a late start. Aircraft B destined for airport 3, sustains additional delays from weather. Upon arriving at airport 3, aircraft B lists its reason for delay as late aircraft delay (because of aircraft A's late arrival), as well as weather. At this point, aircraft C is now extremely behind schedule for a future destination because two aircrafts upstream sustained delays. This problem is compounded even further if aircraft C encounters additional delays such security delays, and will lists its reason for delay as late aircraft and security. This scenario identifies how quickly delays cascade through the interconnected domestic U.S. airspace, and the difficulty involved in tracking and addressing lateness –and more so, those grouped as late aircraft delay.

Carrier delays and NAS delays are somewhat easier to address because both can be addressed through preventative actions. In 2010, carrier delays accounted for 29 percent departure delays, while NAS delays were responsible for 25 percent. When asked to determine the driving forces behind delays at the Chicago O'Hare International Airport – one of American Airlines' major U.S. hubs, the Managing Director of Systems Operation Control, contended that ORD like every other airport is limited by finite space. This, he said, continues to be ignored by industry players who continue to consciously over schedule their operations. It is timely to recall that these are a combination of NAS and carrier components which may be carefully managed to curb congestion and delays. He lamented that if one carrier decides to reduce its footprint at ORD in an effort to help the system, that void would be immediately swallowed up by another player seeking to gain ground.

He also cites lack of air traffic control (ATC) flexibility –a NAS component – as another major cause of delays, and suggests a rationing of airport access based on size of aircraft to reduce such delays. He explained that giving priority to bigger aircraft would create an environment where the propensity for large volume of passengers commuting via bigger aircrafts would be less. Also, this proposal does not address how an aircraft (of any size) that is waiting on a flight connection from smaller aircrafts would be impacted by extended waiting that occur both the arriving and departing aircraft. Likewise, this pitch fails to address potential safety issues that would arise from smaller airplanes running out of fuel during such extended wait. These concerns should not be discredited in light of the considerable amount of delays that have been caused by national airspace system at ORD in 2010.

Conclusion

This study has determined that there is substantial evidence to support claims that flight delays are an albatross to the United States –for which, there are no easy fixes. On the one hand, government deregulation of the system was necessary to improve efficiencies and drive cost down. But on the other, the deregulated U.S. industry has begun to cannibalize its own gains because of the absence of a substantial regulatory framework. Beyond the 15 minutes definition of "official lateness," no acceptable industry standard regarding how much delay is reasonable for any domestic U.S. airports exists. As such, the culture of lateness and the resignation to same is deeply entrenched in U.S. air travel. Because of this absence it is imperative for the industry to identify and coalesce around workable standards that can be managed to bring delays within acceptable limits. In 2010, passengers collectively waited for almost 16 years for aircrafts operating in ORD's airspace alone. By contrast Midway International passengers', less than 15 NM away, collectively waited just about 5 years on aircrafts in that airspace during the same year. This confirms that current delay levels are an existential threat to U.S. air travel. Moreover, this threat is not expected to self-correct over the short or medium term.

In April 2010 the FAA established the "Three-Hour Tarmac Rule" (Appendix D) to protect airline passengers against a repeat of February 2007 JetBlue nightmare where passengers were trapped aboard the airline's aircraft, during a snow and ice storm, at John F. Kennedy International Airport in New York for 11 hours without food, water or functional lavatory facilities (Huffington Post, 2011). The "Three Hour Tarmac Rule" demands that passenger not be kept on tarmac while aboard a scheduled operation aircraft for three hours or more (FAA, 2010). Importantly, the "Three Hour Tarmac Rule" should not be confused for, or be equated to, an industry on-time-performance-standard. The rule is instead, a regulatory tool, designed to protect airline passengers against industry abuses, while guaranteeing passenger safety. An alternative to the current absence of a workable industry standard to manage delays will be recommended in chapter 6.

CHAPTER VI

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Chapter 6 is the final chapter in this study. The chapter summarizes the thesis and provides recommendations based on discoveries made over the course of this project. The chapter has 3 sections. Section 1 contains a brief summary of the issues that set this thesis in motion, including a restatement of the 3 main questions that have guided this study. The section also provides a brief summary on what has been done over the life of this study to arrive at answers to these questions. Section 2 presents the study's conclusion, and section three presents the study's recommendations.

Summary

As mentioned in chapter 1, flight delays are economic, social, and environmental albatross to U.S. businesses and consumers. The U.S. government reports that in 2007 alone, domestic flight delays cost the U.S. aviation industry $40.7 billion (Joint Economic Committee of the House and Senate Report, 2008). To date, there have been many studies on what the real causes of such delay. Experts submit that the driving forces behind flight delays in the U.S. have been the Airline Deregulation Act of 1978, the growth of the hub-and-spoke network (Morrison 1997, Bryan & O'Kelly 1999, FAA 1999, Flores-Fillol 2009, and Bayles), the use of slot control (Morrison 2007, Daniel 1995, Fernandes & Pacheco 2000, Brueckner 2002, and Berardino 2009), the policies of gate assignment (Yan & Tang 2006, Haghani & Chen 1997, and Mangoubi & Mathaisel 1995), and the issue of insufficient runway and air space congestion (Schaefer & Millner 2001 and Schorr 2006). In 2003 however, the U.S. government developed and implemented an all-encompassing framework to document causes for domestic flight delays. Part of this framework included grouping delays into 5 categories. These categories are: security, late aircraft, carrier, weather, and national airspace/aviation system (NAS) delays. These classifications show that cause of each flight delay is unique, and could be the result of a single condition or a combination of multiple conditions.

Specifically, the purpose of this study was to explore the key causal factors for departure delays at U.S. airports in 2010, using Chicago O'Hare International Airport (ORD) as a case study, and to identify how these factors might be mitigated. The project was guided by 3 questions. These are: (1) "What are the major factors behind departure delays at Chicago O'Hare International Airport?" (2) "What standards of delays are acceptable?" And (3) "can these variables be managed to bring delays within acceptable standards?" This study utilized both primary and secondary data from the Federal Bureau of Transportation Statistics Airline On-Time Performance database, and interviews with American Airlines personnel. Data were analyzed with Microsoft 2010 Excel, ArcMap 10 GIS, and various SPSS 18.0 statistical modules.

Conclusions from O'Hare Study

Beyond the 15 minutes definition of "official lateness," no acceptable industry standard regarding how much delay is reasonable for any domestic U.S. airports exists. As such, the culture of lateness and the resignation to same is deeply entrenched in U.S. air travel. In 2010 alone, flight delays at the O'Hare International Airport totaled an equivalent of 15.59 years of continues delays. Departure delays were responsible for 7.1 years of this total. There were three major factors behind departure delays at Chicago O'Hare International Airport in 2010. These were late aircraft delays accounting for 40 percent of all delays, carrier related issues at 29 percent, and national airspace bottlenecks at 25 percent. Surprisingly, weather and security issues were very much inconsequential to ORD's overall on-time performance. In 2010 weather accounted for only 6 percent of ORD's departure delays, while security related issues accounted for less 1 percent of all delays. These low percentages are primary because of year-to-year improvements in weather-related technologies currently in use at U.S. airports –and specifically at ORD –as well as regulatory measures designed monitor and maintain "human proficiency" standards to deal with adverse weather. Also, at present passengers are instructed to arrive –in some cases – as much as 2 hours in advance to obtain security clearances for domestic flights. This requirement minimizes the threat of security delays in advance.

The months of May and June are prime candidates for lengthy late aircraft delays (Figure 5.3). Typically, travelers may expect late aircraft delays of 30 minutes or more on the 7th, 12th, 13th, 21st, 31st days of the month (Figure 5.4). Tuesday and Fridays are days of the week most likely to experience lengthy late aircraft delays of 25 minutes or greater (Figure 5.5). Atlantic Southeast Airlines had the greatest mean of late aircraft delays at ORD in 2010 (Figure 5.6). These delays averaged above 45 minutes.

Delays by carrier are comparable on any given month (Figure 5.8). Travelers may expect carrier delays of 20 minutes or more on the 3rd, 17th, and 19th days of a typical month (Figure 5.9). Sundays through Saturdays are major days for carrier delays of 15 minutes or greater (Figure 5.10). Comair recorded the greatest mean in carrier delays in 2010. These delays averaged about 27 minutes in duration.

The months of June and September are prime candidates of lengthy NAS delays (Figure 5.13). Travelers may expect NAS delays of 15 minutes or more on the 15th, 18th, and 23rd of a typical month (Figure 5.14). Mondays and Thursdays are major days for NAS delays of 15 minutes or more (Figure 5.15). Continental Airlines the experienced highest number of NAS delays in 2010 (Figure 5.16). These delays average about 27 minutes in duration.

Surprisingly, no month of the year experienced significantly different volumes of weather delays (Figure 5.18). Travelers may expect weather delays of 8 minutes or less on any day of a typical month (Figure 5.19). Typically, no day of the week experiences delays greater than 5 minutes (Figure 5.20). Comair experienced largest number of weather delays in 2010, but these delays averaged 11 minutes or less (Figure 5.21B).

No month of the year experienced a disproportionate number of security delays (Figure 5.23). On average, travelers should not expect security delays greater than 1 minute in any typical month.

The distance a flight travels between departure point A, and its intended destination point B, clearly influences the kinds of delays encountered as well as the duration of such delays. In 2010, the U.S. DOT established 11 distance-groups to cover all domestic destinations –each separated by 250 miles (Figure 5.27, Figure 5.28). ANOVA results revealed that there are significant differences between all causes of delays and each distance group under review. The results also revealed that although departure delays caused by late aircraft arrivals average highest among all five categories at 22.51 minutes, counter to expectations late aircraft delays generally decreased as destination distance away from ORD increased (Table 5.4).

Recommendations

Over the last few decades, U.S. airlines have adopted a variety of interconnectedness models to improve efficiency and reduce waste. While these models have brought gains, they also have their own drawbacks. This study provides some specific suggestions to improve on-time performance and reduce delays at U.S. airports. These suggestions identify workable standards that may be established across U.S. airports to bring flight delays within acceptable limits.

1. Declare delays beyond 20 minutes as fineable.

2. Manage industry culture to change attitudes about lateness (i.e. ATC, flight crews, maintenance crews, travel agencies, and passengers).
3. Manage carrier crews, equipment, and activities to reduce carrier delays (these account for almost 1/3 of the industry's delay problems). This may be accomplished through an educational campaign aimed at carriers, airports, and all other relevant stakeholders. Security delays have been successfully reduced in this manner.
4. Reduce overscheduling. When carriers over schedule this affects timely departures because airlines are required to reconcile passenger excesses before departures. As a result these aircrafts "turn up" in departure airspaces as well as destination airspaces outside of their scheduled times. Resolving these time conflicts, preferably in advance, should reduce NAS delays, airspace congestion, as well as carrier delays.
5. Implement fee/taxation system at the federal level on airports that "oversell" available slots. This will be explained in greater details below.
6. Implement fee/taxation-bonus system on on-time/delayed airlines to encourage efficiency in on-time performance among carriers and schedule compliance. Recommendations number 4 and 5 are explained in greater details below.

Because the industry is operated to some extent as a capitalist enterprise, it is difficult to see how the government could mandate what "reasonable industry standards" for delay (i.e. on-time performance) should be without receiving overwhelming "pushback" from these private entities. However, in the past, carriers have incentivized on-time performance through bonuses and positive job performance reviews, and some hybrid of this type of policy could be crafted by the government. Specifically, the hybrid could include "carrot and stick" incentives to authorize airports to apply reduced tariff credits to airlines that consistently (measured as a percentage of total daily flights by individual carriers) operate within 14 minutes of scheduled time. This reduced tariff credit could later be passed on to the crews of airlines that are awarded the credit in the form of monthly bonuses. At the same time, the model could also serves as a deterrent for consistently late flights by levying premium tariffs against individual airlines for each flight that does not operate within 20 minutes of scheduled operation. The 5 minute gap between on-time tariff reductions and late aircraft operation would serve as a buffer/grace period before premium charges begin to accrue. This model would be a win-win for passengers, airlines, local airports, and downstream industries (and economies) that continue to rely on timely flight operations to optimize profit and productivity. The model would also allow flight delays to be brought within reach of acceptable standards that can be managed and corrected.

Limitations of the Study

This research was constrained by manpower, monetary resources and time. As such, the study focused entirely on departure delays out of ORD in 2010. Although it would take additional research to prove that a clearer understanding of the issues affecting on-time performance at U.S. airports –and specifically

ORD were possible, such studies are necessary if the industry is to address the multiple issues that continues to dog the U.S. domestic airspace. Future studies on these issues could be expanded to include multiple years, multiple airports, and more inputs from airlines and other industry stakeholders willing to respond.

Appendix A

American Eagle Airlines to Increase Nonstop Service between Milwaukee and Dallas/Fort Worth (Source: American Airlines 2011, Mitchell International Airport 2009)

Source: American Airlines 2011, Mitchell Airport 2009

Topic: "American Eagle Airlines to Increase Nonstop Service between Milwaukee and Dallas/Fort Worth

PRNewswire
FORT WORTH, Texas
(NYSE:AMR)

FORT WORTH, Texas, Nov. 24 /PRNewswire-FirstCall/ -- American Eagle Airlines, the regional affiliate of American Airlines, will increase its daily nonstop flights between General Mitchell International Airport in Milwaukee, Wis. (MKE), and Dallas/Fort Worth International Airport (DFW), beginning Jan. 31. The additions will bring the total number of flights between the DFW Metroplex and Milwaukee to five.

American Eagle will operate its Milwaukee service using a combination of 70-seat Bombardier CRJ-700 and 50-seat Embraer ERJ-145 jets.

"We're very pleased with our current service from Dallas/Fort Worth to Milwaukee," said Gary Foss, Vice President - Planning & Marketing, AMR Regional Network. "And we're delighted that Eagle's expanded service will offer even more options to and from Milwaukee while providing our customers in Southeastern Wisconsin with convenient connections to American's global network through its largest hub."

Beginning Jan. 31, the flight schedule between Milwaukee and Dallas/Fort Worth will be (all times local):

Milwaukee to Dallas/Fort Worth (MKE-DFW)

Flight	Departs	Arrives	Days
3234	6:30 a.m.	9:10 a.m.	Daily
3410*	9:15 a.m.	12:00 p.m.	Daily
3638	12:10 p.m.	2:55 p.m.	Daily
3602	4:15 p.m.	6:55 p.m.	Daily
3528*	6:45 p.m.	9:25 p.m.	Daily, except Sat

*New flight

Appendix B

Questionnaire for American Airlines

Research Questionnaire
Researcher: Paul Blackwood
Carrier: American Airlines

1. What are the major forces behind flight delays at Chicago O'Hare International; as experienced by American Airlines?

2. Which of these factors are attributable to American and American Eagle Airlines, and what factors externally driven (.i.e. industry related, or O'Hare specifically)?

American Airline (internal drivers)

O'Hare, Industry, or Other (external drivers)

3. Can these variables be managed to bring delays within acceptable standards?

4. If yes, please explain?

5. If no, please explain?

6. (Follow up to question 3) - What standards (i.e. delay times per individual flight; per airline; per airport (e.g. some ratio of flight to airport size/operation) are in fact acceptable to industry players, or to American Airlines?

7. How does American & American Eagle Airlines handle flight delays at O'Hare International? How are passengers briefed and/or prepared for (i.e. accommodated) delays when they occur?

Arrival Delays

Departure Delays

8. At what point are flights cancelled, and why?

9. Why are cancellations reported in minutes as well as percentages?

10. Which days (of week, and month) present highest challenges for delays and why?

11. Which season or time of year presents the greatest potential for delays, and why?

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12. How many gates does American Airlines/American Eagle Airline use/have at O'Hare, and why?

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13. What are the processes to secure gate usage? In other words, are these gates available to any airline at any time?

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14. As a follow up to question 13, are these processes impacted by slot controls?

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15. Briefly, how does slot control work and what is the idea behind it?

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16. As view by American Airlines, what role does slot control play in flight delays at the Chicago O'Hare International, if any? (Footnote: Perhaps slot control is a primary driver for NAS delays, Late-Aircraft arrival delays, and Carrier delays)

17. Which gates, used by your carrier, experience highest delays at O'Hare, and why?

18. Which gates, used by your carrier, experience lowest delays at O'Hare, and why?

19. What is the importance of O'Hare to your operation?

20. On average how many flights do you to have in and out of O'Hare per day?

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21. What is the annual operational cost of flights delays to your airline at O'Hare? (a ballpark figure will suffice)

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22. What role does gate assignment play, if any, in flight delays at O'Hare?

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23. The industry lists the causes of delays for major U.S. airports as: NAS Delays; Security Delays, Carrier Delays; Weather Delays; and Late Aircraft Delays. Briefly explain what constitutes each of these delays?

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24. With reference to question 23, which of these kinds of delays are within the controls of any airline carrier?

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25. With reference to question 23, which of these kinds of delays are within the controls of any airport?

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26. With reference to question 23, which of these kinds of delays are outside the controls of airline carriers or airports?

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27. What are your views about O'Hare International Airport?

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28. What would you change about O'Hare International Airport?

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Appendix C

Distance Group Description (Source: BTS 2011)

Distance Group Description

Distance Group	Actual Distance (Miles)
1	< 250
2	250-499
3	500-749
4	750-999
5	1000-1249
6	1250-1499
7	1500-1749
8	1750-1999
9	2000-2249
10	2500-2499
11	> 2750

Source: BTS 2011

Appendix D

Three-Hour Tarmac Rule (Source: FAA 2010)

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Air Traffic Organization Policy

Source: FAA, 2010

Effective Date:
April 29, 2010

N JO 7110.524

Cancellation Date:
March 10, 2011

SUBJ: Enhancing Airline Passenger Protections (Three-hour Tarmac Rule)

1. Purpose of This Notice. This notice provides interim guidance concerning Department of
Transportation (DOT) Rule, Enhancing Airline Passenger Protections, Title 14 Code of Federal
Regulations, part 259, commonly referred to as the "Three-hour Tarmac Rule." Some verbiage contained in this notice is extracted from the previously mentioned rule. The rule was published in the Federal Register on December 30, 2009, and is effective on April 29, 2010. This notice is intended to facilitate the successful management of the requirements contained in the Enhancing Airline Passenger Protections Rule.

2. Audience. This notice applies to Federal Aviation Administration (FAA) tower facilities, Federal contract towers, Terminal, En Route and Oceanic, and System Operations Services.

3. Where Can I Find This Notice? This notice is available on the MYFAA employee Web site at https://employees.faa.gov/tools_resources/orders_notices/ and on the air traffic publications Web site at http://www.faa.gov/air_traffic/publications/.

4. Explanation of Policy Change. In response to numerous instances of passengers experiencing lengthy tarmac delays, the DOT has issued a final ruling entitled "Enhancing Airline Passenger
Protections," also referred to as the "Three-hour Tarmac Rule," effective April 29, 2010. To reduce coordination and/or confusion, requests for an aircraft to return to the ramp, gate, or alternate deplaning area from entities other than the pilot-in-command of that aircraft will not normally be accepted unless the aircraft operator is unable to contact the flight crew via radio or Aircraft Communications Addressing and Reporting System (ACARS). The intent is to

have a single source initiating the request and a single focal acknowledging receipt.

5. Procedures.
a. Add Paragraph 3-1-15, Ground Operations Related to the "Three-hour Tarmac Rule," to
FAA Order JO 7110.65 to read as follows:

3-1-15. GROUND OPERATIONS RELATED TO THE "THREE-HOUR TARMAC RULE"
When a request is made by the pilot-in-command of an aircraft to return to the ramp, gate, or alternate deplaning area due to the "Three-hour Tarmac Rule":

a. Provide the requested services as soon as operationally practical, or

b. Advise the pilot-in-command that the requested service cannot be accommodated because it would create a significant disruption to air traffic operations. .....

b. Add the following definitions to the Pilot Controller Glossary:
TARMAC DELAY - The holding of an aircraft on the ground either before departure or after landing with no opportunity for its passengers to deplane.

TARMAC DELAY AIRCRAFT - An aircraft whose pilot-in-command has requested to taxi to the ramp, gate, or alternate deplaning area to comply with the "Three-hour Tarmac Rule."

TARMAC DELAY REQUEST - A request by the pilot-in-command to taxi to the ramp, gate, or alternate deplaning location to comply with the "Three-hour Tarmac Rule."

THREE-HOUR TARMAC RULE - Rule that relates to Department of Transportation (DOT) requirements placed on airlines when tarmac delays are anticipated to reach 3 hours.

6. Distribution. This notice is distributed to the following ATO service units: Terminal, En Route and Oceanic, System Operations Services, and Technical Operations; the ATO Office of Safety; service center offices; the Air Traffic Safety Oversight Service; the William J. Hughes Technical Center; and the Mike Monroney Aeronautical Center.

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