RETHINKING THE HUB AND SPOKE AIRLINE STRATEGY: AN ANALYSIS AND DISCUSSION OF AMERICAN AIRLINES'S DECISION TO DEPEAK ITS SCHEDULE AT O'HARE INTERNATIONAL AIRPORT

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Submitted to the Department of Aeronautics and Astronautics and the Sloan School of Management in Partial Fulfillment of the Requirements for the Degrees of

Master of Science in Aeronautics and Astronautics
and
Master of Science in Management

In Conjunction with the Leaders for Manufacturing Program at the
Massachusetts Institute of Technology
June 2003

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ACKNOWLEDGEMENTS

First and foremost, the author would like to thank the employees of United Airlines who welcomed her at a time of great turbulence and allowed her the opportunity to learn. Specifically, she would like to thank Andrew Studdert, former Chief Operating Officer for his initial enthusiasm for the internship; Peter McDonald and John Schneider for arranging and supporting her position in Operations Analysis; Greg Coldren, Chris Spidle, and many others for their day to day help and interaction; and Marty St. George for his endless enthusiasm.

The author would also like to thank the many professors and colleagues at MIT and The Boeing Company who helped to create, shape, and guide the internship, project, and thesis. Specifically, the author thanks Tom Kochan for championing the idea in the first place; John Hansman for enthusiastically accepting an advisory role alongside Tom; Peter Belobaba, J. P. Clarke, and many others for fantastic instruction in preparation for the internship; Arnie Barnett for checking in before, during, and after the internship; Charlie Hix for drumming up enthusiasm within Boeing; Paul Lagace and Cynthia Barnhart for helping me maintain perspective; and Bill Hanson for his continued encouragement.

Finally, this internship and thesis work would not have been possible without the funding and support of the Sloan Foundation, the MIT Global Airline Industry Program, the MIT Leaders for Manufacturing Program, and The Boeing Company.

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ABSTRACT

The airline industry downturn that began in early 2000 was exacerbated not only by the terrorist attacks in the United States on September 11, 2001, but also by other pressures for strategic change. Continued growth and competition of low cost carriers coupled with changing purchasing habits of passengers have led industry analysts, airline executives, and investors alike, to question the continued viability of the traditional hub and spoke airline strategy. The financial success of Southwest Airlines and other low cost carriers is partly attributable to its high levels of employee productivity and equipment utilization. In April 2002, American Airlines made a step toward emulating this facet of Southwest's strategy by depeaking its flight schedule at Chicago's O'Hare International Airport. American's schedule change was analyzed, and the decision was evaluated from the market share, operational reliability, and cost perspectives. Average connection times increased by 6 minutes, and the average number of connections per arriving flight decreased by 2. Computer Reservation System market share data implied a market share neutral decision. Department of Transportation on-time performance data implied an improvement in reliability. Finally, the reduction in degree of schedule peaking implied a potential cost improvement through increased equipment utilization, lower required staffing levels, and improved employee productivity.

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TABLE OF CONTENTS

1 INTRODUCTION

The current airline industry downturn and subsequent financial crisis has revived considerable debate about the continued viability of the traditional network carrier business strategy. With increased competition, reduced passenger traffic, and falling average fares, costs have become increasingly important determinants of carrier profitability. Carriers previously reliant on business passengers' willingness to pay high fares are now struggling to align previously unchecked costs with the new level of revenues.

One example of a carrier's attempt to reduce costs is American Airlines's decision to depeak its departure and arrival banks at O'Hare International Airport in April 2002. The traditional network airline paradigm dictates a highly peaked schedule to minimize passenger connection times; thus in turn increasing attractiveness of itineraries and hopefully revenue. American's decision to depeak breaks away from the traditional paradigm and could signal the advent of a new business model for network carriers.

To understand and evaluate the implications of the changes that American Airlines has made to its schedule, one must first understand the context of these changes by reviewing both the history of the industry and the nature of competition in the current environment. This thesis will include a brief industry history with emphasis on past events leading up to the development of hub and spoke networks as well as the high cost structures of some carriers. Next, the recent financial crisis will be described and an argument for strategic change will be presented. American's decision to depeak its schedule will be introduced as a departure from traditional network carrier practices.

The schedule change is then analyzed for changes in connection times, degree of peaking, and connectivity. Schedule performance is then analyzed and discussed form the perspectives of market share, reliability, and cost. Finally, the thesis includes a discussion of the overall merit of this new strategy in light of current industry conditions.

1.1 Brief History of the U.S. Commercial Airline Industry

Passenger aviation started after World War I when airplanes were plentiful, and individuals who owned them were willing to ferry people short distances. There was no scheduled service however, and given the breadth and power of the railroad industry, it was unlikely any would develop without government intervention. In 1918, the U.S. Post Office Department began airmail service. Over the next six years, scheduled airmail service grew from the east coast to transcontinental service and included regularly scheduled night flying. As the extent of airmail service grew, the railroads lost more and more mail revenue; this led to the introduction of the Contract Air Mail, or Kelly Act of 1925.

The Kelly Act of 1925 turned over mail routes to private carriers and thus gave the railroad executives the opportunity to buy or control airmail service. Soon many different mail services competed across the country. This competition along with high rates for carrying mail fostered technological innovation. The advent of more powerful engines allowed the transport of not only mail, but also passengers. The Air Commerce Act of 1926 established processes and procedures for cataloging and certifying the airworthiness of aircraft and pilots. Soon, with the improvement of technology and safety, and the popularity of Charles Lindberg, airmail carriers were supplementing their income with passenger revenues.

In 1929, Postmaster General Walter Brown recognized the long-term need for more organized development of passenger aviation. He outlined and began to implement a plan for reforming the then-corrupt method of payment for airmail. He also began to decrease the magnitude of payment of airmail service, thus encouraging efficiency improvements and shifting air carrier profit reliance from mail to passengers. Brown also used his authority to award mail routes as a means to effect air carrier consolidation, and by the end of 1930, four major strong carriers existed: United, TWA, American, and Eastern. Additionally, four major routes existed: three transcontinental routes (northern, central, and southern) served by United, TWA, and American, and an east coast route

served by Eastern. At the same time, Pan Am served overseas routes. (Heppenheimer 1995)

1.1.1 Regulated competitive environment

The Civil Aeronautics Act of 1938 and its subsequent reforms established the Civil Aeronautics Board (CAB) and the Civil Aeronautics Authority (CAA). Together, these agencies monitored and regulated the economic performance and safety and operations of the airlines. Specifically, the CAB set fares and determined which airlines could service which cities. In 1958, the Federal Aviation Act limited the jurisdiction of the CAB to routes that crossed over state lines and carriers who served such interstate routes. (Mola 2003)

During this regulated period, prices were set on a cost-plus basis. Additionally, the CAB deliberately set prices even higher on popular routes in order to subsidize the cost of serving smaller markets. Further, the level of profits a carrier was allowed was proportional to its amount of capital investment, and so carriers were encouraged to add more capacity in the form of larger planes and increased frequency. Thus, with guaranteed profits, the costs and size of these national carriers grew somewhat unchecked. (Chmura 1983)

The industry was not completely without competition during this period. Multiple carriers often served large markets. In these markets, carriers competed on service: number of passengers per flight attendant, better and more frequent meals, and more frequent flights. The large carriers also competed with non-regulated carriers on popular intrastate routes such as Los Angeles to San Francisco. In this market, the CAB allowed the regulated airlines to drop prices to match those of the much lower cost Pacific Southwest Airlines. (Chmura 1983)

1.1.2 Deregulation and the development of hub and spoke carriers

In 1978, the Airline Deregulation Act called for the gradual deregulation of the industry, and the dissolution of the CAB by the end of 1984. The incumbent airlines were left to

decide for themselves which routes to serve. When the CAB was dissolved in 1984, its remaining functions were transferred to the Department of Transportation (DOT). Among these functions was the Essential Air Service program that ensured federal or local government subsidies for carriers who could no longer afford to serve small and midsize cities. (Chmura 1983)

The establishment of hubs was an outgrowth of the desire of established carriers to offer more destinations and thus stimulate more demand. Hubs allowed carriers to expand service networks for less cost than establishing service on each of the routes separately. Hubs also allowed them to survive the burst of post-deregulation competition by consolidating passengers headed to multiple destinations at spoke stations, and redistributing them on connecting flights at the hub. Eventually, these connecting passengers would subsidize the airline's domination of flight offerings and frequency at hub airports, thus giving the airline a competitive advantage at the hub. (Brueckner and Zhang 2001)

At the same time that the previously regulated airlines were adapting their operations to the new environment through the development of hub and spoke systems, new competitors also entered the scene. For example, Southwest Airlines, previously a Texan intrastate service provider had the opportunity to grow its network. While Southwest found it difficult to compete head-to-head at hubs with hub airlines, it chose to continue the strategy that had worked so well in Texas of operating out of smaller, less used, near by airports. (Gittell 2003)

2 AIRLINE CARRIER BUSINESS STRATEGIES

From the time of deregulation until the present, various airlines have entered and exited the industry. Some carriers that faced financial difficulties successfully restructured under Chapter 11 bankruptcy protection, while others merged with stronger airlines. As carriers grew and developed, two dimensions for classifying airline business strategies emerged: cost and schedule.

2.1 The Threat of Low Cost Carriers

Often, airlines are categorized by whether or not they try to use lower costs as their competitive advantage. Low cost carriers compete by lowering fares, yet maintaining reasonable profit margins. Current low cost airlines include carriers such as Southwest Airlines, Air Tran, American Trans Airways jetBlue Airways, and America West. In this classification, low cost is usually synonymous with no frills service, which may or may not be an appropriate indicator. Other indicators of low cost airlines include single class seating, acquisition of used and refurbished aircraft, fleet commonality, and more efficient use of assets such as people, fleet, facilities.

Carriers not considered to be low cost include those airlines that grew out of the era of industry regulation. These airlines such as United, American, and Delta once operated in an environment in which costs were not held in check because competition was based not on fares, but on service. Higher quality service meant better meals, more frequent and less full flights, and more flight attendants for a given number of passengers. Following deregulation, theses added costs continued to be passed along to the passengers. Another factor contributing to the high costs of some carriers is labor costs. Airlines that grew out of the regulated era have been operating for more than 70 years, and therefore, have more senior labor forces than some of the newer low cost carriers. Finally, high costs have been attributed to a high mix of fleet types, low productivity flight crew schedules, and the general complexity of operating a large network.

As low cost carriers have grown both in size and number, they have begun to present a significant threat to larger, more costly airlines. By 2000, the low cost carriers

represented about 20% of available capacity and about the same level of domestic market share. The low cost carriers now also provide competition in over 700 of the top 1000 domestic markets by enplanements. This low cost competition has continued to put pressure on the larger higher cost carriers to reduced their costs and improve operational efficiencies. It has also brought into question whether the some of the high costs are inherent to the hub and spoke operations that emerged after deregulation.

2.2 Hub and Spoke Network Carriers

The other distinction often made between carriers is whether that airline operates its schedule as hub and spoke or point-to-point. This categorization refers to the methodology dominating schedule design. In the case of hub and spoke, or traditional network carriers, flight schedules are built focusing on the hub airports and trying to maximize the number of flight itineraries that can be built by connecting flights into and out of the hubs. The traditional network carriers such as United and American had their roots in the regulated environment and operated vast networks enhanced through agreements with regional carriers and alliances with other network carriers.

Point-to-point operators focus instead on serving individual markets at high frequency and see any connecting itineraries as "bonus." Current point-to-point operators include Southwest Airlines and Jet Blue Airways. While some might claim that Southwest also operates hubs since passengers do make connects, the difference is that Southwest does not actively schedule these connections. Instead, connections are viewed as bonus: an additional offering to their point-to-point operations. (Flint 1993, Flint 2002) While some low cost carriers operate hub and spoke networks, Southwest Airlines's point-to-point scheduling strategy is often a focal for comparison with the traditional carriers. Whether or not a significant portion of Southwest's success can be attributed to its scheduling methodology or not, has become a popular debate as traditional carriers struggle against their low cost competition.

2.3 The Debate of Hub and Spoke versus Point-to-Point

The debate of hub and spoke versus point-to-point did not begin with the current industry downturn. During the early 1990's during the first Gulf War, analysts already were questioning whether the hub and spoke model was still viable. Some blamed over capacity, economic recession, and carrier bankruptcies for the downturn, while others claimed that all airlines needed to operate like Southwest Airlines. (Flint 1993) As a result, large hub and spoke carriers began to offer more direct flights, and worked to improve hub efficiencies with introduction of more regional and commuter aircraft. (Ott Jan. 1993) Carriers such as United, Delta, and Continental also attempted low-cost, short-haul service on some routes to try and head off the low cost competition. (Ott Nov. 1993) Finally, many smaller hubs were dropped or downgraded, as airlines focused on hubs with large local populations so that carriers could cover the cost of complexity of a hub with higher revenues from local passengers. (Feldman and Cameron 1993)

The merits of the hub and spoke strategy were still touted, as analysts and academics alike stood behind the potential benefits: greater frequency and travel options, access to small cities, increased competition for passengers. (Feldman and Cameron 1993, Nero 1999, Lepak 1997) At the time, however, both were quick to point out that these benefits could only be realized if hubs were operated efficiently. (Aykin 1995) American Airlines Chairman Robert Crandall blamed some of his company's losses on the higher costs of carrying passengers through hub airports, specifically, the periods of increased and decreased activity driven by the traditional short connection schedule paradigm. Some analysts at the time also suggested carriers should consider more continuous flight schedules like Southwest operates as shown in Figure 2.1. (Ott Nov. 1993, Feldman and Cameron 1993) This paradigm shift was not attempted, however as the economy picked up, and airlines found revenue gains through revenue management improvements and cost reductions by outsourcing services. (Costa et al. 2002)

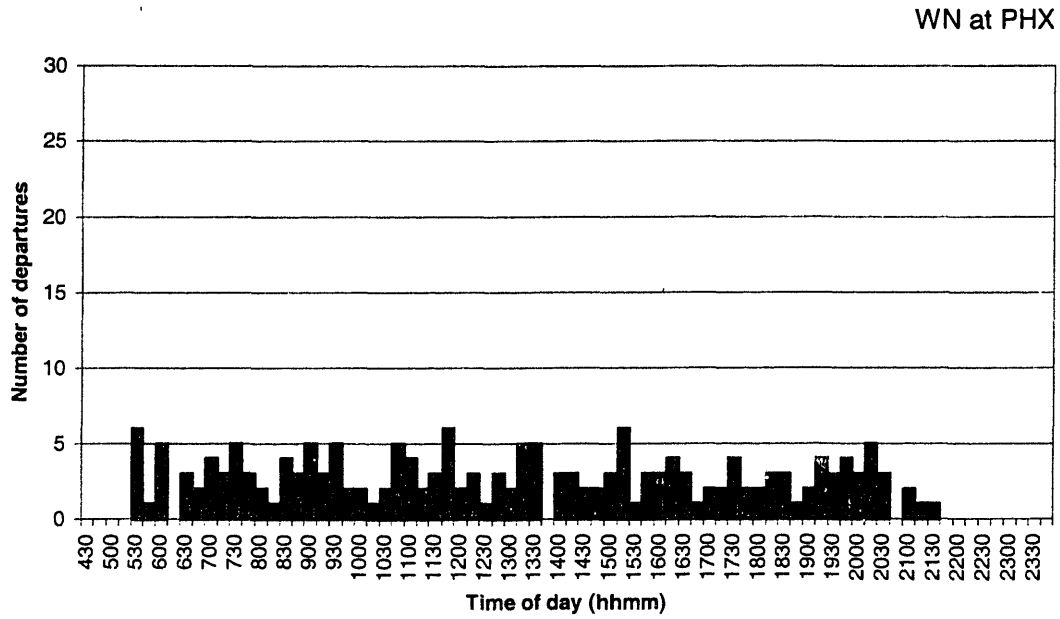


Figure 2.1 Southwest Airlines at PHX Arrivals and Departures in 15-minute Intervals, April 2002

During this most recent downturn, the debate between hub and spoke and point-to-point has again resurfaced. The criticisms are essentially the same: traditional hub and spoke carriers are not experiencing cost economies of scale they should be. Traditional carriers such as American, United, USAir, and Delta have much high costs and much lower productivity than their lower cost competitors; therefore they find it harder to continue to match these competitors low fares. (Feldman 2001, Donoghue 2002, McDonald 2002) This time, however, the possible solutions are less clear and more difficult to implement. The next chapter will provide more detail about the current crisis, what the airlines have done thus far in an attempt to recover, and what makes this crisis different than previous downturns.

3 CURRENT INDUSTRY CRISIS

3.1 Industry Performance and Response

As seen in Figure 3.1, the current industry crisis began in 2000, when carrier profits fell significantly from the highs of the previous three years. In 2001, the U.S. carriers suffered unprecedented losses, in part due to the terrorist attacks of September 11, as highlighted by the dramatic one-time drop in revenue passenger miles (RPMs) as shown in Figure 3.2. While RPMs did partially recover from the sharp decline in September 2001, passenger traffic never returned to early 2001 or 2000 levels.

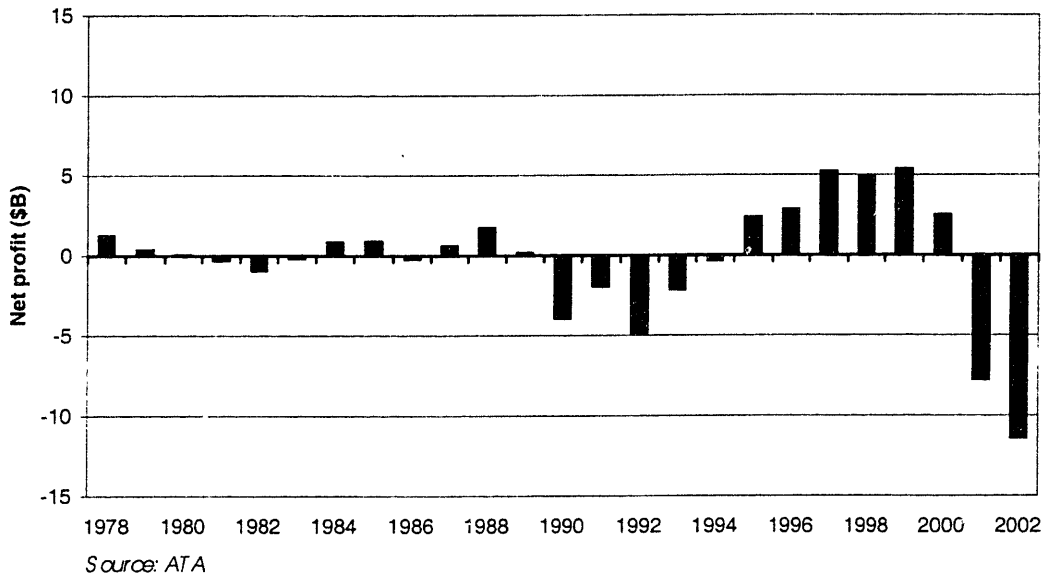
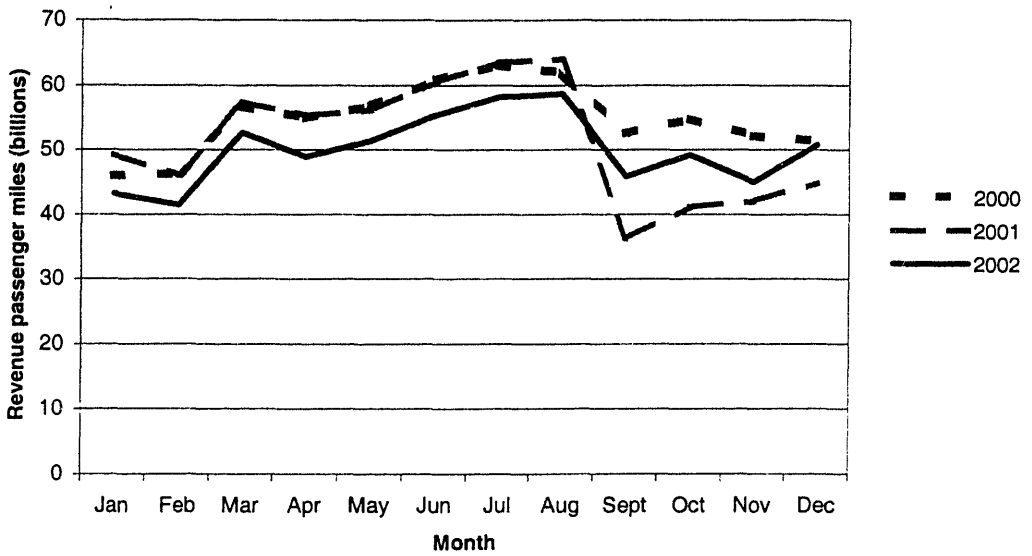


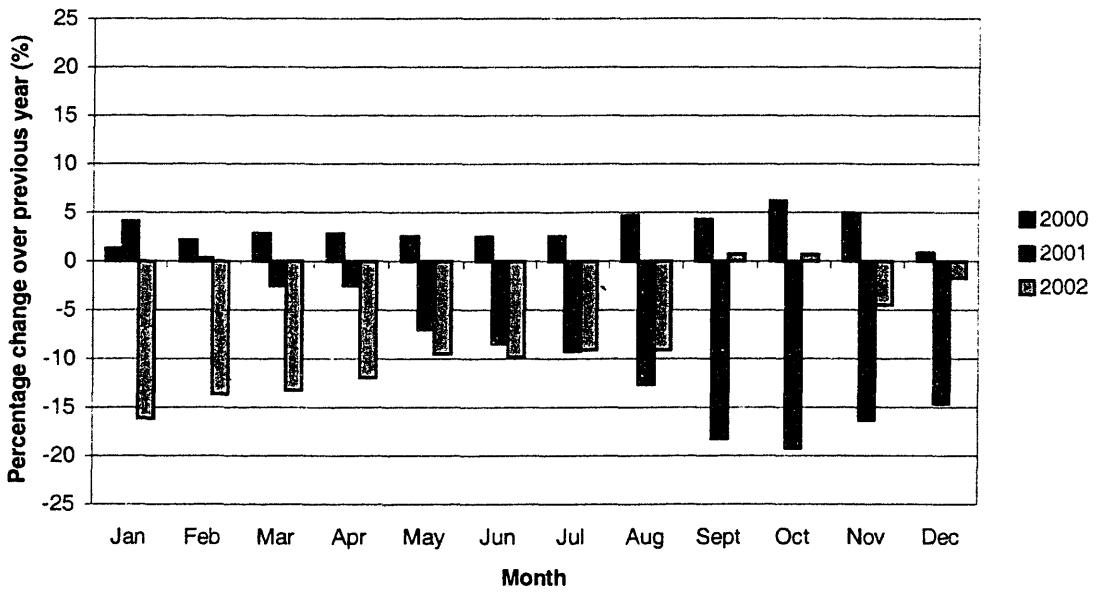
Figure 3.1 U.S. Airline Industry Carrier Net Profit or Loss

Another factor contributing to carrier losses was the decreasing revenue per passenger as shown in Figure 3.3. This chart shows that airfares had been declining from previous years since March 2001, and only continued to fall during 2002. With the decline in fares and the reduction in passenger traffic, total passenger revenue had declined significantly. Fears of further terrorist attacks, the war on terrorism, and the impending war with Iraq and fear of increased fuel costs all retarded traffic recovery.



Source: ATA Monthly Passenger Traffic Report

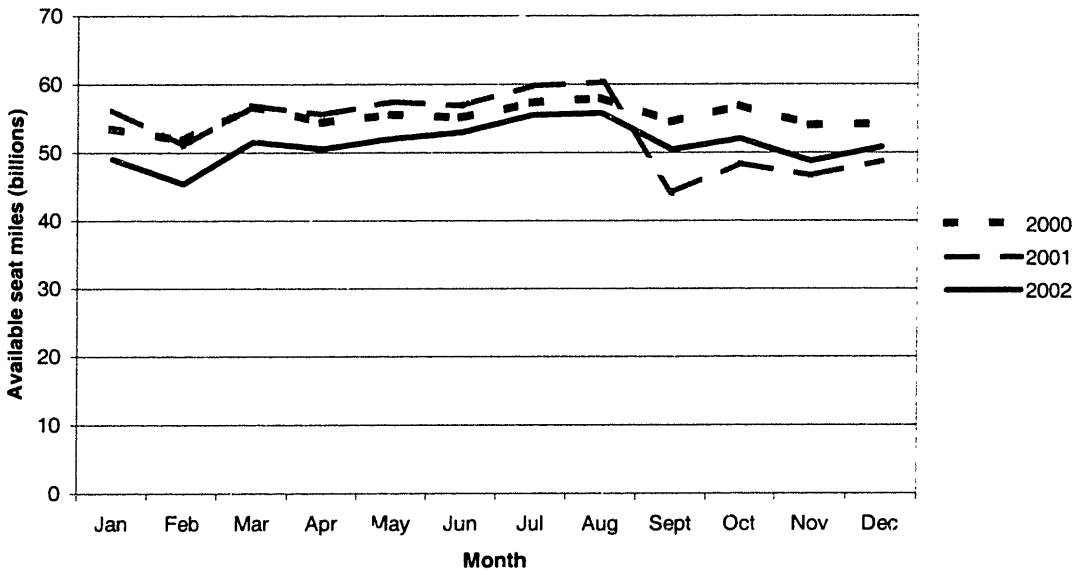
Figure 3.2 U.S. System-wide RPMs



Source: ATA Monthly Passenger Traffic Report, 1000mi domestic trip (all classes), excludes WN

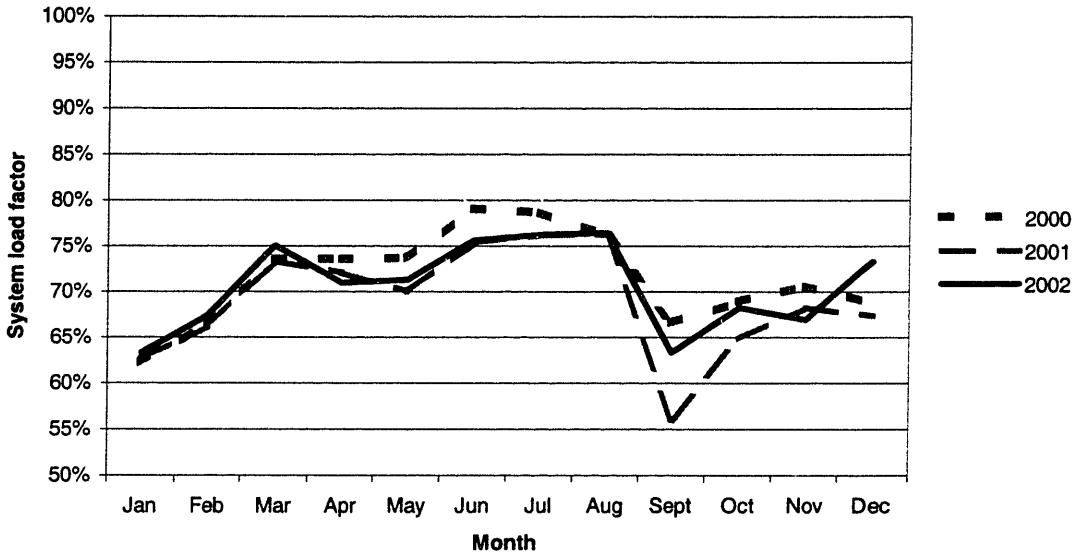
Figure 3.3 Average Passenger Revenue Change over Previous Year

In response to the sharp decline in passenger traffic, the U.S. carriers cut capacity as seen in the chart of available seat miles (ASMs) for 2000, 2001, and 2002 in Figure 3.4. A significant drop in capacity followed the September 11 terrorist attacks, and though capacity again rose, it did not return to 2000 levels. Capacity was cut slightly higher than passenger demand dropped, however, and 2002 load factors increased slightly over 2001 levels as seen in Figure 3.5. This means that even though both traffic and capacity were down, passengers were not necessarily noticing a difference on their flights, which were as full or fuller than before September 11.



Source: ATA Monthly Passenger Traffic Report

Figure 3.4 U.S. System-wide ASMs

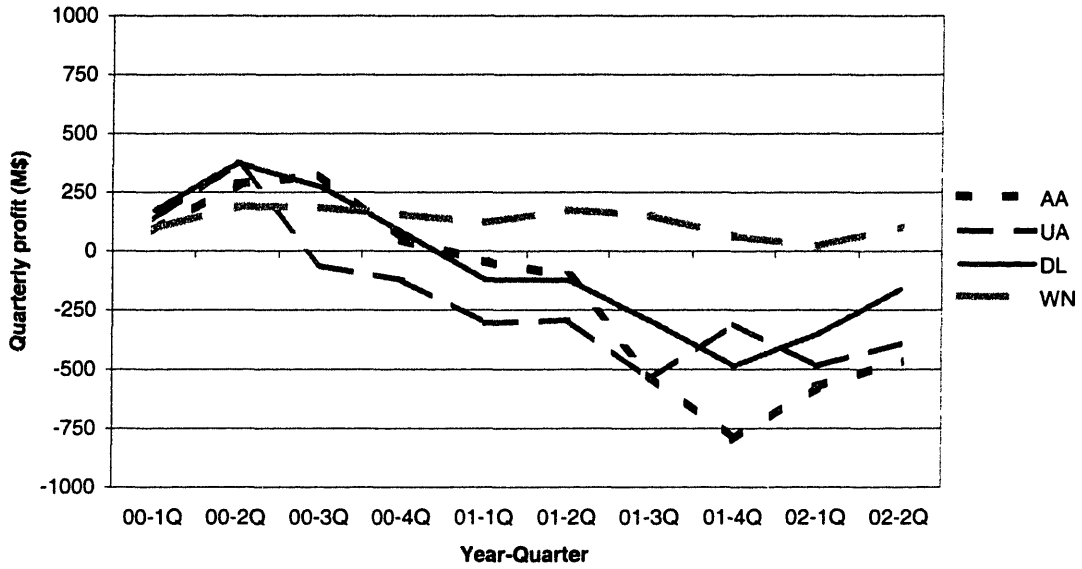


Source: ATA Monthly Passenger Traffic Report

Figure 3.5 U.S. System-wide Load Factor

3.2 Specific Carrier Performance and Response

The previous section presented industry level changes in profit, passenger traffic, but did not address how different carriers were affected by these changes. Figure 3.6 shows the quarterly profit and loss for four of the major U.S. carriers: American Airlines (AA), United Airlines (UA), Delta Airlines (DL), and Southwest Airlines (WN). The data show that traditional network carrier profitability had been deteriorating since after the second quarter of 2000. The terrorist attacks during the third quarter of 2001 only served to exaggerate these losses. Southwest profitability, however was only slightly affected by the downturn in 2000, and decreased a lower percentage after September 11, than did the other carriers.



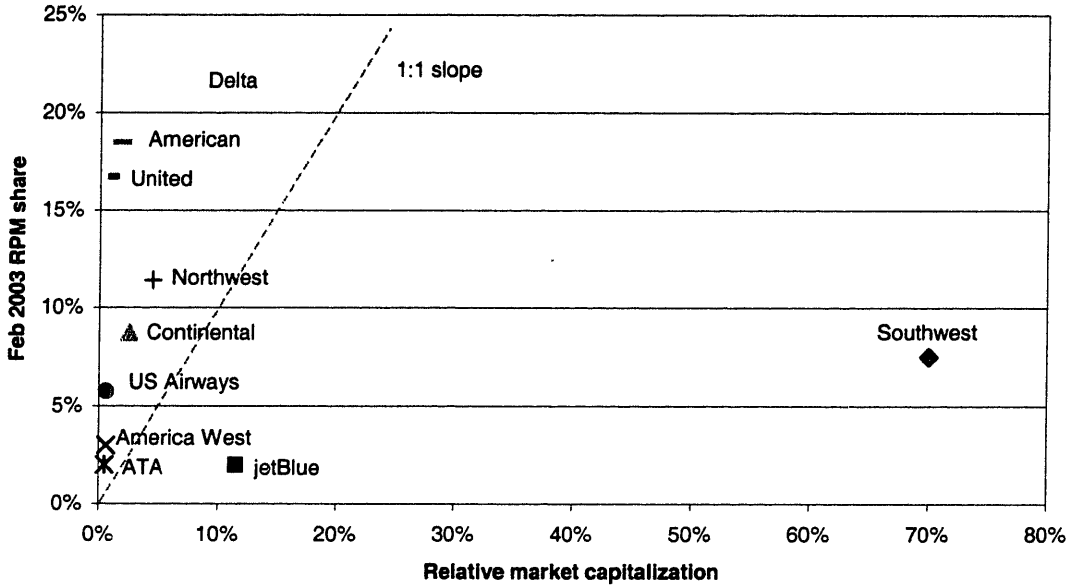
Source: Airline Reports

Figure 3.6 Carrier Profit and Loss, Q1 2000 through Q2 2002

Aside from remaining profitable since early 2000, Southwest's performance has deviated from the traditional hub and spoke carriers in other ways. For example, by the end of September 2001, the majority of U.S. major carriers had announced plans for employee lay-offs. (Ott 2001) As time progressed, many carriers added to those initial estimates as more capacity cuts took place, accompanied by service reductions and new aircraft deferment. (Bond Sept. 2002) At the same time, United and US Airways, and Northwest, Continental, and Delta sought to establish extensive code-share agreements that would effectively broaden those carriers' networks. Meanwhile, a handful of low cost carriers including Air Tran, jetBlue, and Southwest continued to grow their networks, establishing more service, upgrading their fleet, and maintaining their workforces. (Bond Mar. 2002)

At the time of publication of this thesis, US Airways and United Airlines were restructuring under Chapter 11 bankruptcy protection, American Airlines stock was no longer listed on the S&P 500, while the market capitalization of Southwest Airlines and jetBlue Airways far outweighed their share of RPMs. (See Figure 3.7) These data imply

that investors are demanding more than market share from the airlines. Investors are instead rewarding the slow, steady growth and consistent profitability of airlines such as Southwest.



Source: Yahoo! Finance and airline traffic reports

Figure 3.7 RPM Share versus Relative Market Capitalization, All U.S. Majors, Plus ATA and jetBlue

3.3 Additional Pressure for Strategic Change

The data presented in Section 3.1 and Section 3.2 imply, and many industry analysts and investors agree, that the U.S. airline industry is at the dawning of a new era. With revenue per passenger falling, the previously effective profit lever of large network carriers is getting smaller and smaller. An obvious cause of this revenue decline is the price pressure from the low cost carriers. This price pressure will drive change because the low cost carriers can remain profitable at a lower average fare, thus driving carriers with higher costs into bankruptcy.

The lower costs and lower fares of these airlines are not a result of the current crisis, however and therefore are not the only reason that this industry downturn differs from others of the past. Carriers have attempted to recover by using their usual methods

of lay offs and wage concessions to cut costs. Clearly other dynamics in the industry are contributing to this call for permanent, strategic change. Other possible factors include: customer choice and near perfect information, labor relations and labor costs, and decreasing willingness to pay.

3.3.1 Customer choice- near perfect information

Prior to the advent of the Internet, most flight reservations were booked through travel agencies via the Customer Reservation System (CRS), or directly with the airline. In each case, the booking agent controlled the amount of information shared with the customer about flight options. Customers could influence choice by asking for specific travel dates and times, or airlines, but the agent booking the reservation could have conflicting interests due to airline incentives. Flights for a given origin-destination city pair (O-D) appeared ranked by departure time and total elapsed time. Showing up on the "first screen" of the CRS search was an important factor in the number of bookings an airline received, thus influenced market share. Competition for positions on that first screen was fierce and airlines sought to schedule flights with the most popular departure times and the shortest connection times. (McDonald 2002)

As more and more ticket sales started to take place on the Internet, customers gained much more knowledge about their travel options. An individual traveler was more likely to take the time to view multiple screens worth of options. Most importantly, the default on many Internet travel sites is to display itineraries in order of increasing price; therefore, encouraging travelers to place more importance on price rather than time. Finally, the DOT started to require airlines to publish the on-time (within 15 minutes) performance of each scheduled flight, so customers could start to judge for themselves which flight would get them to their destinations at the right time and for the right price.

This shift in power away from the airlines and the travel agents has made it possible for customers to see the competitive landscape more clearly. Further, customers know that they can book flights at the last minute and find the least expensive fare on the

flight, or the most expensive fare, depending on the method of searching for a flight. This added knowledge is causing airlines that were traditionally dependent on business travelers willing to pay high fares to reassess their revenue management strategies recognizing that the near perfect information of customer choice might no longer sustain a strategy of charging a different price to every customer. (Costa et al. 2002, Donoghue 2002)

3.3.2 Labor relations and labor costs

Another element of the current industry providing pressure for permanent structural change is high labor costs. High labor costs can be attributed to at least two different sources: the era of regulated operations, and a history of poor management/labor relations. During the time period that the industry was regulated, the government price setting policies allowed carriers to operate with a cost-plus mentality. The airlines reported their costs, and the government ensured that fares were high enough to cover costs, plus maintain a particular profit margin. Airline management, therefore, often found it easier to avoid confrontation with labor unions than to risk revenue losses due to a strike. (Mola 2003, Chmura 1983)

When the industry was deregulated, there was a spurt of growth as more passengers began to travel. By the time the price competition from airlines such as Southwest began to significantly erode carrier revenues, many of the large network carriers were locked into expensive labor contracts with their various unions. A limiting aspect of many airline labor contracts is the low level of employee productivity written into the contract. (Sprayregen et al. 2002)

The high level of labor costs is not the only problem to over come. Many carriers in the industry are also faced with confrontational rather than cooperative relationships with their union work forces. A history layoffs, pay cuts, and work slowdowns as well as competition for the highest wage among unions at different airlines, have all served to breed mistrust and confrontation between labor and management. These degraded relationships have not only sustained high labor costs, but also have often prevented

airlines from taking advantage of productivity improvements through any means other than lay-offs.

Again, the contrary example in the airlines industry is Southwest Airlines. Southwest has not laid off a single employee and has maintained high levels of employee productivity and cooperative behavior. (Gitell, 2003) As investors and passengers' awareness of Southwest and its business practices increase, the traditional carriers feel pressure to understand and copy elements if its business strategy.

3.3.3 Unwillingness to pay

A third factor that contributed to the need for structural reform in the airline industry was an emerging unwillingness to pay high fares. Part of this unwillingness to pay stemmed from the near perfect information now available to customers as described in Section 3.3.1. Another contributing factor may have been that the cross-industry call for "faster, better, cheaper" reached the air passengers. In the case of air travel, faster would mean not just a faster travel time, but a faster, easier ticketing, check-in, boarding, connection, and customer service experience. Better means less hassle, fewer lines, flexible rules, extensive choice, and reliable service. Finally, cheaper means that the airlines need to do it all, do it well, do it for less.

The call for cheaper air fares has come not only for the traveler paying for his or her own ticket, but also from companies who pay the bill for business travelers. The Lean movement has taken hold in many in many industries, driven by customers' demands and competition from lower cost competitors. As a result, companies are struggling to find ways to cut costs in order to provide faster, better, cheaper products and services to their own customers. (Jordan and Michel 2001) Part of cutting costs and improving processes to increase productivity is the elimination of non-value added work, activities, and expenses. (Hammer 2001)

Increased company cost consciousness has had a number of effects on business travel and business fares paid to airlines. First, large companies have used their bargaining power to negotiate lower corporate rates and fewer scheduling restrictions.

Alternatively, companies are encouraging employees to limit their trips, and/or book lower fares with restrictions. Finally, more companies and employees are making use of travel alternatives such as video conferencing, teleconferencing, and various information technology tools. (Costa et al. 2002, Velocci 2002, Sprayregen 2002)

These pressures for price reduction, cost reduction, and productivity improvements all lead to the need for significant change in the industry. While Southwest Airlines and some other low cost carriers are well prepared to compete in this changed environment, the traditional hub and spoke carriers are not. As US Airways and United Airlines restructure themselves under Chapter 11 bankruptcy protection, and American Airlines struggles to make changes outside of bankruptcy court, all three will need to make lasting and dramatic changes. For US Air and United, changes come in the form of contract renegotiations, and wage concessions. Thus far, only American has taken a significant step away from business as usual in the form of depeaking its schedule at Chicago O'Hare International Airport.

3.4 American Airline's Hub Paradigm Shift

As mentioned in Section 2.2, one of the mantras of the traditional hub and spoke network schedule is the peaking of flights in and out of the hub airport. Motivated by the desire to offer customers the shortest connection times and depart at popular times, thus earning a spot on the first CRS screen, carriers such as American Airlines had very peaked schedules. Figure 3.8 depicts AA's scheduled mainline arrivals and departures over fifteen minute intervals[1] out of O'Hare International Airport (ORD) for March of 2002.

[1] It should be noted that dividing flight departures or arrivals into 15-minute intervals can be misleading if all flights are in reality scheduled near one end of the interval.

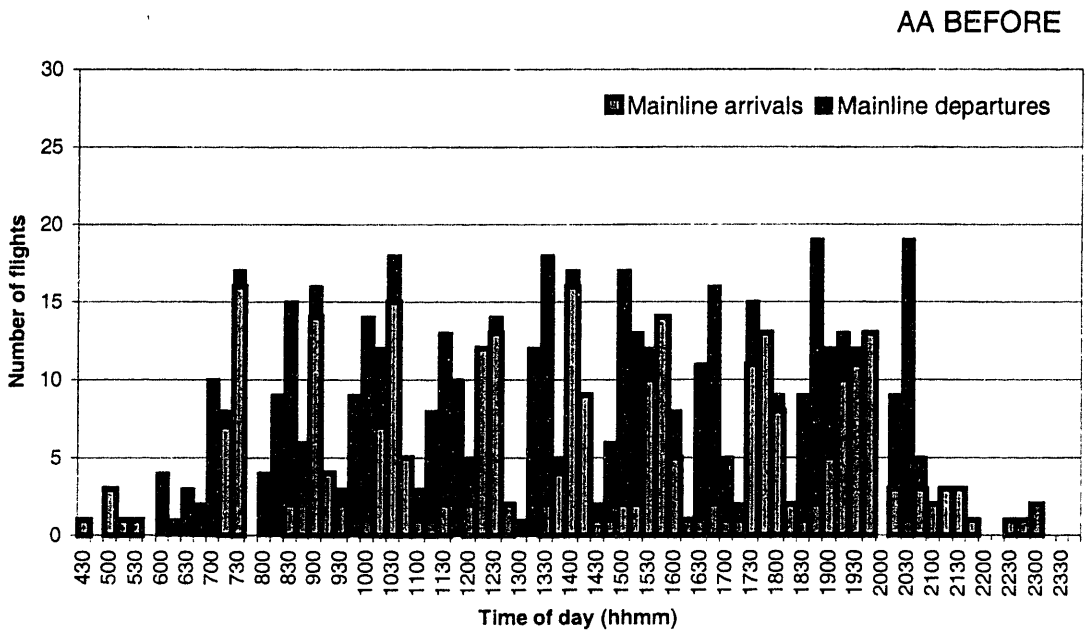


Figure 3.8 American Airlines Scheduled Mainline Arrivals and Departures in 15-minute Intervals at ORD, March 2002

As a result of the competitive effects of low cost carriers such as Southwest Airlines, as well as the other pressures for strategic change highlighted in Section 3.3, American Airlines decided to experiment with depeaked banks at O'Hare. In April 2002, American moved toward a more continuous flow of arrivals and departures as depicted in Figure 3.9 While a depeaked schedule runs the risk of reduced revenue potential, a steady flow of departures and arrivals should have a favorable effect on operational costs. Without the extreme peaks and valleys of its previous schedule, AA has the potential to improve employee productivity and facility and equipment utilization. If these potential cost reductions outweigh potential revenue losses, American has made an important step toward restructuring itself to better compete in this changed industry. Additionally, American has shown investors that it is willing to change and more importantly, to try and become more like Southwest.

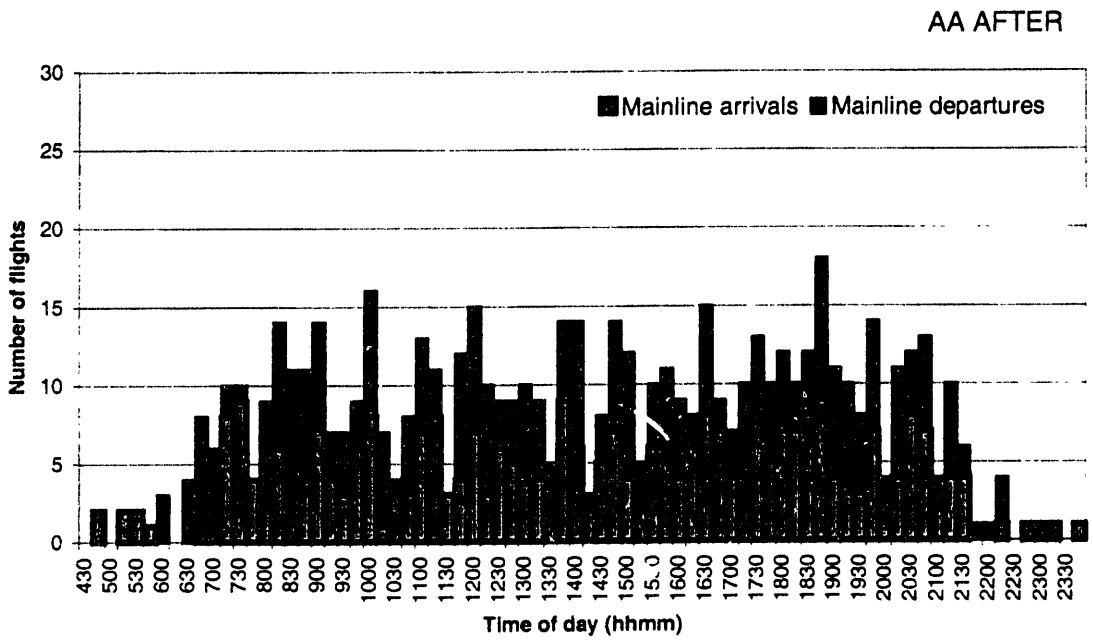


Figure 3.9 American Airlines Scheduled Mainline Arrivals and Departures in 15-minute Intervals at ORD, April 2002

4 ANALYSIS METHODOLOGY

The analysis of American Airlines's decision to depeak its flight schedule at O'Hare includes: a high level look at the schedule changes compared with previous AA schedules as well as other airline hub schedules; an assessment of the effects of the change on degree of peaking and connectivity including measurements such as average connection time, average number of possible connections per flight arriving into the hub, and discussion of network effects; an assessment of actual schedule performance through the evaluation of market share data and DOT reported reliability data. Prior to performing any analysis, however, one must attempt to understand the limitations of the proposed analysis and available sources of data.

4.1 Analysis uncertainties

Isolating the effects of a schedule change is extremely challenging. The more cities an airline serves, the more complicated the network, and the more complexity in the system. The more complex a system, the less clear the cause and effect relationships of specific changes. One must also take into account, or at least consider, a variety of additional changes and effects that might influence the analysis such as: seasonality, one-time shocks or changes, industry trends, and iterative changes.

Seasonal effects can occur in both passenger demand and traffic patterns. During winter months, for example, warm, sunny destinations maintain a higher level of leisure traffic than other destinations, while overall demand increases during summer months with more vacation travel. Changing seasons also mean changing weather patterns. Changes in the weather can have adverse effects on reliability measures such as on-time departures and arrivals. There are also network effects of such delays: a severe thunderstorm in Chicago can cause a flight delay out of Los Angeles. Likewise, a late arrival at Boston from Chicago can in turn lead to a late departure from Boston, thus causing a cascade of delays. Finally, seasonal changes in the jet stream cause airlines to adjust their expected flight times to the wind in order to more accurately predict the arrival of flights at their destinations.

One-time industry-wide or carrier specific shocks can come in a number of forms. The most obvious of the recent past was the terrorist attacks of September 11, 2001, causing an unprecedented depression of air travel, as well as sharp declines in industry wide capacity. Another such shock was American Airlines's acquisition of significant assets from the estate of TWA in early 2001. Through this transaction, American not only gained additional fleet and personnel, but also gained an additional hub airport in St. Louis. The addition of a new centrally located hub increases the number of flight options for connecting passengers.

The same industry trends mentioned in Section 3.1 can also influence the results of an analysis. Decreasing demand, capacity, and revenue as well as changes in customer preference and buying power (referred to in Sections 3.3.1 and 3.3.3) can all influence carrier market share. Increasing load factors can lead to more frequent departure delays as it takes longer to board a full flight than it takes to board one that is half empty. Fewer departures and arrivals at specific airports such as O'Hare can decrease air and runway traffic, thus improving on-time performance for all carriers at that airport.

Perhaps the most difficult changes to account for in assessing American's decision to depeak its schedule at O'Hare are the small iterations the airline and its competitors make to their schedules and operations. Such changes include block time adjustments, turn time changes, flight cancellations, boarding procedure changes, arrival and departure measurements. Many of these frequent and difficult to track changes influence the consistency of DOT reliability reporting. Consider, the factors involved in the evaluation of the on-time performance of a flight: scheduled departure and arrival times, and actual departure and arrival times. Increasing the estimated block time (gate to gate time) and holding all else equal can improve the reliability measurements. Completing the boarding process earlier and leaving the gate before the scheduled departure time might result in a similar performance improvement. These types of changes in scheduling and operations policies and procedures clearly complicate the assessment of true performance.

4.2 Data set descriptions

In order to address some of the uncertainties addressed above, comparisons performance are made for two different sets of times. First, comparisons are made with data summarized at the month level for March and April of 2002. This time period represents the initial change from the traditionally peaked schedule at O'Hare to the rolling hub. Comparing data from two consecutive months has the advantage of the industry being relatively stable with respect to the previously mentioned trends in revenue, capacity, and traffic, as well as after the terrorist attacks of September 11, 2001. Also, both months are after the integration of TWA fleet, personnel, and routes, hopefully minimizing any network effects of the merger.

To address some of the seasonality issues, data from July of 2001 and July of 2002 also are compared where appropriate. The month of July was selected because it usually represents peak demand, and because it allows a few months for American to have made minor adjustments to its new schedule philosophy, as well as time for passengers to react to advertised changes in schedule structure while choosing flights. Finally, having a comparison of pre and post September 11, 2001 data might help to discriminate between effects of system-wide changes and effects of schedule changes.

Three main sources of data were used for the analysis: Official Airline Guide (OAG), Department of Transportation (DOT), and Computer Reservation System (CRS). The OAG data contain airline schedule information as reported by the individual carriers and include details such as scheduled departure and arrival time, aircraft type, scheduled day of week. DOT data sources were used for reliability data such as on-time performance, delay minutes, and taxi times. Finally, CRS data were used to estimate carrier market share.

The majority of data manipulations and calculations were performed using existing and modified SAS programs at United Airlines. A significant portion of the analysis required the evaluation of connecting itineraries. As the OAG contains only scheduled flight leg information, a methodology must be adopted to identify possible connecting flights, and determine itinerary viability. The chosen methodology can

greatly bias any analysis performed. United Airlines created the itinerary sets used for this analysis. A brief description of the rules most likely to bias this analysis can be found in Appendix A.

In order to simplify the analysis, the author chose to further limit the set of itineraries. First, unless otherwise noted, only domestic mainline and commuter flights are considered. Second only flights scheduled to operate on a daily basis were considered. Additionally, the set of itineraries includes only direct connections, single stops, and single connections. Itineraries requiring more than one connection were not considered- primarily to reduce the data set size, but also because the relevance of the schedule change for double connecting passengers is presumably less than for single connecting passengers. Finally, unless otherwise noted, the analysis is performed with sets of itineraries that include only the first best connection for each city pair. In brief, this means that for any given arriving flight, only one connection will be build for any given final destination. This itinerary generation rule is further described in Appendix A.

The discussion in this section was intended to prepare the reader for the presentation and discussion of the analysis, rather than to address thoroughly each concern. More specifics about the data sets and their limitations will be addressed as data are presented. The remaining sections of this chapter will readdress different points raised in this section and discuss them in the context of the presented data and analysis.

5 ANALYSIS OF AMERICAN AIRLINES'S DEPEAKED SCHEDULE AT O'HARE

5.1 Overview of Schedule Changes

Section 3.4 introduced the changes that American Airlines made to its schedule in April 2002. Figure 5.1 shows a direct comparison of the American Airlines domestic mainline scheduled departures from O'Hare International Airport in March and April 2002. In this depiction, one can see that American's new scheduling philosophy essentially cut off the tops of the nine previously distinct peaks and redistributed flights into the surrounding time intervals, thus flattening out the banks rather than eliminating them altogether. As a result, the maximum number of departures per 15-minute interval has changed from 19 in March 2002, to 10 in April 2002. Figure B.1 in Appendix B shows a similar trend for the comparison of the July 2001 and July 2002 departure schedules, with the maximum number of departures per 15-minute interval changing from 18 in July 2001 to 10 in July 2002.

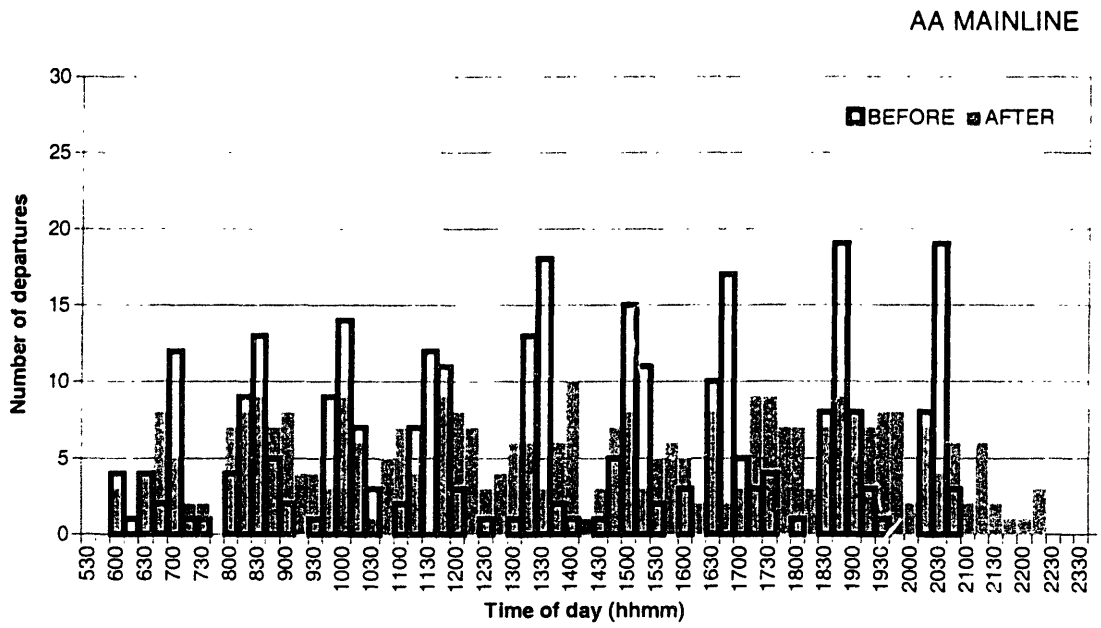


Figure 5.1 Comparison of Domestic Mainline Scheduled Departures per 15-minute Interval, American Airlines at ORD, March and April 2002

Figure 5.2 and Figure 5.3 show how the schedules of American domestic commuter and international flights changed. The commuter flight schedule has also been slightly depeaked, with the maximum number of flights scheduled per fifteen-minute interval dropping from 9 to 5. The changes in the distribution of international departures are likely attributable to seasonal schedule changes rather than the depeaking decision. Figure B.2 and Figure B.3 in Appendix B confirm that the depeaking in April 2002 was isolated to American's O'Hare hub. Both the American Dallas-Fort Worth and St. Louis hubs have very peaked schedules with distinct arrival and departure banks as well as periods of little to no flight activity.

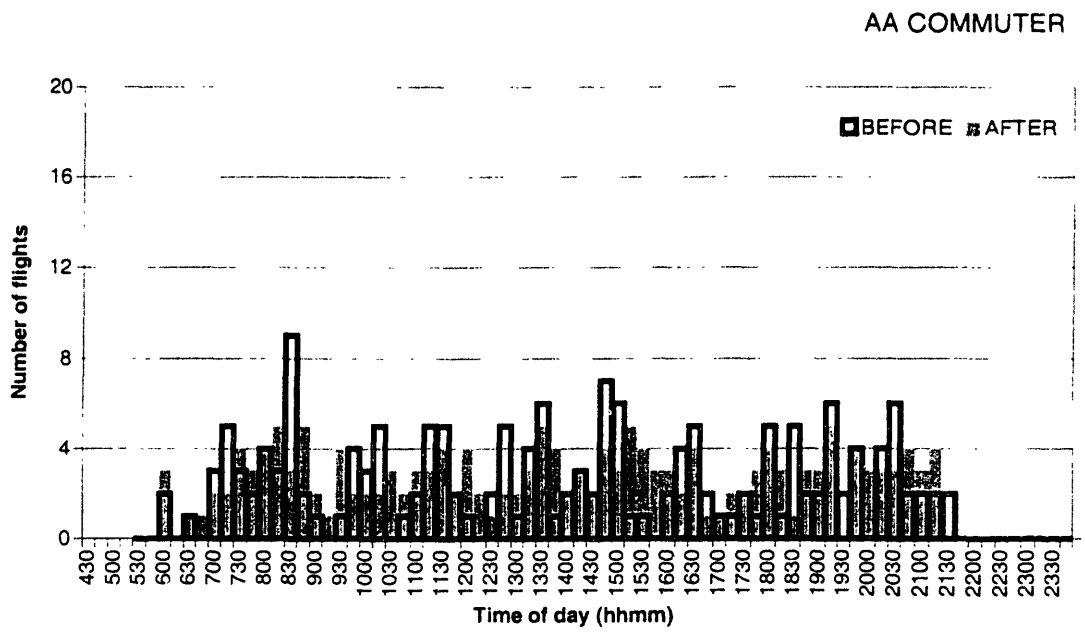


Figure 5.2 Comparison of Domestic Commuter Scheduled Departures per 15-minute Interval, American Airlines at ORD, March and April 2002

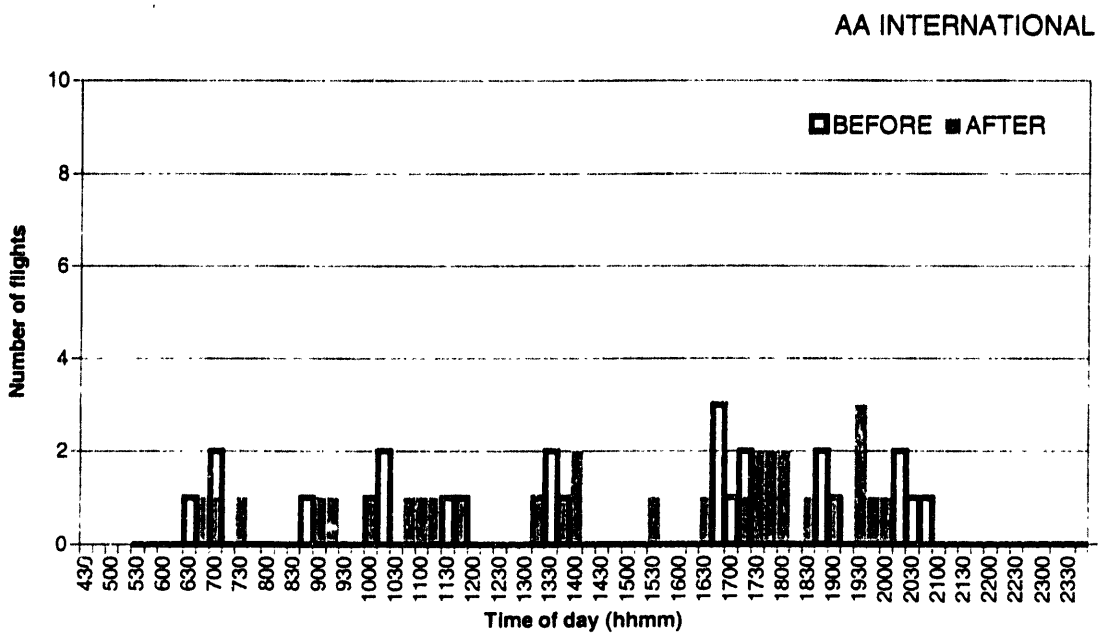


Figure 5.3 Comparison of International Scheduled Departures per 15-minute Interval, American Airlines at ORD, March and April 2002

5.1.1 Comparison of American Airlines's schedule with other airline hubs

Figure 5.4 and Figure 5.5 show the April 2002 departure schedules of United Airlines at O'Hare and Southwest Airlines at Phoenix, respectively. United's schedule has strongly peaked banks during the first half of the day, moving toward more continuous departures in mid-afternoon, returning to more traditional, yet tightly packed banks as the day ends. United's flight schedule at Denver does not show the same depeaking in the afternoon, instead maintaining distinct banks with distinct arrival and departure components throughout the entire day. For details, see Figure B.4 in Appendix B.

Southwest Airlines's schedule at Phoenix as previously shown in Section 2.3 shows a much more steady flow of departures and arrivals. While the total number of daily flights is significantly lower than American's, American's new scheduling strategy clearly emulates Southwest's. Figure B.5 in Appendix B shows that Southwest uses a similar scheduling philosophy at Chicago Midway Airport.

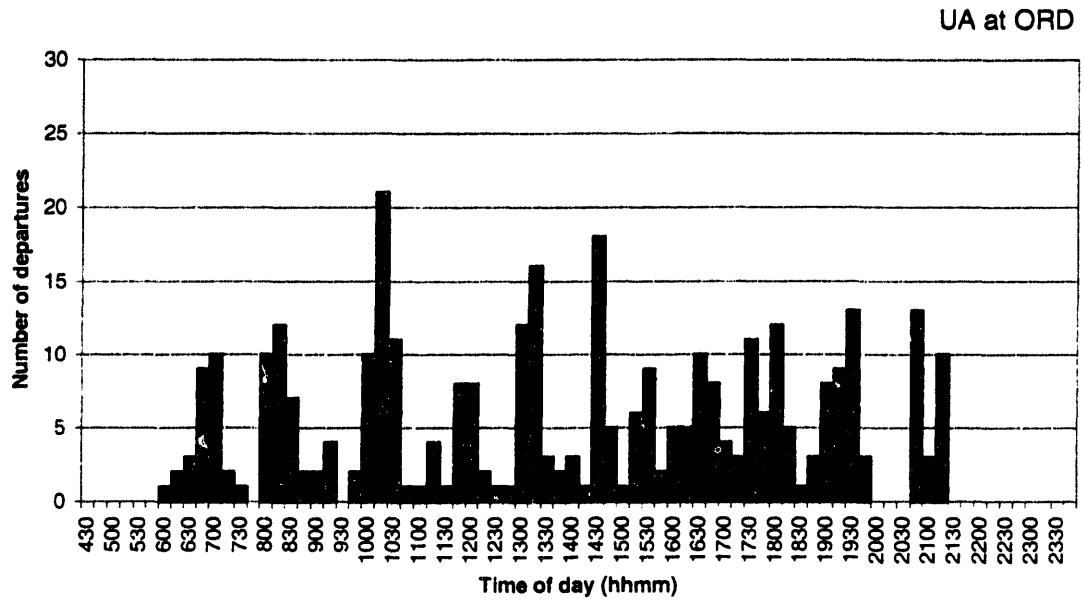


Figure 5.4 United Airlines at ORD Scheduled Departures in 15-minute Intervals, April 2002

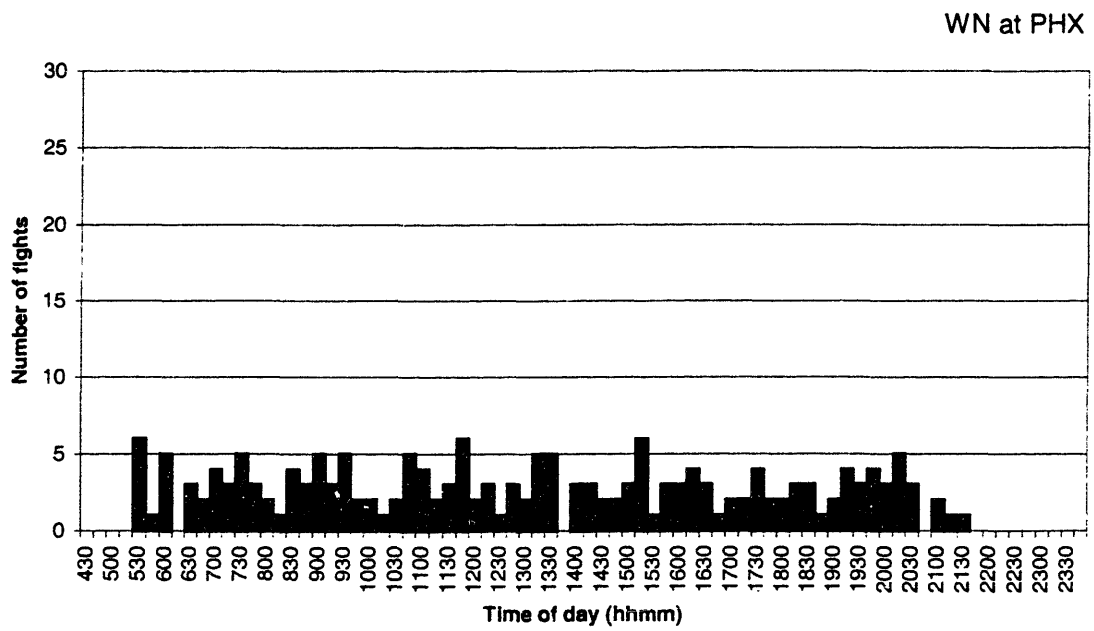


Figure 5.5 Southwest Airlines at PHX Scheduled Departures in 15-minute Intervals, April 2002

5.1.2 Comparison of degree of peaking

The figures described in Section 5.1.1 provide a quick visual description of the differences in schedule structure at the various hub airports. The fact that the different airlines and hubs operate different numbers of daily flights; however, make it more difficult to compare the "degree of peaking" of a given set of schedules. Figure 5.6 through Figure 5.9 show the flights scheduled per 15-minute interval as a percentage of total departures for AA at ORD in March 2002, AA at ORD in April 2002, UA at ORD in April 2002, and WN at PHX in April 2002. For a more direct carrier-to-carrier comparison, only the time interval from 6AM to 10PM was considered. While the trends in general are the same as were seen in the non-normalized data, it is now possible to make direct comparisons between American Airlines or United Airlines and Southwest Airlines.

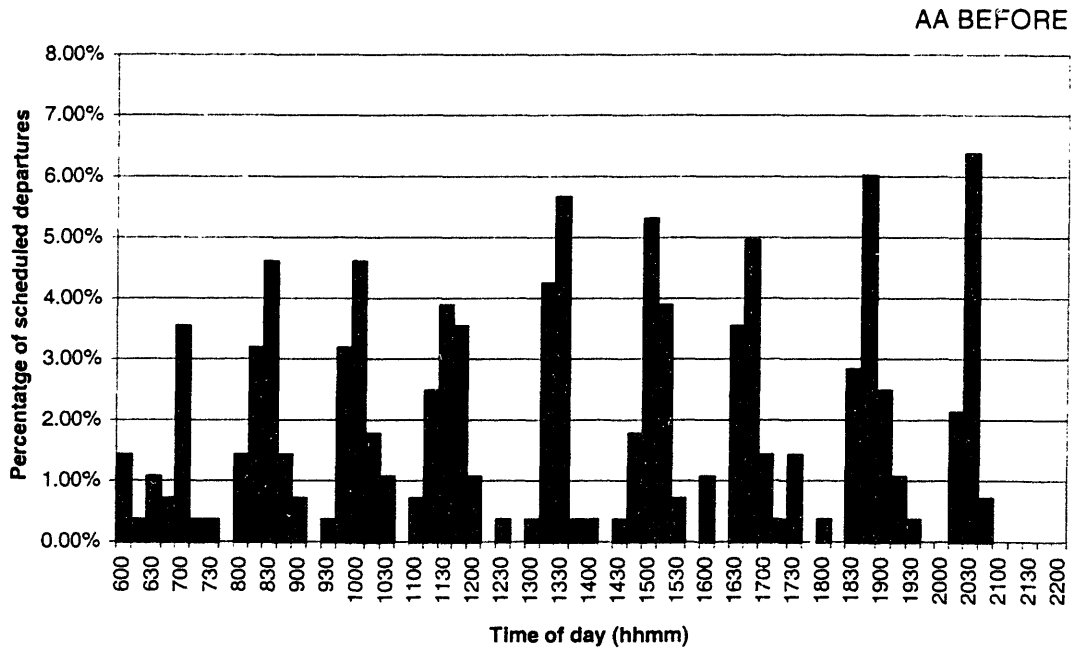


Figure 5.6 American Airlines at ORD Scheduled Departures in 15-Minute Intervals, March 2002, Normalized by Number of Flights

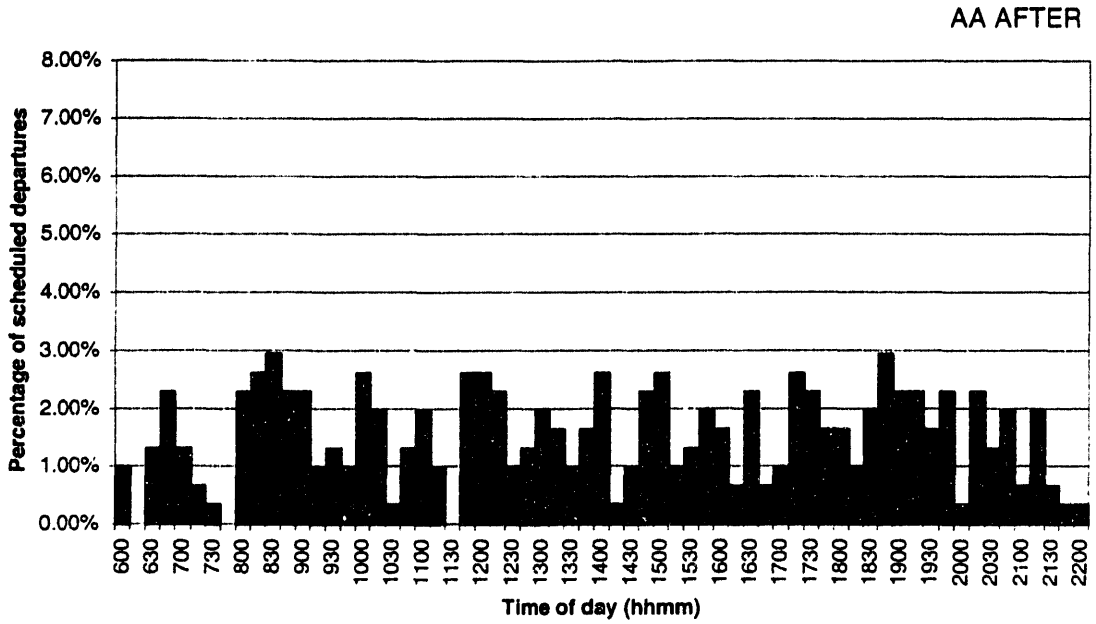


Figure 5.7 American Airlines at ORD Scheduled Departures in 15-Minute Intervals, April 2002, Normalized by Number of Flights

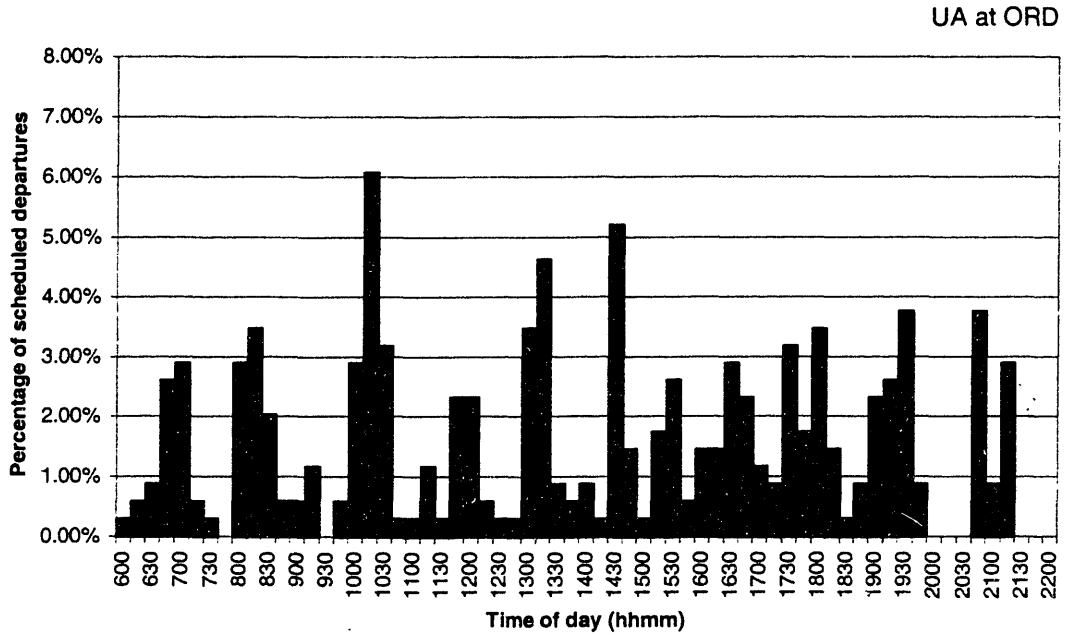


Figure 5.8 United Airlines at ORD Scheduled Departures in 15-minute Intervals, April 2002, Normalized by Number of Flights

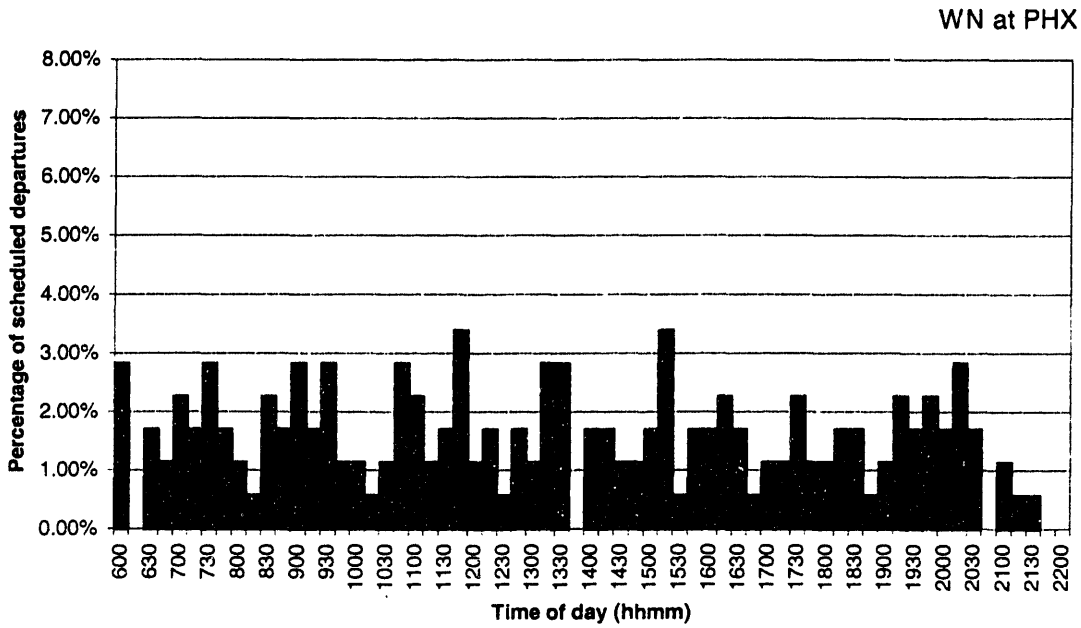


Figure 5.9 Southwest Airlines at PHX Scheduled Departures in 15-minute Intervals, April 2002, Normalized by Number of Flights

Table 5-1 lists the mean and standard deviation for the percentage of daily departures scheduled per 15-minute interval for the airline hub schedules depicted above, as well as for AA at DFW in April 2002, UA at DEN in April 2002, and WN at MDW in April 2002. (The plots for these additional hubs can be viewed in Figures B6 through B8 in Appendix B.) If the flights were evenly distributed throughout the day, then the mean would be 1.45% of departures scheduled per 15-minute interval and the standard deviation would be 0%. Comparing the means and standard deviations with the visual charts above, one can see that in cases where the standard deviation is greater than the mean, the schedule has a lot of peaks. If the standard deviation is less than the mean, then flights are more evenly scheduled throughout the day.

The standard deviation measurements show a decrease for American's schedules at O'Hare from 1.79% in March 2002 to 0.82% in April 2002. Now, the variation in American's schedule at O'Hare is much closer to Southwest's at Phoenix which was 0.85% in April 2002. Comparing American in March with United in April, one can see

that United's schedule was already less peaked (1.42%) at O'Hare than was American's schedule (1.79%). Finally, the schedules for American at Dallas-Fort Worth and United at Denver have the greatest standard deviations of the group at 2.31% and 2.14% respectively.

Table 5-1 Mean and Standard Deviation of Percentage of Total Flights Scheduled per 15-minute Interval

	AA-ORD Mar-02	AA-ORD Apr-02	AA-DFW Apr-02	UA-ORD Apr-02	UA-DEN Apr-02	WN-PHX Apr-02	WN-MDW Apr-02
Mean percentage departures per interval	1.54%	1.52%	1.54%	1.54%	1.54%	1.54%	1.54%
Departure STD	1.79%	0.82%	2.31%	1.42%	2.14%	0.85%	1.17%
Number of scheduled departures	283	307	424	346	244	177	125

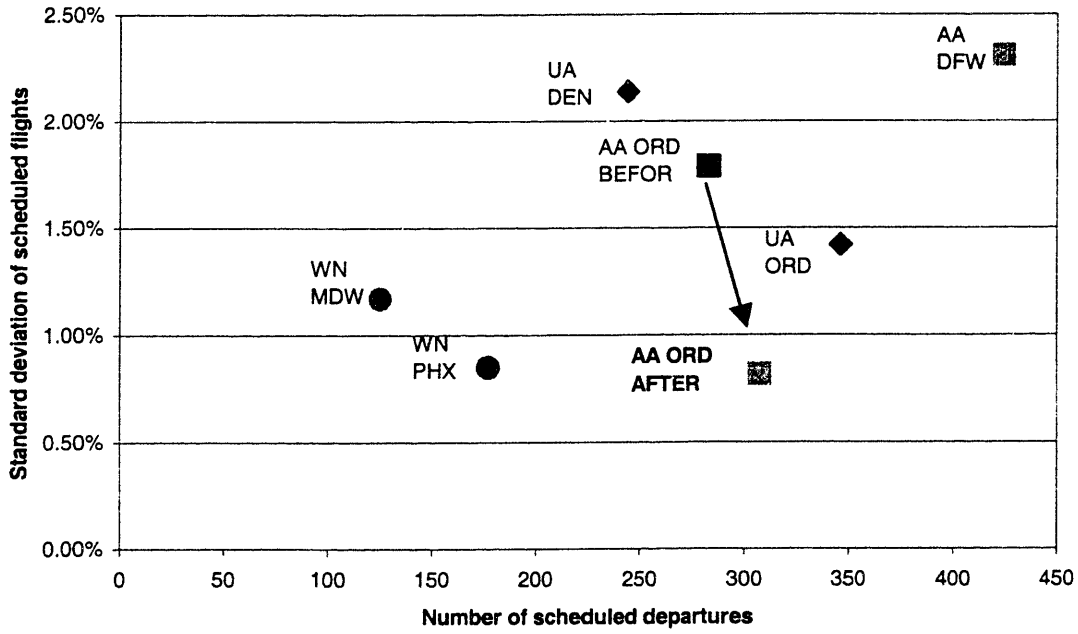


Figure 5.10 Degree of Peaking versus Number of Scheduled Departures

Figure 5.10 is a graphical representation of the degree of peaking, or standard deviation of scheduled departures, versus the number of departures scheduled over the selected time interval. The figure again shows that American's degree of peaking decreased while the total number of scheduled departures slightly increased. It also shows that American's schedule at DFW not only has a significantly greater number of departures, but also has a high degree of peaking than the other hubs represented.

5.2 Network Effects of Schedule Change

For the hub and spoke carriers, an important aspect of the flight schedule at a hub is its degree of connectivity. Figure 5.11 is a notional representation of where various airline hub airport schedules fall on the range of low to high degrees of connectivity and peaking. Hubs included for comparison are American Airlines at O'Hare (AA ORD) both before (old) and after (new) the schedule change, United Airlines at O'Hare (UA ORD), Delta Airlines at Atlanta (DL ATL), Northwest Airlines at Memphis (NW MEM), Continental Airlines at Newark (CO EWR), and Southwest Airlines at Phoenix (WN PHX). The location for the degree of connectivity was loosely based on the number of daily flights at that hub and the number of possible connections per arrival. The location for the degree of peaking was based on the comparison of mean and standard deviation of percentage of total flights scheduled per 15-minute interval as described in Section 5.1.2.

While more exact positions in this space might be assigned, the relative positions of the various hubs are enough for understanding the implication of the change that American has made at O'Hare. Prior to April 2002, American Airlines's schedule at ORD had both a high degree of connectivity and high degree of peaking. After the change, one could argue that the degree of connectivity might have decreased only slightly, while the degree of peaking decreased significantly. One could also argue that American Airlines has entered a new competitive space, being the only airline to operate a hub schedule with both a high degree of connectivity and a low degree of peaking.

If one believes that a high degree of peaking is a proxy for operational complexity, and thus cost, one could argue that airlines operating in the upper right

quadrant offer customers a large number of convenient connections, but at a high cost. On the other hand, carriers operating in the lower right quadrant maintain lower costs, but do not offer as many flight connections. While this framework makes it easy to compare the connectivity of a schedule at a specific airport, it is not as useful for understanding the effects on the connectivity of an airline's entire network. The framework also does not distinguish what characteristics of connectivity have changed. The following sections propose a few methods for analyzing the change in connectivity of American's schedule at both a network level and a hub level and attempt to identify the specific changes in connectivity at the hub.

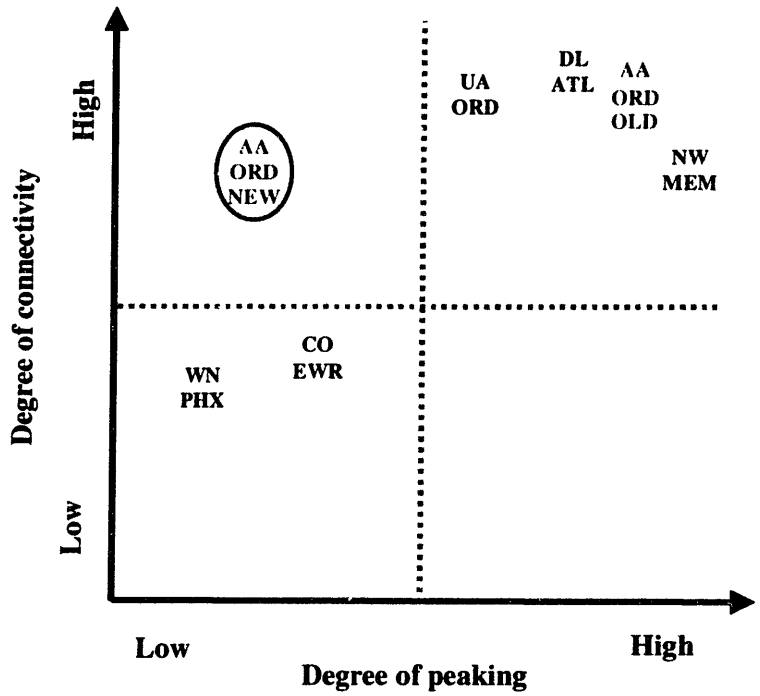


Figure 5.11 Notional Graphic of Carrier Hub Schedule Degree of Connectivity versus Degree of Peaking
Source: Chris Spidle at United Airlines

5.2.1 Network connectivity

Perhaps the simplest measure of entire network connectivity is the comparison of how many origin destination (OD) pairs a given airline serves. Such a calculation considers

both how many different cities an airline serves as well as how many of those cities are connected with each other. An alternative measure is to consider instead the number of possible itineraries a customer can book on a given airline on a given day and normalize that number by the total number of daily flights the airline operates. This measure would consider not only the number of cities that are connected, but also the path and frequency of connection. The ratio of possible itineraries to number of daily departures could also be thought of as the average number of possible paths a passenger could be taking for any given number of enplanements.

Table 5-2 contains the number of possible itineraries per departure, the number directional OD pairs, and the number of OD pairs per departure for the major U.S. airlines (plus jetBlue) for both March and April of 2002. The data are ordered by decreasing number of possible itineraries per departure in April 2002. The number of possible itineraries represents all direct flights, single stops, and valid single first best connections as defined in Appendix A. Comparing the two measures, one immediately sees that the rank of a number of the airlines would be different if the table was ordered instead by the number of directional OD pairs. For example, America West would be ranked lower, and Delta and Southwest would be ranked higher. As expected, there is a correlation between the number of OD pairs and the itineraries per departure, as confirmed by the similar directional change in the two measures from March to April.

The measurement of itineraries per departure suggests that American Airlines's network connectivity dropped slightly between March and April 2002. It is not clear, however if this change in connectivity was a result of depeaking at O'Hare or a result of a reduced number of OD pairs. To try and better understand how the changes at ORD may have affected the entire network, the next section will examine connectivity at the hub level.

Table 5-2 Measures of Network-level Connectivity

		Possible itineraries per departure		Directional OD pairs	
	Airline	Mar-02	Apr-02	Mar-02	Apr-02
CO	Continental	32.5	32.7	17704	17569
NW	Northwest	24.2	24.0	17876	17431
DL	Delta	21.0	21.5	19055	19163
HP	Am West	16.9	18.7	4780	4974
AA	American	18.9	18.5	16164	15265
UA	United	18.0	18.0	14690	14791
US	US Air	17.1	17.0	12033	12012
F9	Frontier	11.8	12.4	927	1035
AS	Alaska	8.7	9.1	2513	2814
FL	AirTran	5.8	5.8	763	779
TZ	ATA	5.6	5.5	557	558
WN	Southwest	4.9	4.9	2330	2322
B6	jetBlue	2.5	2.5	120	120

5.2.2 Change in hub connectivity

Similar to the method applied in Section 5.2.1 for network level connectivity, one measure of how the connectivity of American's schedule has changed locally at O'Hare would be to calculate the number of possible itineraries that pass though O'Hare. Table 5-3 shows the number of possible AA connecting itineraries passing through ORD and the number of scheduled daily departures from ORD for March and April 2002. The total number of departures includes both mainline and commuter flights because the possible itineraries include these flights as well. Even though both the number of departures and the number of connecting itineraries increased in April, the ratio of the two actually decreased. This discrepancy implies a slight decrease in connectivity at the hub from March to April when American depeaked its flight schedule.

Table 5-3 Measures of Hub-level Connectivity, AA at ORD

	Number of possible connecting itineraries through ORD	Number of daily departures from ORD	Itineraries per departure
March 2002	16,168	450	35.9
April 2002	16,897	478	35.3

Another element of connectivity at a hub level to consider is the number of possible connections a passenger can make after arriving on an incoming flight. Figure 5.12 shows two histograms comparing distribution of the number of possible connections for each arriving flight for American Airlines at O'Hare in March and April 2002. The distributions imply a slight decrease in the number of connections a passenger can make on any given American flight into O'Hare. The average number of connections per arrival was 36 in March 2002 and 34 in April 2002. These data are summarized in Table 5-4.

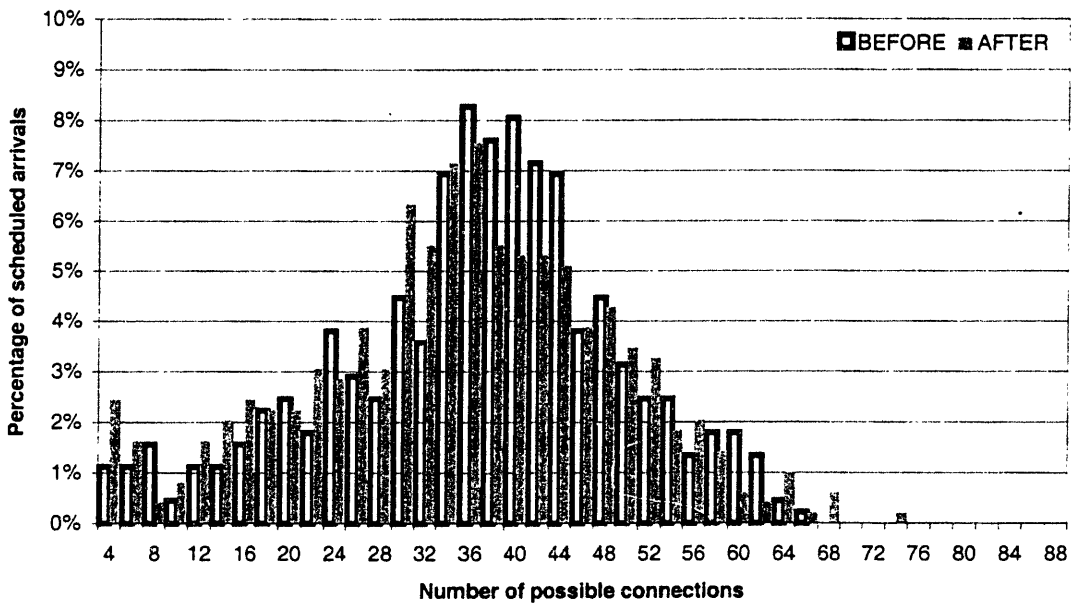


Figure 5.12 Histogram of Number of Connections per Arriving Flight, AA at ORD

Table 5-4 Number of Possible Connections per Arriving Flight, AA and UA at ORD

	AA at ORD		UA at ORD	
	Number of daily scheduled arrivals	Average possible connections per arrival	Number of daily scheduled arrivals	Average possible connections per arrival
March 2002	450	36	529	42
April 2002	478	34	533	41

Figure 5.13 shows the comparison of distribution of United Airlines arrivals by the possible number of connections for March and April 2002. Again, these data include both mainline and commuter arrivals and connecting itineraries. In general, a passenger arriving on a United flight at O'Hare will have more options for connections than an American passenger. The average number of connections per arrival for United at ORD was 42 in March 2002 and 41 in April 2002. These data are also summarized in Table 5-4.

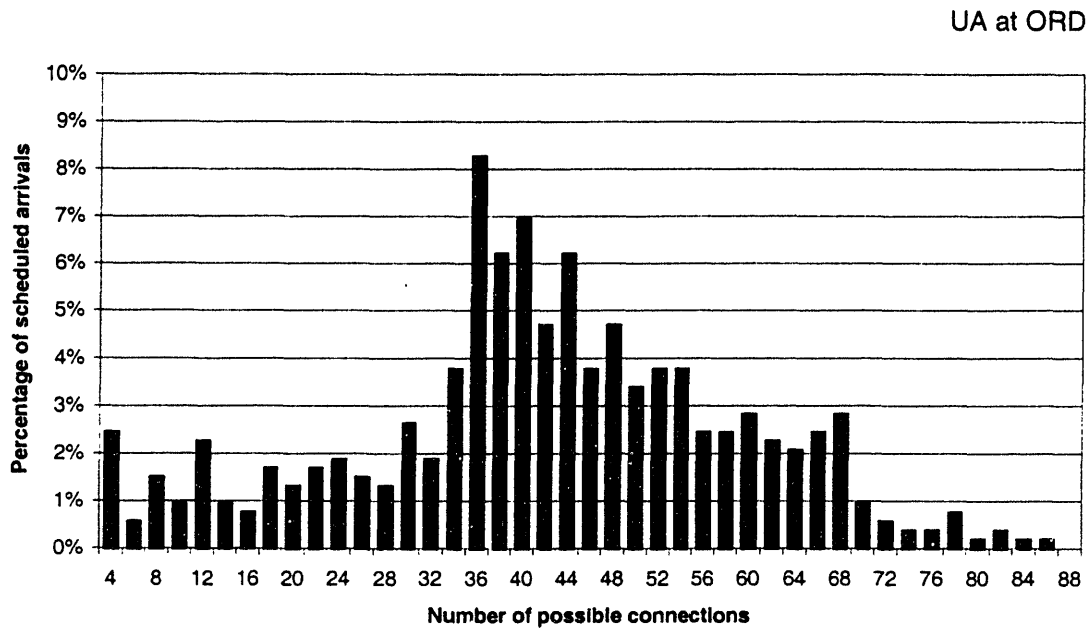


Figure 5.13 Histogram of Number of Connections per Arriving Flight, UA at ORD

Figure 5.14 shows the average number of possible connections per arriving flight versus the degree of peaking as defined in Section 5.1.2. These data confirm the hypothesis that American has decreased its degree of peaking at O'Hare with minimal impact on the connectivity of the hub. Of course, the number of connections per arrival represents only one measure of hub connectivity. In addition to how many connections are offered, a more comprehensive measurement of connectivity might also consider the connection time.

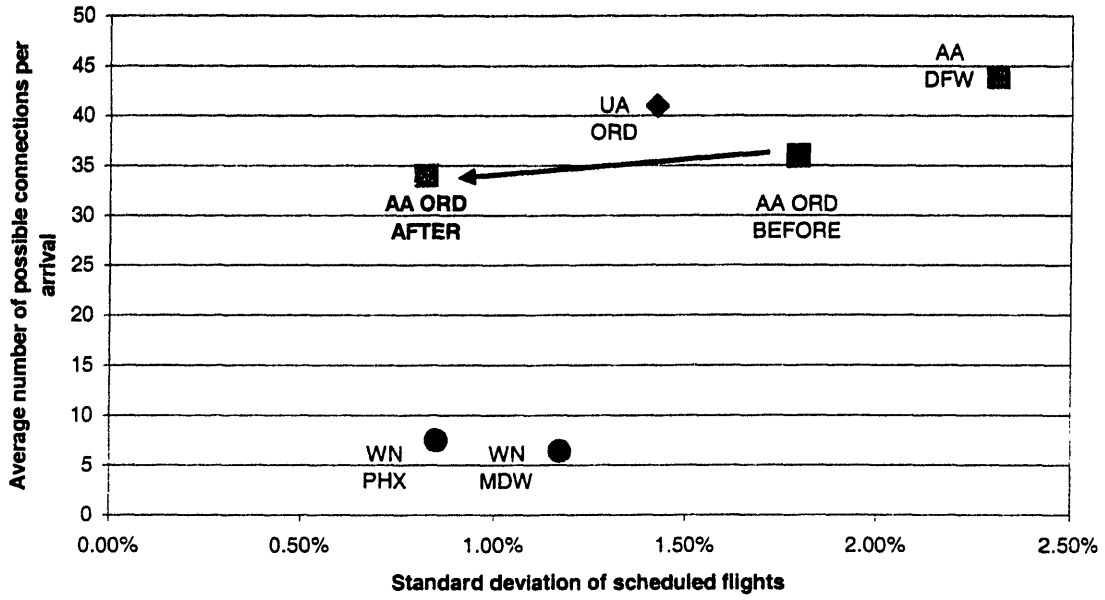


Figure 5.14 Average Number of Connections versus Degree of Peaking

5.2.3 Change in connection times

While the number of possible connections a passenger can make may not have been significantly changed when American depeaked its banks, one would suspect that the average connection time increased. Figure 5.15 is a comparison of the individual itineraries distributed by connection times (in 5-minute intervals) for all American Airlines itineraries connecting through O'Hare in March and April of 2002. The data show a marked increase in the number of itineraries with 80 to 140 minutes of connection time, and a corresponding decrease in the number of itineraries with connection times between 45 and 65 minutes. The average itinerary connection time changed from 79 minutes in March 2002 to 85 minutes in April 2002. These data are summarized in Table 5-5.

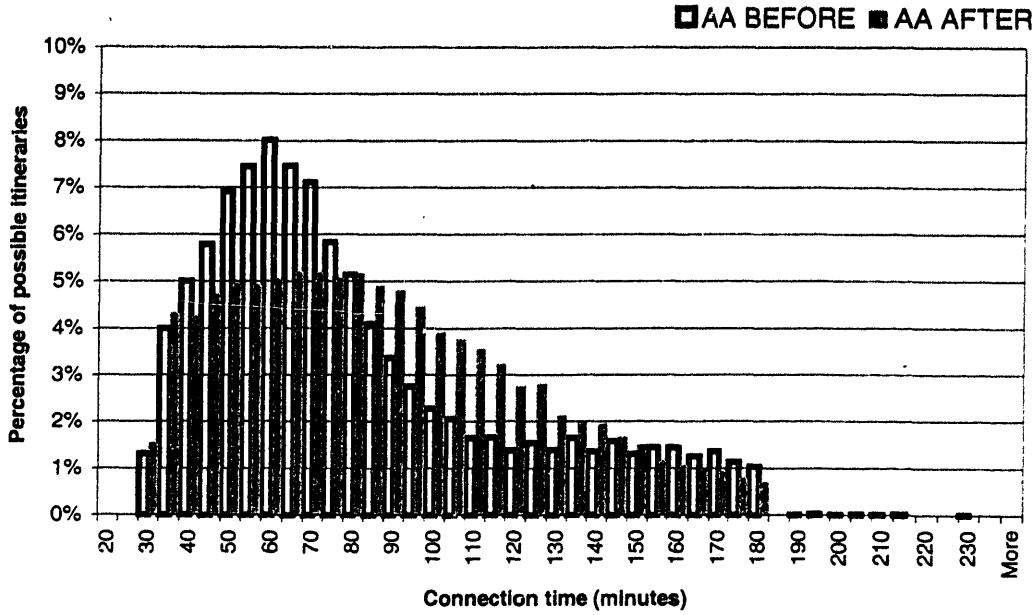


Figure 5.15 Histogram of Individual Itinerary Connection Times, AA Domestic Flights Connecting through ORD

Table 5-5 Average Scheduled Time per Connection for All Itineraries, AA and UA at ORD

	AA at ORD		UA at ORD	
	Number of daily scheduled arrivals	Average scheduled time per connection	Number of daily scheduled arrivals	Average scheduled time per connection
March 2002	450	79 min	529	79 min
April 2002	478	85 min	533	78 min

An alternative way to evaluate the change in connection times would be to first group the itineraries by Origin-Destination (OD) market, and then consider the average connection time for any[2] combination of flights serving that market. Figure 5.16 shows how the average connection time per OD market that American serves through O'Hare changed between March 2002 and April 2002. In this chart, the data again show that connection times have increased after the depeaking of American's flight banks. The increase in connection time per OD market was 5 minutes, fairly consistent with the

[2] The reader is reminded that for this analysis, only the 'first best connections' are part of the set of itineraries. Please see Section 31 and/or Appendix A for a more complete explanation.

overall average increase of 6 minutes. The average connection times per OD market are summarized in Table 5-6.

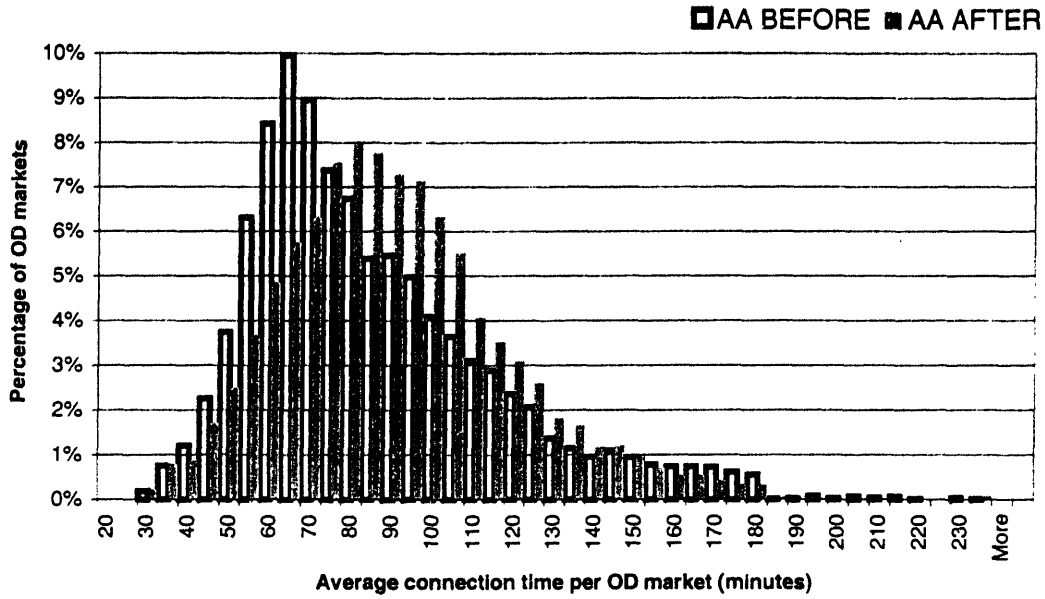


Figure 5.16 Histogram of Domestic Itinerary Connection Times Summarized by OD Market, AA Flights Connecting through ORD

Table 5-6 Average Scheduled Time per Connection by OD Market, AA and UA at ORD

	AA at ORD		UA at ORD	
	Number of OD markets	Average connection time per OD market	Number of OD markets	Average connection time per OD market
March 2002	6036	86 min	7549	82 min
April 2002	5863	91 min	7703	82 min

Figure 5.17 and Figure 5.18 compare the connection times of American and United flights connecting through O'Hare in April 2002 for all possible itineraries and itineraries summarized by OD market, respectively. The United OD market data includes only markets that are also served by AA, thus making a more direct comparison. Both sets of data show that United Airlines offers passengers a greater number of connection times between 45 and 80 minutes than does American Airlines. The UA data presented in these figures are also summarized in Table 5-5 and Table 5-6.

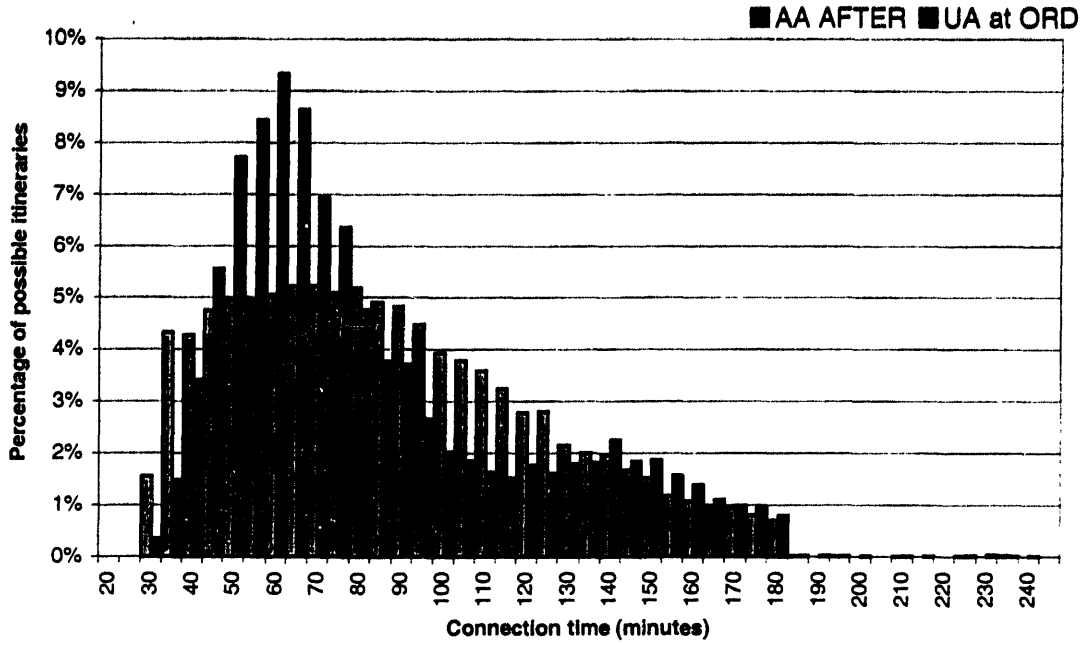


Figure 5.17 Comparison of Itinerary Connection Times, AA and UA Flights Connecting through ORD, April 2002

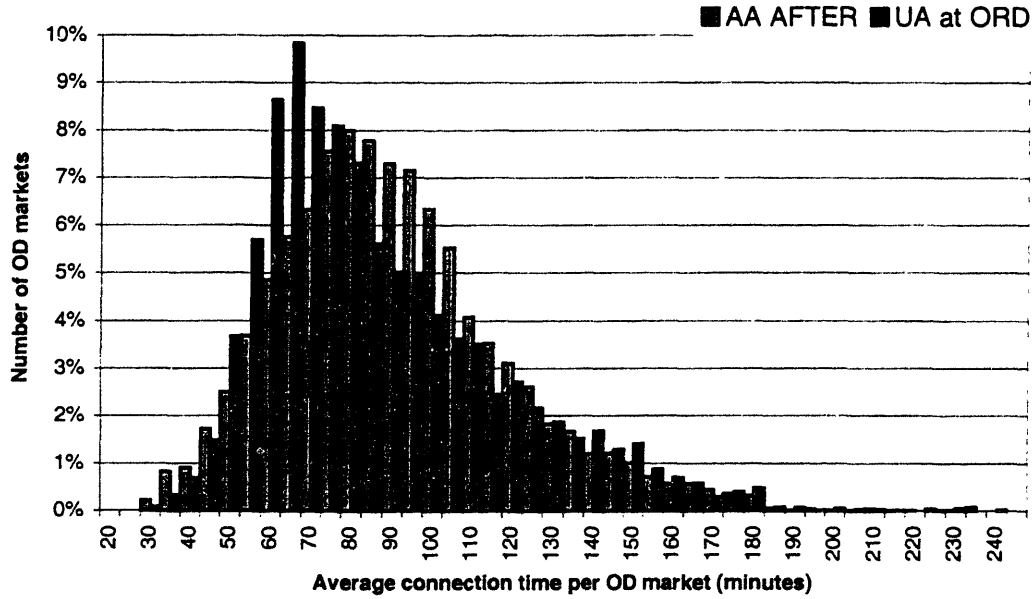


Figure 5.18 Comparison of Itinerary Connection Times Summarized by OD Market, AA and UA Flights Connecting through ORD, April 2002

5.2.4 Alternative Paths

Examining American Airlines's change at one hub in isolation of the schedules and connection offerings at its other hubs limits the understanding of the possible effects of depeaking. As an example, consider the OD market LAX-BOS. A customer planning to make a trip from Los Angeles to Boston will have at least four different flight path options on American Airlines: a direct flight path with no stops or connections, a flight path with a stop or connection at ORD, a flight path with a stop or connection at STL, or a flight path with a stop or connection at DFW. Further, each of those different flight paths may be offered multiple times and various times of day. Table 5-7 and Table 5-8 summarize American's offerings in this market for March and April of 2002 and July 2001 and July 2002, respectively.

Table 5-7 Summary of Various American Airlines LAX-BOS Flight Paths for March 2002 and April 2002

		Total	Direct	Connect at ORD	Connect at DFW	Connect at STL
Mar 2002	Number of possible itineraries	20	3	7	5	5
	Average elapsed time (min)	440*	323	435	453	435
	Average connection time (min)	62	N/A	60	56	71
		Total	**Direct**	**Connect at ORD**	**Connect at DFW**	**Connect at STL**
Apr 2002	Number of possible itineraries	21	3	7	6	5
	Average elapsed time (min)	452*	337	453	468	431
	Average connection time (min)	63	N/A	68	55	67

* Average trip time calculation includes only connecting itineraries, not direct itineraries.

Table 5-8 Summary of Various American Airlines LAX-BOS Flight Paths for July 2001[3] and July 2002

		Total	Direct	Connect at ORD	Connect at DFW	Connect at STL
Jul 2001	Number of possible itineraries	26	5	8	7	6
	Average elapsed time (min)	440*	341	445	469	439
	Average connection time (min)	62	N/A	60	56	71
		Total	**Direct**	**Connect at ORD**	**Connect at DFW**	**Connect at STL**
Jul 2002	Number of possible itineraries	23	4	7	7	5
	Average elapsed time (min)	466*	336	459	490	442
	Average connection time (min)	64	N/A	65	67	58

* Average trip time calculation includes only connecting itineraries, not direct itineraries.

Looking at the OD market level summary data, one can quickly see the difficulty in isolating the effects of the depeaked banks. In both comparisons, there have been changes in more than the connection times at O'Hare. The average direct flight times have changed, as have the average connecting times at the Dallas and St. Louis hubs. For each month listed, the connecting path with the shortest average elapsed time was through STL even though in July 2001, March 2002, and April 2002, the shortest connection time was through DFW.

Table 5-9 summarizes which of American's three main hubs (DFW, ORD, or STL) have the shortest total elapsed time for various directional connecting markets. The markets summarized are markets with at least one connecting itinerary offered through ORD and at least one connecting itinerary offered through either DFW or STL. The data show a shift in shortest elapsed time from ORD to STL from March to April 2002. The July year over year comparison again shows an increase in the percentage of markets with the shortest elapsed time through STL, but also shows an increase at ORD. This

[3] The July 2001 itinerary data consider TWA flight information as AA flight information.

comparison is complicated by the fact that the STL flights still operated under the TWA name in July 2001. These same data are presented graphically in Figure 5.19.

Table 5-9 Proportion of Shortest Average Elapsed Time for AA Directional OD Markets with Paths Connecting Through ORD and at Least One Other AA Hub

	Number of directional connecting markets	Fraction of flights with shortest average elapsed time		
		DFW	ORD	STL
July 2001	2,371	32%	31%	37%
March 2002	3,248	23%	41%	36%
April 2002	3,116	23%	33%	44%
July 2002	3,085	23%	32%	45%

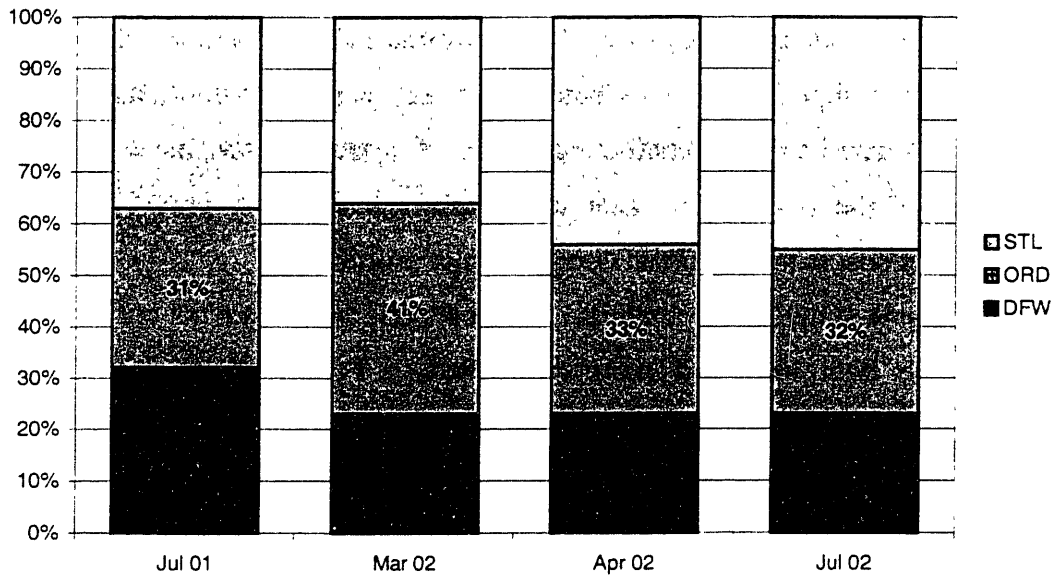


Figure 5.19 Distribution of Shortest Elapsed Time for AA ORD Connecting Markets

Both of these market specific analyses demonstrate the complexity in trying to evaluate the network effects of American's schedule change at O'Hare. It is unlikely that one hub schedule was created in isolation of the other two. If passengers are more likely to select flights based on total elapsed time rather than just connection time, then it would be important for an airline to understand how an average shift in connection times at one

hub will affect connecting passenger flight selection based on the airline's other path offerings. In the specific case of American Airlines at O'Hare, one might hypothesize that after the depeaking in April, some connecting passengers would shift their choice of path from connecting through ORD to connecting through STL, while others would opt instead for a shorter elapsed time on another carrier.

5.3 Analysis of Schedule "Performance"

The previous section attempted to better understand the changes made in American Airlines's schedule at O'Hare in April 2002, in the context of network effects. Coupling this understanding of how possible connecting paths were affected with the understanding of schedule density varied throughout the day (Section 5.1), one can begin to evaluate the schedule performance. The performance of an airline schedule can be evaluated from multiple perspectives including market share, operations, and cost. Often, these are considered to have conflicting goals. A systems view, however, considers profitability as the overarching goal and market share (as a proxy for revenue), operations, and cost as the important components of profitability.

The goals of revenue, operational, and cost performance are not only interrelated, but also have both long and short-term effects. For example, poor operational performance may not have near term revenue effects, but may lead to frustrated passengers who eventually stop flying a particular airline. Unfortunately, the complexity of the airline system, as well as the organizational structure of traditional hub and spoke airlines make these holistic views of profit optimization difficult to model, measure, and predict. This section will analyze and discuss American's new flight schedule from the separate perspectives of revenue, operations, and cost and then summarize the analysis at a system level.

5.3.1 Market Share performance

Assuming fares to be competitive, and system capacity to be constant, a better performing schedule from a revenue perspective will contain flight options that are more

attractive to more passengers If one believes time and flexibility to be important factors in passenger choice, then optimizing a schedule for market share would imply short connection times and frequent and/or redundant flight paths. As demonstrated in Section 5.2, evaluating or understanding the changes in American Airlines's schedule at ORD in the context of American's entire flight network is extremely challenging. Predicting customer choice based on the various flight offerings of different airlines introduces another order of magnitude of complexity.

5.3.1.a System-level market share

As discussed in Section 5.2, it is important to consider AA's change in the context of the entire system. Schedule changes at ORD might or might not result in overall itinerary or market share performance. Table 5-10 shows the network level domestic market shares (from CRS data) for American Airlines for the months of July 2001, April 2002, March 2002, and July 2002. In this analysis, the July 2001 system market share was calculated by combining TWA and AA system shares.

Table 5-10 CRS System-Level Market Share Data, American Airlines Domestic Markets

	Number of directional OD markets	AA System share
July 2001	23,108	21.7%
March 2002	23,044	23.0%
April 2002	21,940	22.0%
July 2002	22,238	22.0%

The American market shares show an increase from July 2001 that might be attributable to the synergy of merging AA and TWA in the beginning of 2002. There was a decrease in system-wide market share from March to April 2002, which might be attributable to a decrease in schedule attractiveness due to an average increase in connection times at for flights passing through ORD.

5.3.1.b O'Hare connecting markets

The market shares most likely to be affected by the changed bank structure, are those that have connections at O'Hare. Table 5-9 summarizes market share data for AA markets with connections through ORD. The July 2001 CRS hub data contained an error in combining the AA and TW data, and therefore are not presented. The data show that although the 3-hub combined market share for markets did not change, the actual share of passengers connecting through ORD did decrease from March to April 2002. These data imply that while fewer connecting passengers passed though ORD, STL and/or DFW appear to have picked up additional passengers so that the system still carried the same share, or slightly more.

Table 5-11 CRS Market Share Estimates, American Airlines All Domestic Markets Connecting through ORD

	Number of directional connecting markets	AA 3-Hub share	AA ORD share	AA System share
July 2001	5,282	--	4.2%	22.2%
March 2002	5,768	14.6%	4.0%	20.3%
April 2002	5,576	14.6%	3.8%	20.9%
July 2002	5,646	14.7%	4.2%	21.1%

5.3.1.c Chicago local markets

Since O'Hare is a major hub for American with significant competition from United Airlines, and Chicago is a city with two airports, the secondary one served by Southwest, it is equally important to examine the change in market share for local markets originating or terminating in Chicago. In this analysis, Chicago O'Hare and Midway flights and markets are summarized and considered as CHI markets. This means that the predicted share is for passengers taking any AA flight out of ORD or MDW to a common destination. Table 5-12 shows the local market shares for all AA domestic Chicago markets. The data show an increase in local passenger share from March 2002 to April 2002. Year over year in July the market share held constant.

Table 5-12 CRS Market Share Estimates, American Airlines All Local Domestic Chicago Markets

	Number of directional local markets	AA CHI share
July 2001	288	33.6%
March 2002	272	33.2%
April 2002	310	35.4%
July 2002	310	33.5%

5.3.1.d Market Share performance summary

Overall, American Airlines's system level market share decreased slightly when the schedule change took effect at O'Hare. At the same time, connecting market share through ORD also decreased slightly, but the local Chicago market share increased. These trends suggest that while American Airlines did lose some market share due to its increased connection times, those lost connecting passengers may have been partially replaced by local passengers. Since local passengers are often higher yield than connecting passengers one might conclude that from a market share perspective, American's decision to depeak was revenue neutral.

5.3.2 Operational performance

Well performing schedules from an operations perspective will first and foremost, operate smoothly, if not on time. On-time or 'smooth' performance implies a schedule that allows enough time for passengers to make connections and airport personnel to service aircraft, transfer luggage and cargo, and board the next group of passengers. A good schedule for operations will also take into account that the schedule and its specific fleet and crew assignments will seldom operate perfectly, and provide some level of robustness.

Weather, unexpected maintenance, incoming delays can all effect operational performance, and a schedule that makes allowance for these potential problems might operate more effectively. All else equal, optimizing a schedule for operational performance implies longer connection times for passengers, longer turn times for aircraft

(the amount of time a specific aircraft remains at the gate), and flexibility for gate and fleet swapping. There is some debate, however, whether a schedule with continuous flows of arrivals and departures will be more or less robust in times of irregular operations. With a highly peaked schedule, the valleys of inactivity allow the carriers and the airport a time cushion for recovery. If a carrier has a steady flow of flights, then it is possible that delayed flights will continue to pile up throughout the day, and the schedule will not be recovered.

This section will use DOT flight actual flight performance data to assess the operational effects of American's decision to depeak its banks at O'Hare. All data are for actual mainline flights flown, and do not include commuter flight performance or any scheduled flights that were cancelled. Additionally, the data consider only AA flights operated at ORD in July 2001 as opposed to including any TWA flights.

5.3.2.a On-time performance analysis

Airlines report on-time flight information to the Department of Transportation (DOT) in a number of forms. For example, for each departure, the airline reports whether the flight departed before or at the scheduled departure time (Departure :00), and whether the flight departed at or before five minutes past the scheduled departure time (Departure :05). Similarly, for each arrival, airlines report Arrival :00, Arrival :05, and Arrival :14.

In times of "normal" industry operations the change in on-time performance could be useful in determining the operational performance of the newly depeaked schedule. With airline schedules and capacity decreased, however, on-time performance is improving for all airlines, and schedule effects might not be apparent. Comparing July year over year in addition to March and April of 2002, might help to separate these effects.

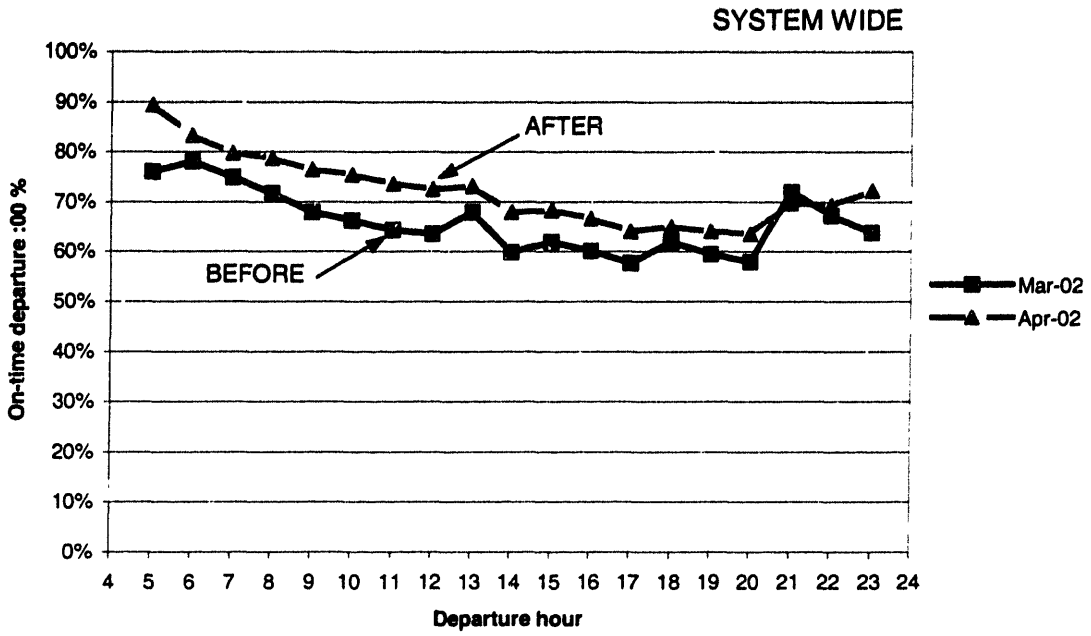


Figure 5.20 American Airlines Departure On-Time :00%, System-wide, March and April 2002

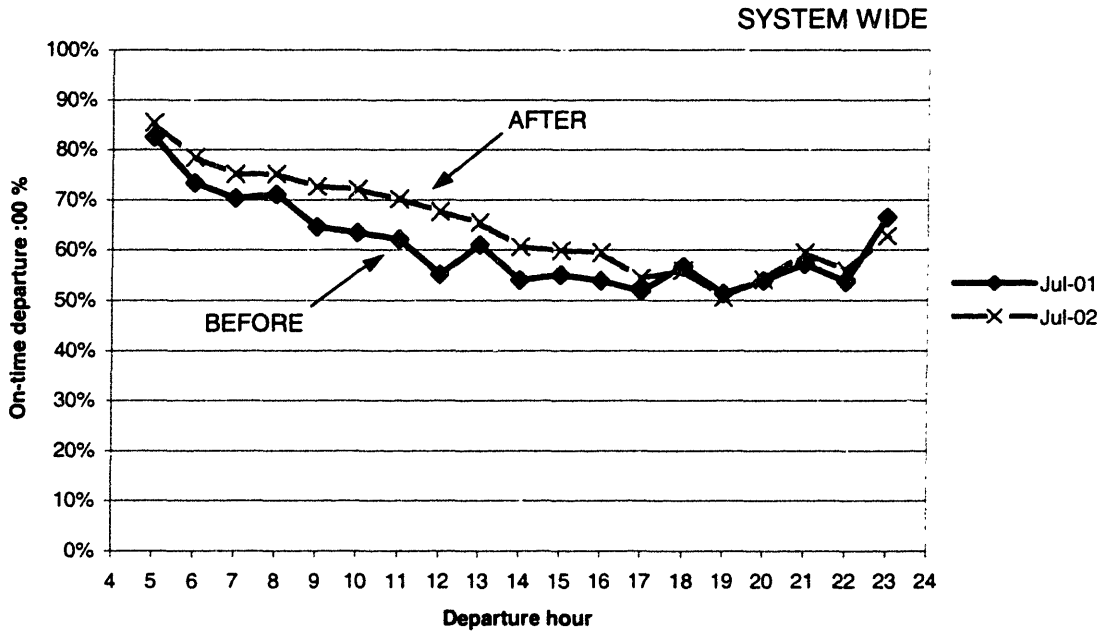


Figure 5.21 American Airlines Departure On-Time :00%, System-wide, July 2001 and July 2002

The system wide on-time Departure :00 % for American Airlines in March and April 2002, and July 2001 and 2002 are shown in Figure 5.20 and Figure 5.21, respectively. Each month of data shows the trend of on-time departure percentage starting out high in the early morning, decreasing as the day progresses, and then rising again as the number of departures tapers out in the evening. This trend is expected, as delays that occur in the morning tend to propagate throughout the day: late departures leading to late arrivals, turning again into late departures. Comparing March and April 2002 data, one sees an improvement in departure performance in the beginning to midday, with that improvement disappearing by the end of the day. A similar trend is seen between the July 2001 and July 2002 data. The corresponding Arrival :00% data also show similar trends, but less overall improvement. These data can be viewed in Figure B9 in Appendix B.

A summary of system-level average on-time departure and arrival data for July 2001, March 2002, April 2002, and July 2002 is recorded in Table 5-13. The total number of flights is clearly down year over year in July 2002. Part of this decrease in flights can be attributed to an over all schedule depression following September 11, 2001, and part is likely due to consolidation of TWA and AA flight schedules. All on-time measurements improved from July 2001 to July 2002 and March 2002 to April 2002. More improvement was seen for Departure :00 and Arrival :00 than for Departure :05 and Arrival :14. A similar look at the on-time arrival and departure statistics for AA flights at ORD might help to determine what if any of this on-time improvement can be attributed to network effects of the schedule change at ORD.

Figure 5.22 and Figure 5.23 show the ORD on-time Departure :00% for March and April 2002, and July 2001 and 2002, respectively. The data show similar, but more exaggerated trends throughout the day as the system-wide data. This makes sense as the scheduled departure and arrival times are reported in local time, so the level of flight activity, builds more gradually at a system level, so the amplification of delays would be expected to be more severe at a station level. Just as at the system level, the arrival data

show similar trends, but less improvement throughout the day. These arrival data for ORD arrivals can be viewed in Figure B10 Appendix B.

Table 5-13 System-Wide Monthly On-Time Performance for AA, July 2001[4], March 2002, April 2002, July 2002

	July 2001	March 2002	April 2002	July 2002
Avg. Daily Flights	2,823	2,332	2,397	2,473
Departure :00%	60.4%	65.5%	71.9%	65.1%
Departure :05%	75.2%	77.1%	81.8%	76.5%
Arrival :00%	57.9%	59.7%	65.5%	62.5%
Arrival :14%	79.1%	80.4%	83.8%	80.3%

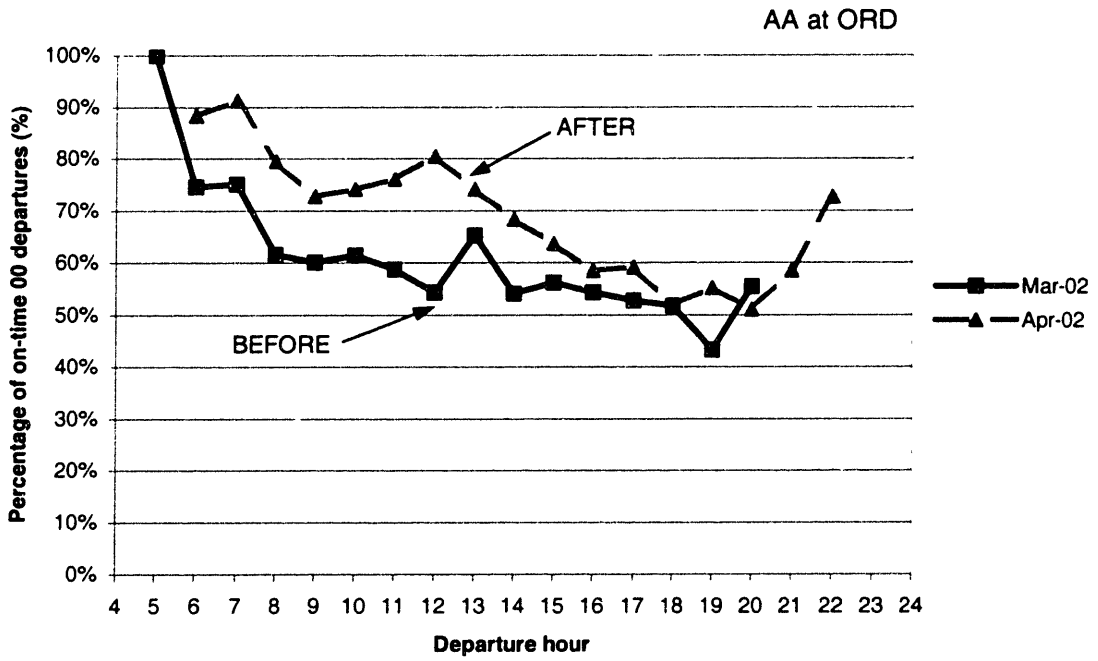


Figure 5.22 American Airlines Departure On-Time :00%, for All Flights at ORD, March and April 2002

[4] The system level data for July 2001 include TWA flight arrival and departure statistics along with AA statistics.

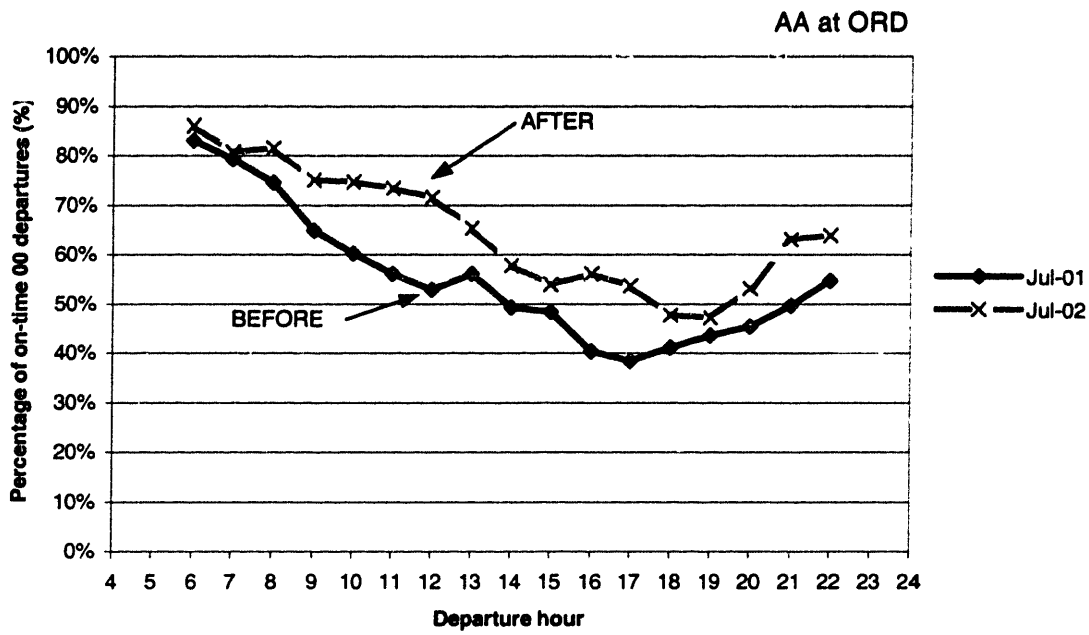


Figure 5.23 American Airlines Departure On-Time :00%, for All Flights at ORD, July 2001 and July 2002

Table 5-14 and Table 5-15 contain the monthly arrival and departure performance data for July 2001, March 2002, April 2002, and July 2002 for AA flights at ORD and DFW respectively. At both hubs, the on-time performance was improved April over March and July over July. Compared with the system wide data, both hubs perform worse than average in departure performance. ORD also performs worse than average in arrival performance, but flights arriving at DFW tend to arrive on time more often than the system average. This fact highlights a potential deficiency of the DWF hub since if flights are arriving on average earlier than other flights in the system, one would expect that DFW would also have a higher than average on-time departure percentage. This is not the case; as the Departure :00% at DFW is lower than the Arrival :00% implying aircraft cannot be turned in the appropriated amount of time at DFW.

Table 5-14 AA at ORD Monthly On-Time Performance of Mainline Flights, July 2001, March 2002, April 2002, July 2002

	July 2001	March 2002	April 2002	July 2002
Avg. Daily Flights	312	275	297	313
Departure :00%	55%	59%	68%	64%
Arrival :00%	55%	58%	62%	64%

Table 5-15 AA at DFW Monthly On-Time Performance of Mainline Flights, July 2001, March 2002, April 2002, July 2002

	July 2001	March 2002	April 2002	July 2002
Avg. Daily Flights	477	425	433	444
Departure :00%	44%	53%	66%	59%
Arrival :00%	61%	61%	68%	63%

The data imply that a system-wide improvement in on-time performance may have occurred after September 11, 2001. The additional improvement in April 2002 at ORD allowed American to maintain a higher level of performance in July 2002, when the total number of daily departures was equal to that of July 2001. The same argument cannot be made in the case of flights at the DFW hub as the total number of daily flights in July 2002 is still below that of July 2001. On the other hand, capacity was still reduced system-wide in July 2002, and while American might have operated the same number of flights at ORD, the total number of daily flights at ORD were still decreased, and might have accounted for the sustained improvement.

Another uncertainty concerning on-time performance as pointed out in Section 5.2.4 is that some scheduled trip times were changed. To help understand whether the adjustment of individual market trip times would greatly affect the on-time performance data, the average changes in flight time and connection time were calculated. Figure 5.24 shows these changes in average times such that the times plotted for March 2002 show the difference from times scheduled in July 2001, the April times represent the difference compared with March, etc. These data show that while the average connection time may have increased significantly in April 2002, the average scheduled flight times had decreased significantly. Thus, by July 2002, the average total elapsed time had actually

decreased approximately 1 minute from July 2001. This implies that any on-time performance improvements were not artificially induced by changes in block time.

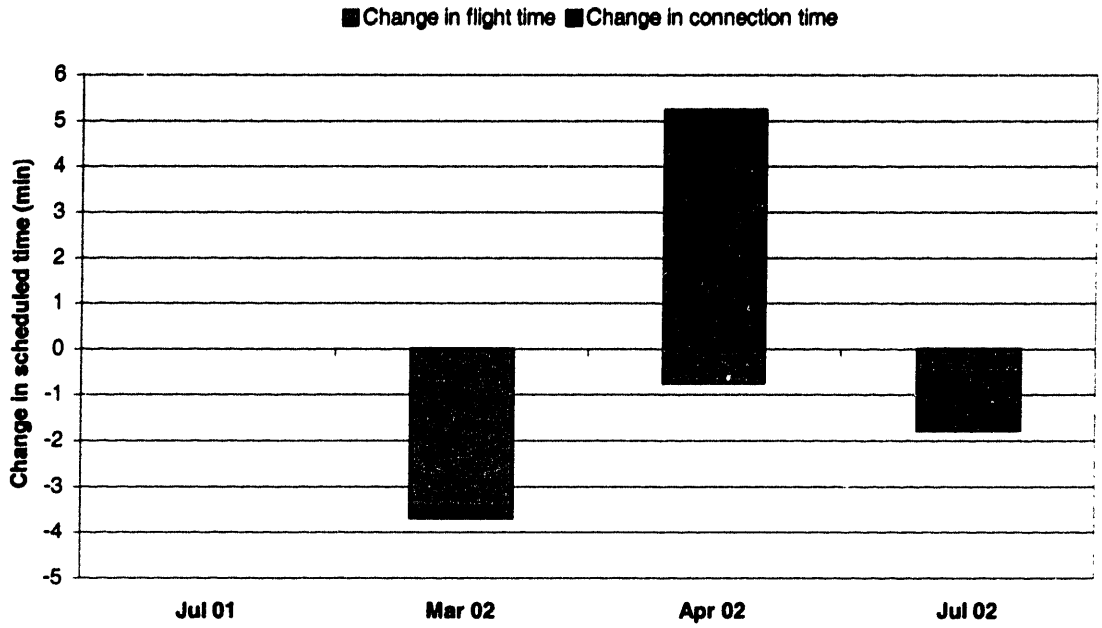


Figure 5.24 Change in Average Flight and Connection Times for AA Flights Connecting at ORD

5.3.2.b Delay minutes

In addition to reporting whether a flight is on time or not, airlines report the length of each departure or arrival delay. Figure 5.25 shows the average length of departure delay per delayed flight as a function of scheduled departure time for all American Airlines flights departing in March and April 2002. Comparing these data with Figure 5.22, one can see that not only are more delays occurring as the day progresses, but the average delays are getting longer. At a system level, there does not appear to be much difference in the average length of delay during the months selected for comparison.

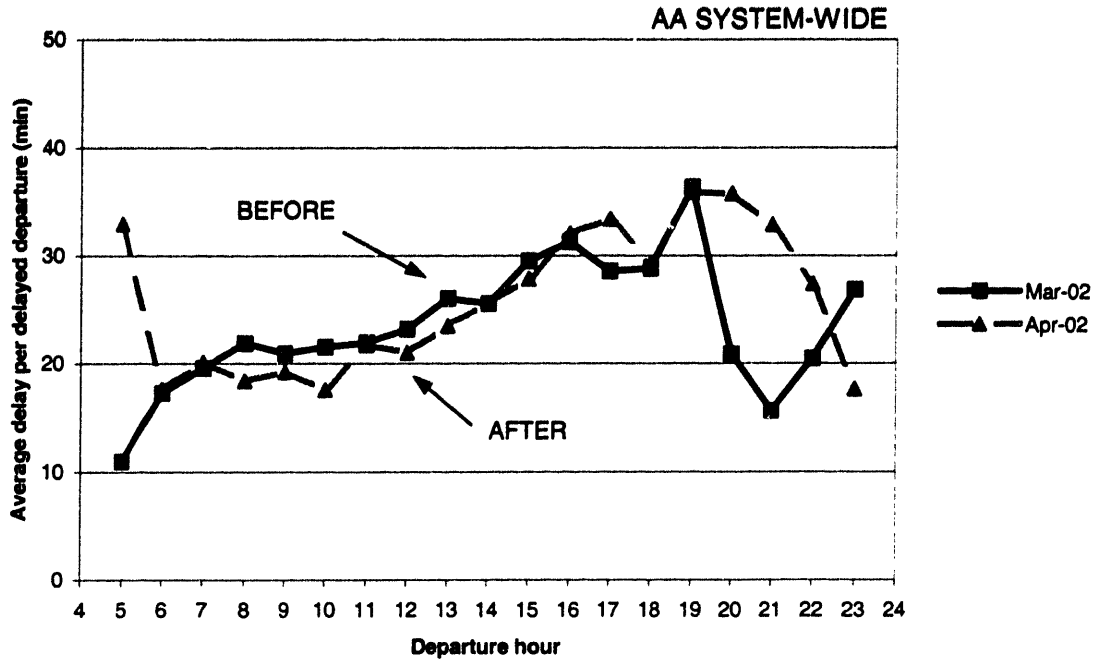


Figure 5.25 Average Number of Departure Delay Minutes per Flight, American Airlines System-wide Departures, March and April 2002

Figure 5.26 shows the same departure delay time for American Airlines departures from O'Hare. In general, the hub airport shows the same trend of increasing average delay time throughout the day as the system data; however, there appears to be more variation from March to April. Table 5-16 summarizes the average delay time per delayed arrival and departure for AA flights at a system level, at ORD, and at DFW for the months of July 2001, March 2002, April 2002, and July 2002. The average number of departure delay minutes for flights departing from ORD decreased nearly 5 minutes from March to April 2002. There was also a 2 minute decrease year over year in July. Meanwhile, there was an increase in departure delay minutes both system wide and at DFW. This implies that the depeaked schedule helped to improve departure performance at O'Hare.

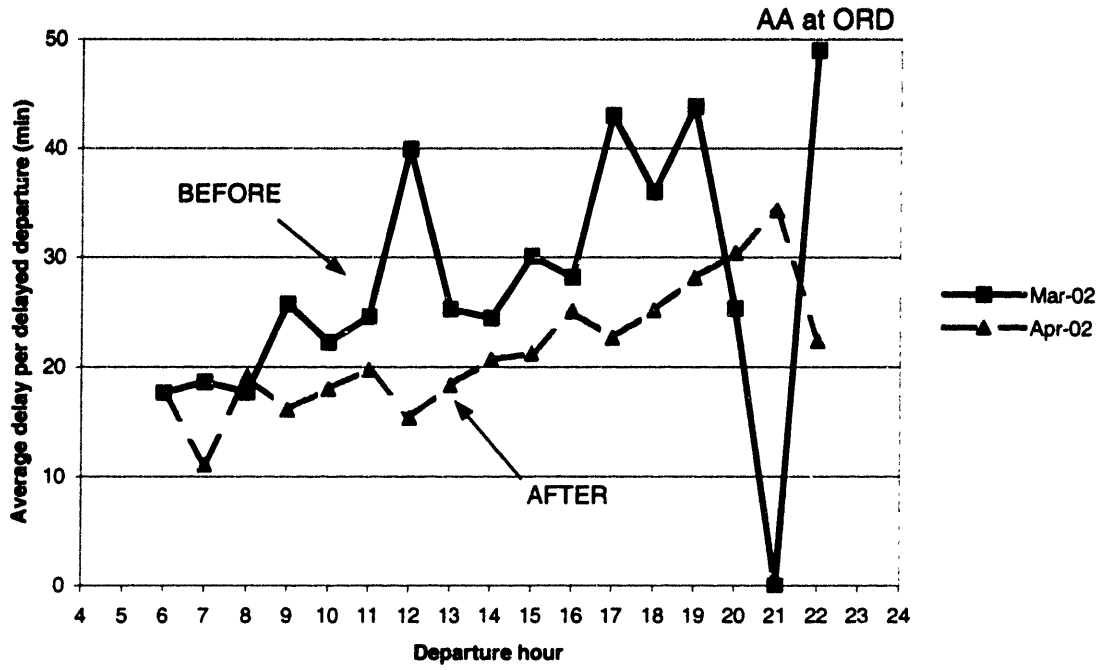


Figure 5.26 Average Number of Departure Delay Minutes per Flight, American Airlines Departures at ORD, March and April 2002

Table 5-16 Monthly Delay Time per Delayed Mainline Flight for AA, July 2001, March 2002, April 2002, July 2002

		July 2001	March 2002	April 2002	July 2002
Average daily flighs	System	2,823	2,332	2,397	2,473
	ORD	312	275	297	313
	DFW	477	425	433	444
Average depart delay (min)	System	24.0	25.3	26.2	27.4
	ORD	28.4	27.9	23.0	26.3
	DFW	18.2	24.5	28.1	26.5

5.3.2.c Taxi times

Figure 5.28 and Figure 5.27 show both the distribution of departures and the average taxi-out time per departure for American Airlines flights out of ORD for July 2001 and July 2002, and March 2002 and April 2002, respectively. Both sets of July data show the average taxi-out time gradually increasing throughout the day, peaking in early afternoon

and decreasing as the number of flights tapers off at the end of the day. The July 2002 taxi-out times seem to be slightly lower than the July 2001 times even though the total number of departures is about the same. The March and April 2002 data show a more steady taxi-out time throughout the day, and little difference between the times for the two months.

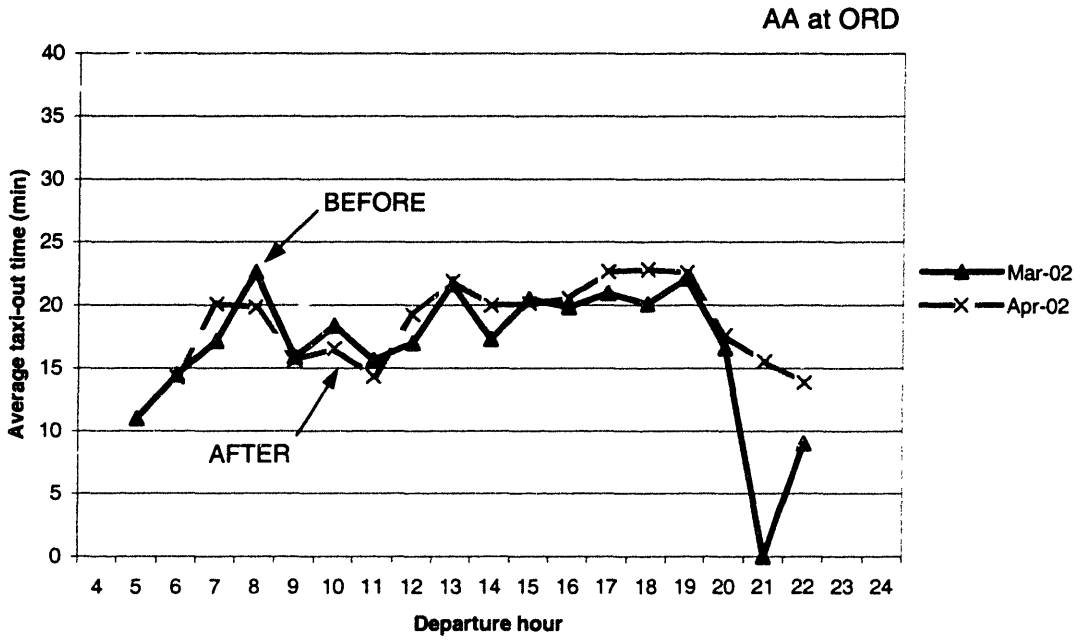


Figure 5.27 Taxi Out Time for American Airlines Departures at ORD, March 20012 and April 2002

Table 5-17 summarizes the average taxi-in and taxi-out times for all American Airlines flights arriving and departing ORD in July 2001, March 2002, April 2002, and July 2002. The taxi-in times are significantly lower than the taxi-out times. This makes sense because any delay due to congestion for an arriving flight will occur prior to landing, while airport congestion prior to take-off will directly affect the taxi-out time. There was a decrease in average taxi-in time of about 1 minute from March to April 2002. The taxi-out time was constant over the same period. Both taxi-in and taxi-out times showed slight improvement from July 2001 to July 2002. The improvement in the July over July data suggest that any taxi-out time improvements might have been a result

of an overall decrease in airport congestion at O'Hare rather than the change in American's departure schedule. Further, the taxi-out times are affected not only by American's degree of peaking in its flight schedule, but also by the degree of peaking of competitors' schedules and ultimately, the degree of peaking of the overall airport schedule.

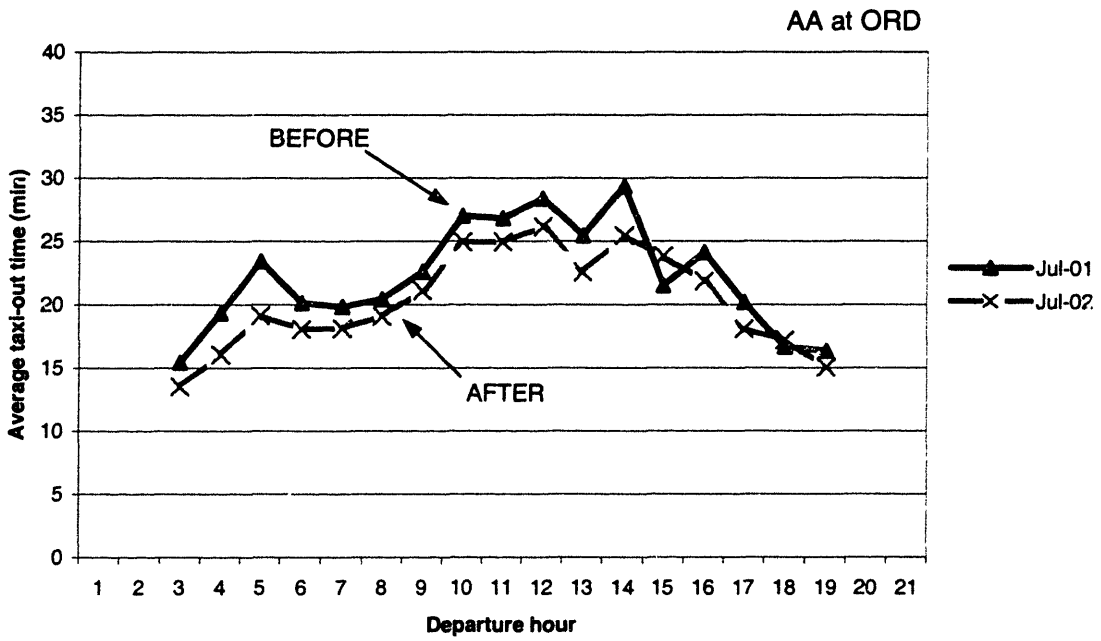


Figure 5.28 Taxi Out Time for American Airlines Departures at ORD, July 2001 and July 2002

Table 5-17 AA at ORD Monthly Average Taxi-out Times for Mainline Flights, July 2001[5], March 2002, April 2002, July 2002

	July 2001	March 2002	April 2002	July 2002
Avg. Daily Flights	312	275	297	313
Avg. taxi-out time (min)	22.4	19.1	19.3	21.0
Avg. taxi-in time (min)	8.8	9.7	8.5	8.5

[5] In the AA ORD July 2001 data, the on-time statistics for the 10 daily TWA flights are not included. Including these flights, AA+TWA operated an average of 322 daily flights out of ORD.

5.3.2.d Summary of operational analysis

American Airlines has had overall on-time performance improvement and a decrease in departure delay minutes at O'Hare. While it is not possible to conclude that these improvements can be attributed solely to the depeaking of banks, one can definitely conclude that the depeaking did not worsen on-time performance or increase delay minutes or taxi times. A more comprehensive evaluation of operational performance would include measures of passenger and baggage misconnects, scheduled and aircraft turn times, and recovery times from disruptions such as security breaches and inclement weather.

5.3.3 Cost performance

From a cost perspective, a well performing, or low cost schedule will take into account factors such as fleet utilization, airport facilities and equipment utilization, labor costs and productivity, and the cost of recovering from disruptions. As no specific cost data were available, the estimation of the performance of the depeaked schedule from a cost perspective will be a discussion of expected trends.

Given the more steady flow of arrivals and departures, one would expect equipment utilization to improve. In a schedule with highly peaked arrival banks, equipment will wait at spoke stations until the appropriate time to take off and meet the scheduled arrival bank at the hub station. In a schedule with depeaked banks, planes can be scheduled to arrive a spoke station and then quickly return. This should significantly improve fleet utilization, or the number of hours throughout the day that a given aircraft spends in the air versus on the ground.

A more steady flow of departures could also result in fewer customers needing to check in at lobby areas or pass through security points at any given time. Similarly, given a more steady flow of flights into and out of the hub airport, one would expect that gates, maintenance equipment, luggage transfer equipment, and outsourced services such as cleaning and catering would be more effectively utilized. If there are always some flights taking off and some flights landing, then the average number of planes on the

ground at a hub at any given time should be reduced. If the reduction was significant enough, then fewer gates would be needed to handle the same number of daily flights.

If fewer gates and other equipment were needed, then fewer personnel would be required to staff those gates and operate that equipment. More importantly, the employees at the hub station would no longer have long periods of downtime as with more peaked schedules. This consistent level of productivity would mean that employees were paid for the same amount of time that was spent working. Flight crews may also experience such productivity improvements, as their schedules would no longer automatically include a long period of downtime waiting for the next departure bank. Furthermore, if scheduled block times can be reduced due to less ramp and runway congestion at peak times, then flight crew costs will go down. Finally, if fewer passengers miss their connections due to slightly increased connection times, the costs of rebooking those passengers could be avoided.

The magnitude of the previously described employee productivity improvements can be best estimated by considering the number of departures "in-work" at any given time throughout the day. Figure 5.29 shows the moving sum of scheduled departures for both March and April 2002. The number of scheduled flights per interval are normalized by the total number of daily flights. This moving sum is meant to be a proxy for the number of departing flights that are "in-work" during any given 15-minute interval.

Whether or not the level of staffing decreases, will depend on what level of coverage American Airlines was previously using. If American was previously staffing at the 10% of scheduled departures level, they might now be staffing at the 7 or 8% level. In each of these cases, the level of coverage will not be enough to completely cover all time periods. If American chose to staff to the highest peak throughout the day, then before the change, it would have staffed for the 12.5% of schedule departures level, and after the change, at the 10% level. In either case, there would be a slight decreased in the required staffing level.

Figure 5.30 through Figure 5.32 show the distribution of the number of arrivals or departures scheduled per 15-minute interval for AA at ORD in March and April 2002,

and WN at PHX in April 2002, respectively. Only the intervals from 6AM to 10PM were considered. These charts are helpful in understanding not only the variation of scheduled flights throughout the day and the maximum flights per interval, but also the amount of potential downtime in the schedule, represented by the count of intervals without any scheduled flights. They can also be helpful in making an estimate of relative productivity of American's new schedule compared with Southwest.

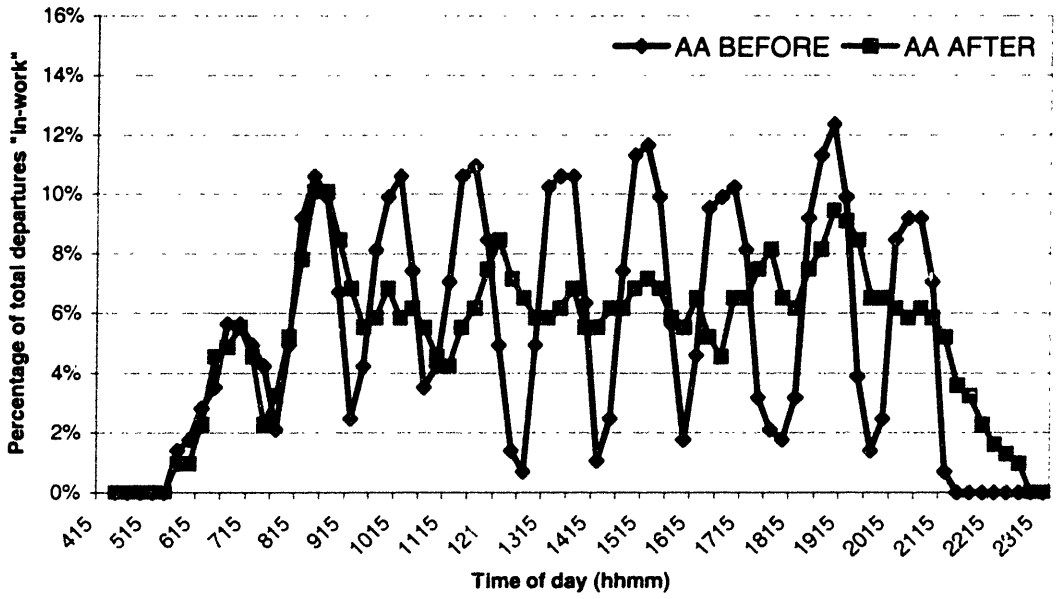


Figure 5.29 60-Minute Moving Sum of Percentage of Scheduled Departures per 15-minute Interval, AA at ORD March, April 2002

After depeaking, American's distribution of scheduled departures per 15-mintue interval had less variation throughout the day. The maximum number of flights scheduled in any interval dropped from 18 in March to 9 in April. Meanwhile, Southwest's departure schedule at Phoenix had a maximum of 6 flights per 15-minute interval. Also noticeable, is that while Southwest's schedule has a strong peak around 2-3 departures per interval, American has two less significant peaks at 3 and 7 departures per interval. This difference implies that while American may have some productivity gains as a result of depeaking, their productivity is not likely to match that of Southwest.

If the scheduled departure distribution had a stronger peak around 4 or 5 departures per interval, then the gain may have been greater.

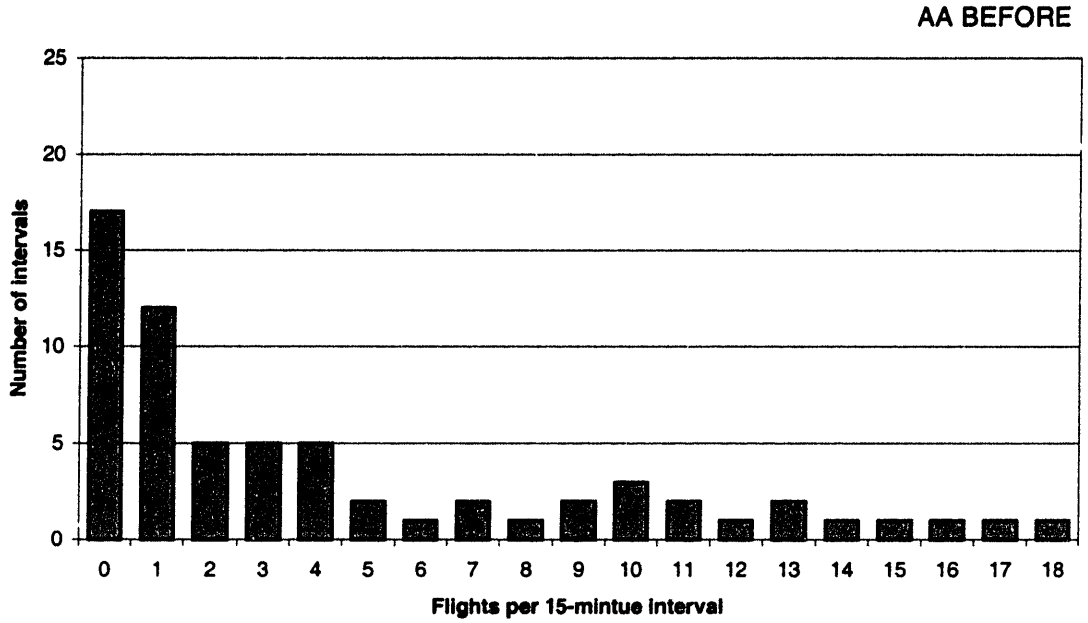


Figure 5.30 Distribution of Scheduled Flights per 15-minute Interval, American Airlines at ORD Domestic Mainline Flights, March 2002

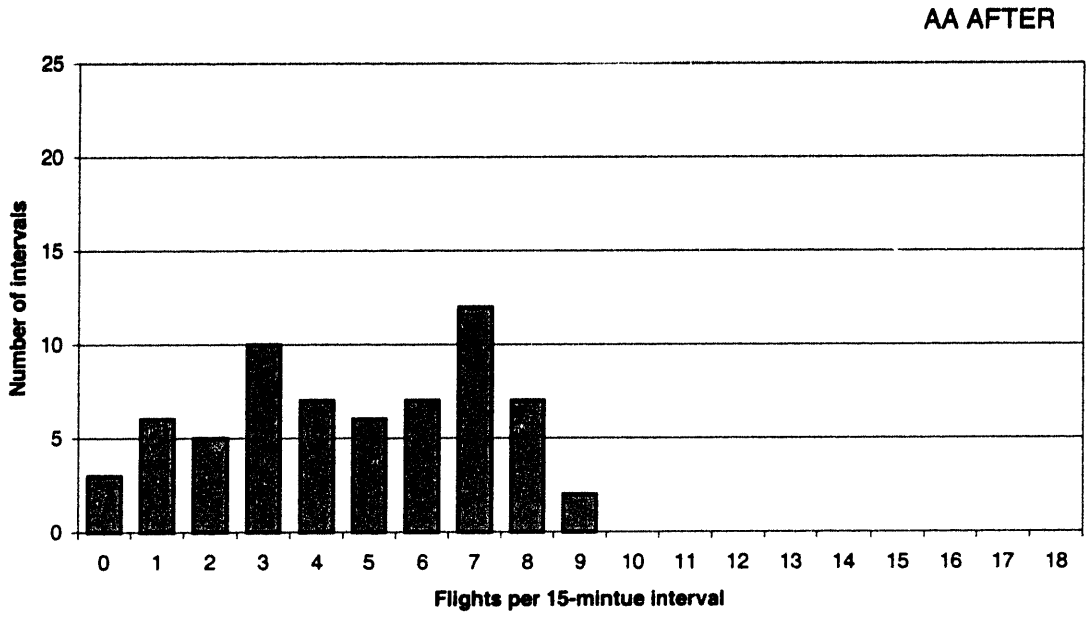


Figure 5.31 Distribution of Scheduled Flights per 15-minute Interval, American Airlines at ORD Domestic Mainline Flights, April 2002

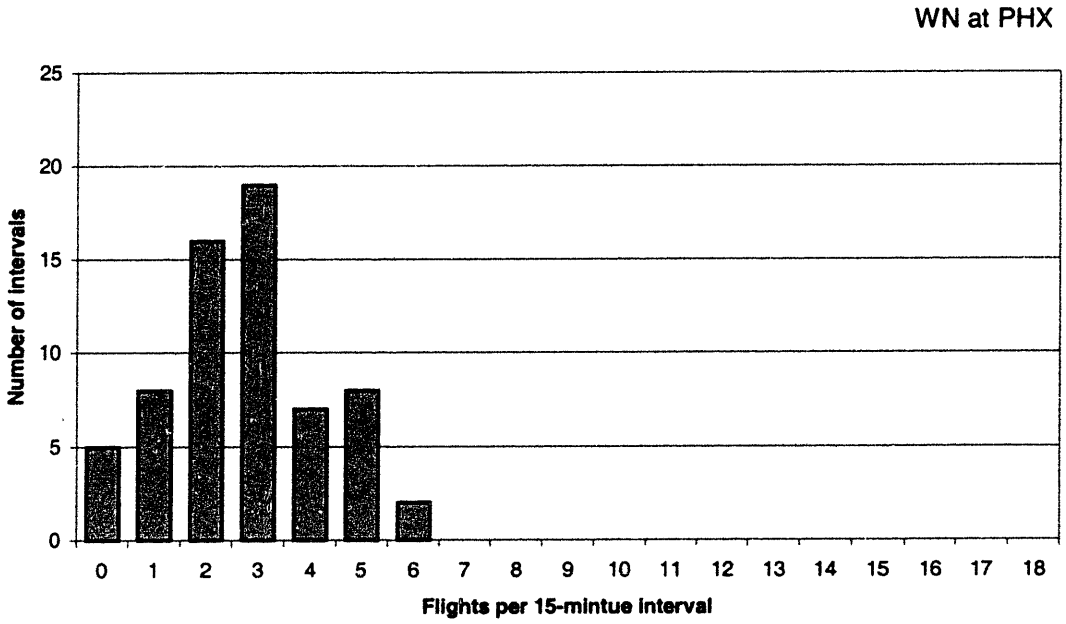


Figure 5.32 Distribution of Scheduled Flights per 15-minute Interval, Southwest Airlines at PHX Domestic Mainline Flights, April 2002

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6 SUMMARY AND CONCLUSION

The analysis of American Airlines's decision to depeak its flight schedule at O'Hare International Airport showed that the decision was neutral from a market share perspective, neutral or favorable from an operations perspective, and likely favorable from a cost perspective. As expected, connection times for the first best connection for a given OD market increased, but only by an average of 5 to 6 minutes. Arriving flights had an average of two fewer possible connections. Meanwhile, the maximum number of arrivals or departures scheduled for a given 15-minute interval decreased from 18 to 9 flights, and the number of 15-minute intervals from 6AM to 10PM without any scheduled departures dropped from 17 to 3.

System-level market share and connecting market share at ORD showed a slight decline from March to April; however local Chicago market share increased over the same time period, and the 3-hub connecting share held constant. These trends imply that while fewer passengers were making connections at O'Hare, more local passengers were flying on American flights and some connecting passengers were making connections through St. Louis and Dallas rather than through ORD. The analysis suggested that American made limited if any market share gains because of the change, but certainly did not lose significant market share. Given the lack of fare or revenue data and the inherent variability of CRS data, it was not possible to make a judgment about schedule performance from a revenue perspective.

On-time departure performance improved both system wide and at ORD in the given time period. While an improvement was noticed from March to April 2002, there was also a year over year improvement in July 2002. This implies that some operational improvement may have been due to an overall decrease in the number of flights in the system, as similar improvements were seen at other hubs and for other carriers. At the same time, the data showed that the improvement at O'Hare was greater than the system wide improvement. Taxi-in times improved for American Airlines flights arriving at O'Hare, implying less congestion for aircraft in the AA gate areas. Taxi-out times did not improve, however, suggesting that even though American had depeaked its schedule,

the fact that competitors maintained peaked schedules meant that overall airport taxiway and runway congestion did not significantly decrease. Finally, an overall cost benefit in the form of employee productivity and equipment utilization was expected based on the reduction of the number of aircraft on the ground at any given time.

American Airlines has made a significant departure from the traditional hub and spoke paradigm of scheduling hub departures and arrivals in peaked banks. Whether or not this strategy can fix the financial difficulties of American or other traditional hub and spoke operators such as United or Delta is at this point unknown. While a number of analysts agree that implementation of a rolling hub, is an important element of carrier recover, they also agree that this is just one step (Costa et al. 2002, Donoghue 2002, Hansson et al. 2002). Embracing this paradigm shift and accepting it as a necessary step, however will be difficult for many airlines. As suggested by former US Airways Executive, this idea frightens airline executives because "it reduces costs more than it increases revenue." (McDonald 2002)

Still, there may be other obstacles to individual carrier as well as industry recovery. With the current war in Iraq and SARS epidemic in the Far East, both international and domestic travel are even more depressed. Without passengers flying and revenue coming in, it may be difficult to realize fully the benefits from strategic changes. For example, being able to operate the same number of flights with few planes currently means that those planes can be retired from the fleet. In times of increased passenger traffic, those valuable assets could instead be used for route expansion or new route service rather than retired. Additionally, during this time of poor financial performance, productivity benefits have a negative impact on morale if they lead to more layoffs. If the industry was in a stage of growth, or a steady state, then productivity benefits could be enacted through attrition or reduced hiring rates. Also, with enhanced airport security measures preventing last minute passenger check-ins, passengers are arriving earlier, airlines are boarding flights sooner, and on-time performance is improving for many carriers; thus, making the argument for improved operational performance becomes more difficult.

Finally, there are the questions of whether this change in strategy will be sustainable in the future, and if it can be applied universally at all hub airports. If the economy again enters a cycle of high growth, will passenger revenues again increase? If passenger revenues increase, will traditional hub and spoke carriers again be able to compete based primarily on time? Should other traditional hub and spoke carriers follow suit, or do they have the incentive to instead stay with their current strategy? If United Airlines decided to depeak its schedule at ORD, perhaps operational improvements for both United and American would increase beyond individual improvements, as the overall airport schedule will become less peaked. On the other hand, United might decided to maintain its peaked schedule, holding firm to the idea that the shortest connection times will attract the greatest revenue.

At the time of publication of this thesis, American had implemented a depeaked schedule in Dallas, but did not yet have similar plans for its St. Louis hub (Ott 2003). Perhaps American will not be willing to take the risk of losing connecting flow through an airport that might not have a large enough population to fill seats with local passengers. If American Airlines is able to avoid Chapter 11 bankruptcy and survive this industry downturn, then the strategy will truly be tested and perhaps these additional questions will be answered.

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APPENDIX A CONNECTION BUILDING AND ITINERARY GENERATION

Connection building and itinerary generation was performed using an in-house model at United Airlines. The analyses performed in this thesis are biased by the parameters used in the connection generation rules. The relevant rules and their corresponding parameter values are presented here so that the reader may better understand the set of connections and itineraries used in the analyses.

Minimum Connection Times:

United uses a database with extensive airport information to determine minimum connection times for each airline/airport combination.

Connection Circuity:

The itinerary builder has an option for limiting the set of viable itineraries with respect to distance flown. For this research the itinerary builder required that any connecting itinerary A-B-C meet the following restriction:

$$\overline{AB} + \overline{BC} \leq 2\overline{AC},$$

where $\overline{AB}$ is the distance between points A and B, $\overline{BC}$ is the distance between points B and C, and $\overline{AC}$ is the non-stop distance between points A and C. See Figure A.1.

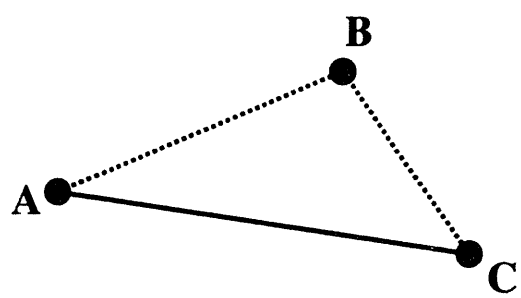

Figure A.1 Schematic of Sample Flight Routings from Point A to C

Total Elapsed Time:

In addition to the previously described distance restriction, connecting itineraries are also restricted in total elapsed time. The following restriction was used for building valid itineraries:

$$T_{AB} + T_B + T_{BC} \leq 240 + T_{AC},$$

where T_{AB}, T_B, T_{BC}, T_{AC} equal the flight time from Station A to Station B, the connection time at Station B, the flight time from Station B to Station C, and the non-stop flight time from Station A to Station C, in minutes respectively. Again, refer to Figure A.1. Any possible itinerary with a total elapsed time of greater than 240 minutes plus the direct flying time will be considered invalid.

First Best and Second Best Connections:

The final itinerary generation rule of interest is whether or not the collection of feasible itineraries includes second best connections or not. To help explain this rule, Figure A.2 shows various flight arrivals and departures to and from Station B over time. Each arrow represents a different flight arrival or departures; those labeled A1 and A2 and C1 and C2 represent two arrivals from Station A and two departures to Station C, respectively.

If the Second Best Connection option is turned on, then the set of valid itineraries will include A1-B-C1, A2-B-C2, as well as A1-B-C2. If the Second Best Connection option is turned off, then only A1-B-C1 and A2-B-C2 are included in the set of valid itineraries.

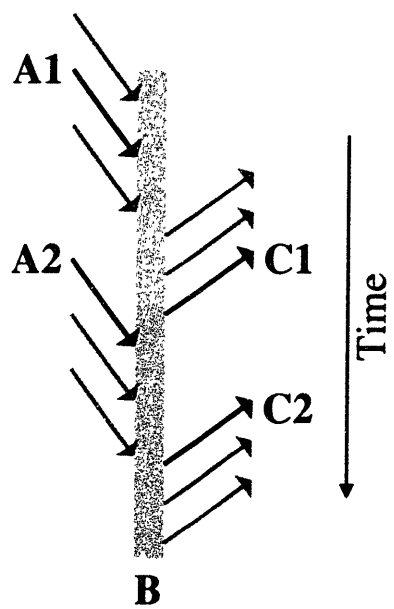

Figure A.2 Depiction of Various Flight Arrivals and Departures at Station B

APPENDIX B ADDITIONAL FIGURES

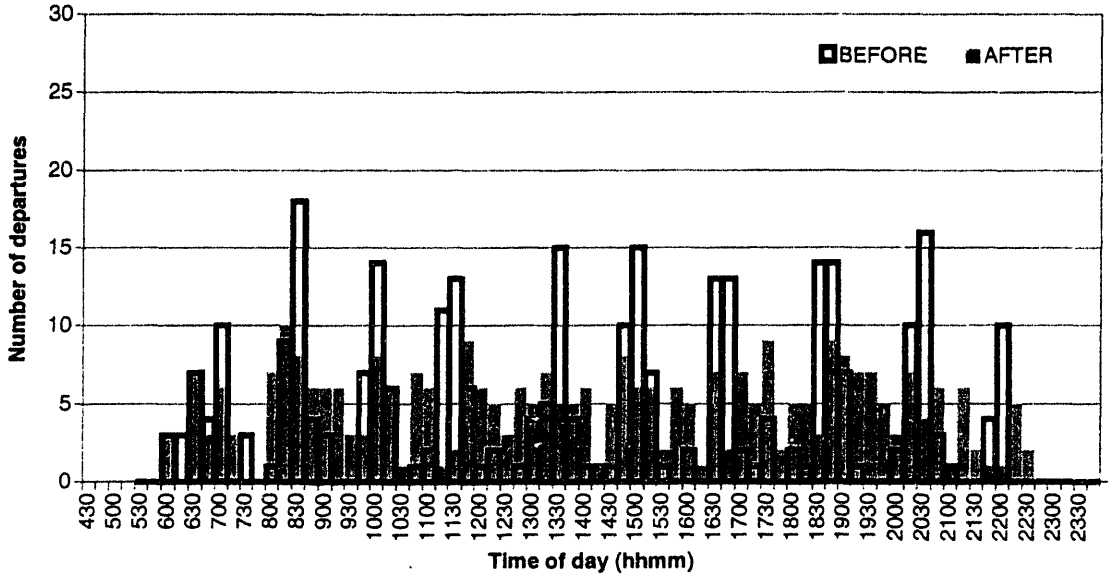

Figure B.1 Comparison of Scheduled Departures per 15-minute Interval, American Airlines at ORD, July 2001 and July 2002

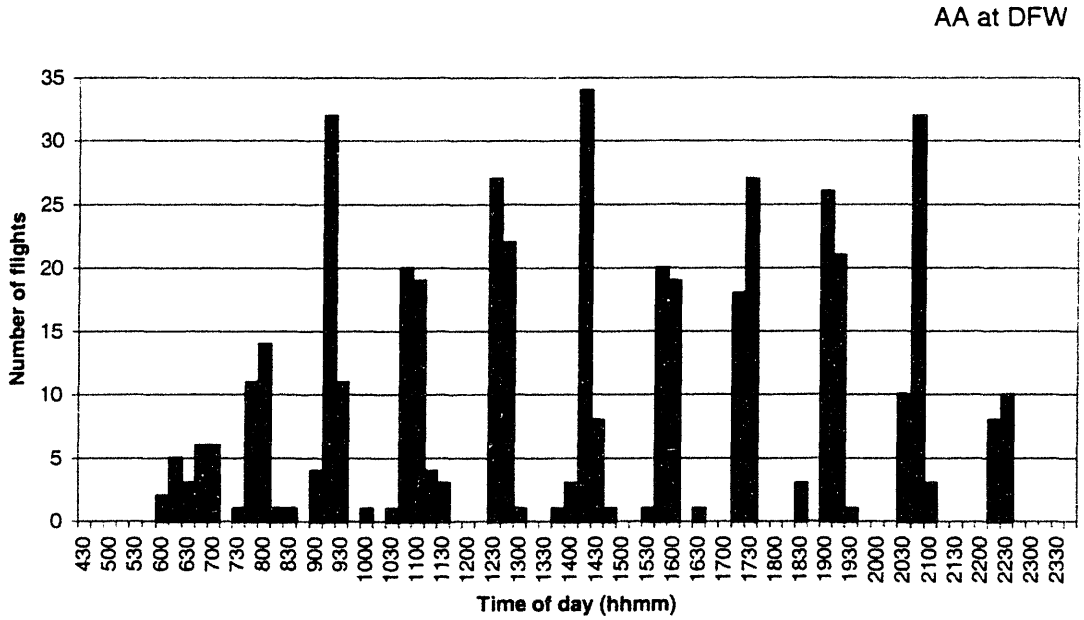

Figure B.2 American Airlines at DFW Departures in 15-Minute Intervals, April 2002

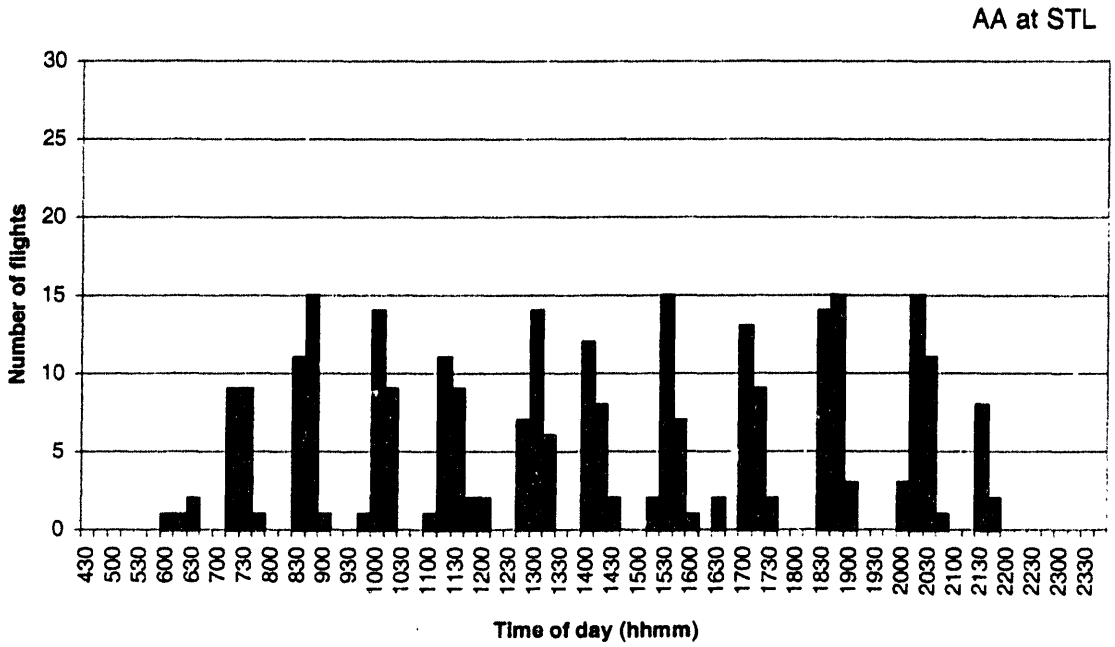

Figure B.3 American Airlines at STL Departures in 15-Minute Intervals, April 2002

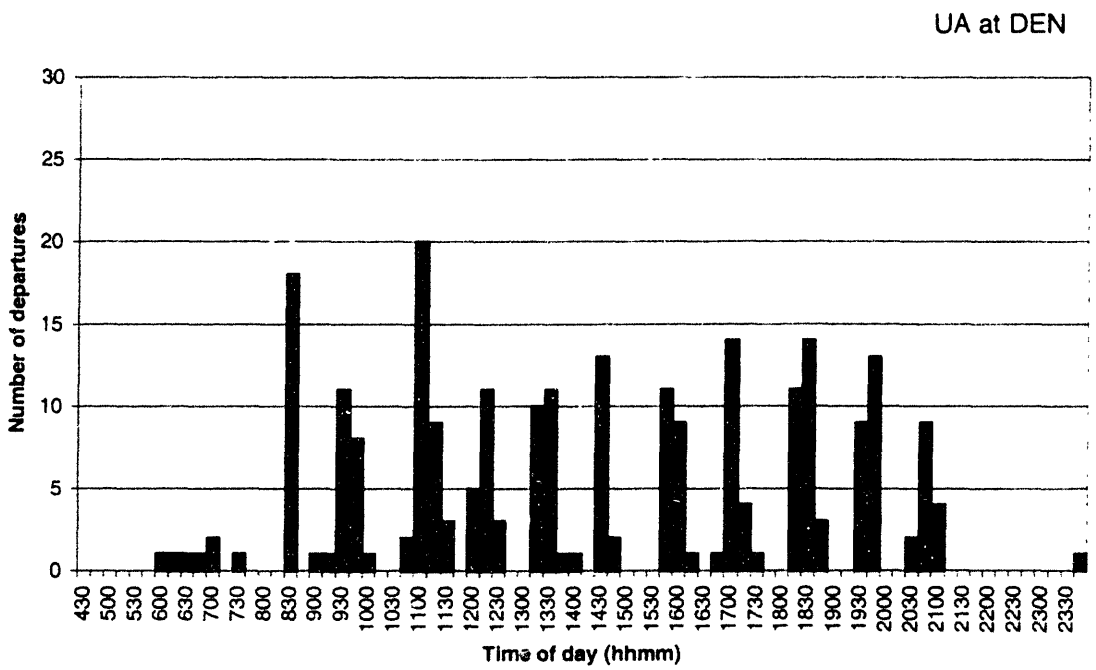

Figure B.4 United Airlines at DEN Departures in 15-minute Intervals, April 2002

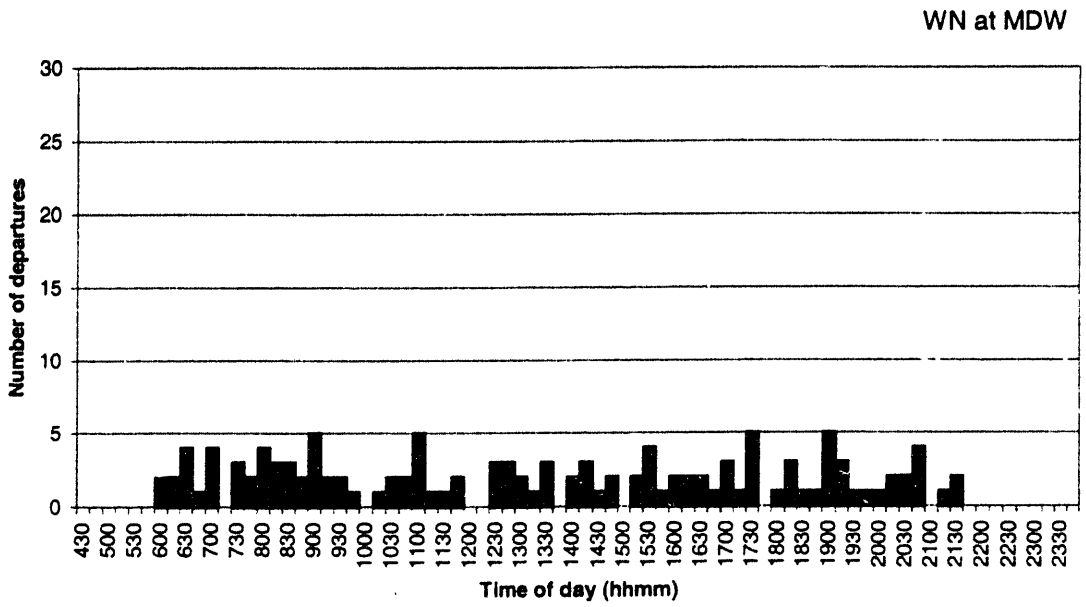

Figure B.5 Southwest Airlines at MDW Departures in 15-minute Intervals, April 2002

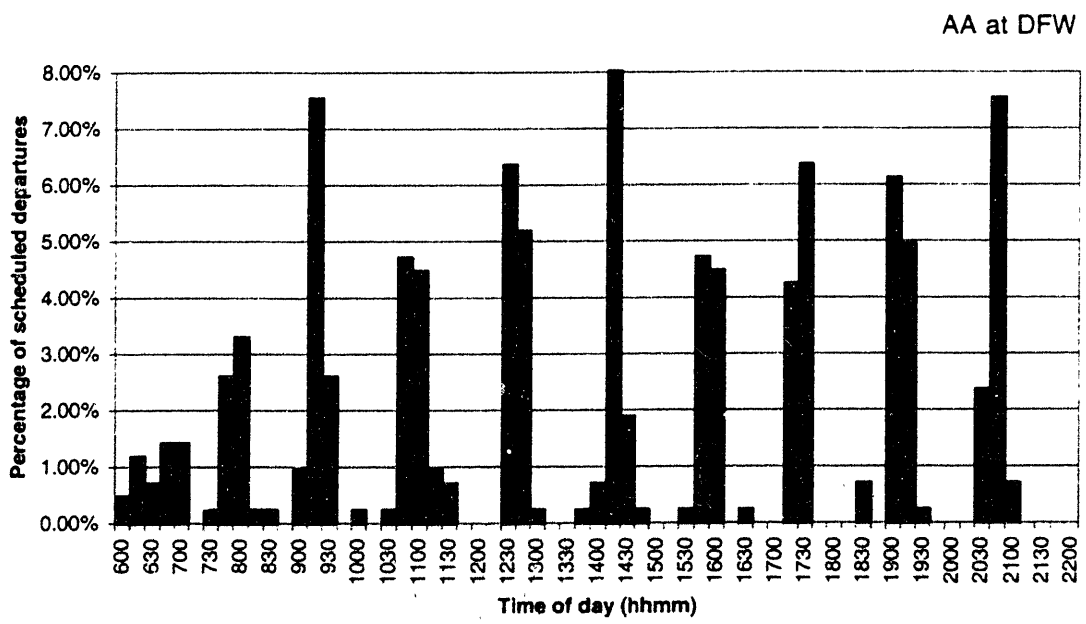

Figure B.6 American Airlines at DFW Departures in 15-Minute Intervals, April 2002, Normalized by Number of Flights

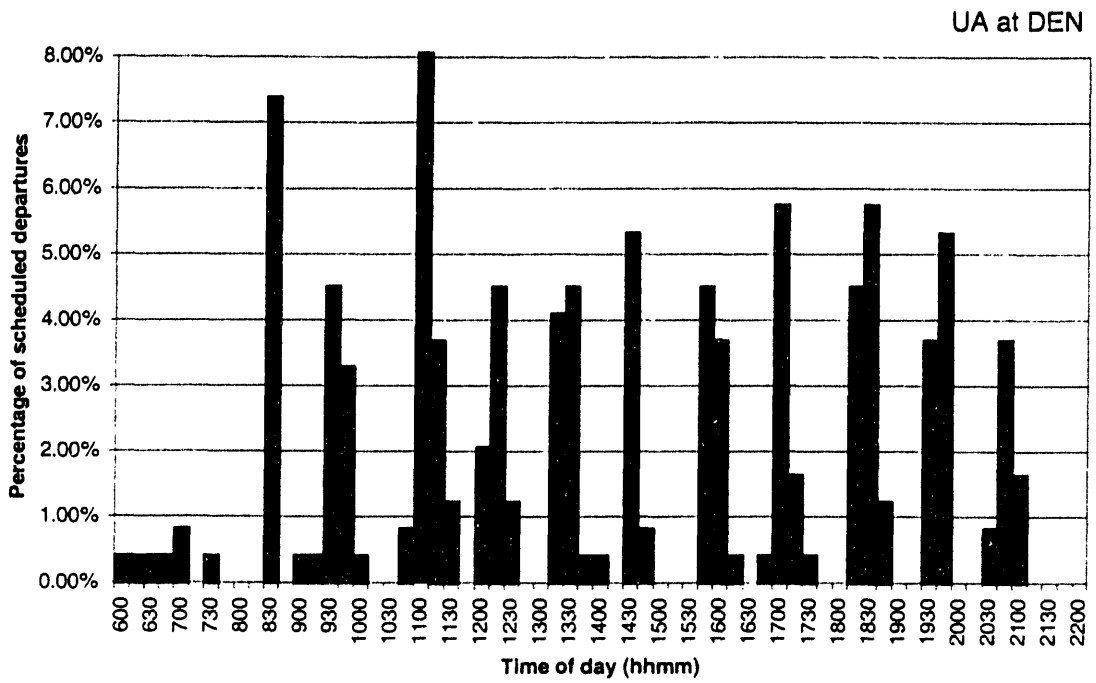

Figure B.7 United Airlines at DEN Departures in 15-minute Intervals, April 2002, Normalized by Number of Flights

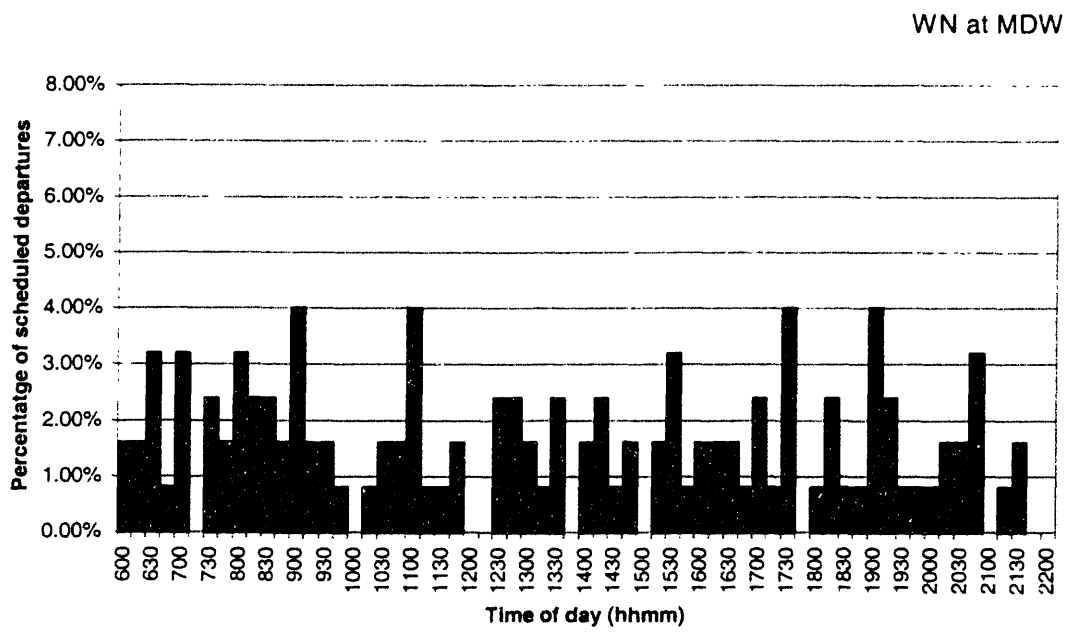

Figure B.8 Southwest Airlines at MDW Departures in 15-minute Intervals, April 2002

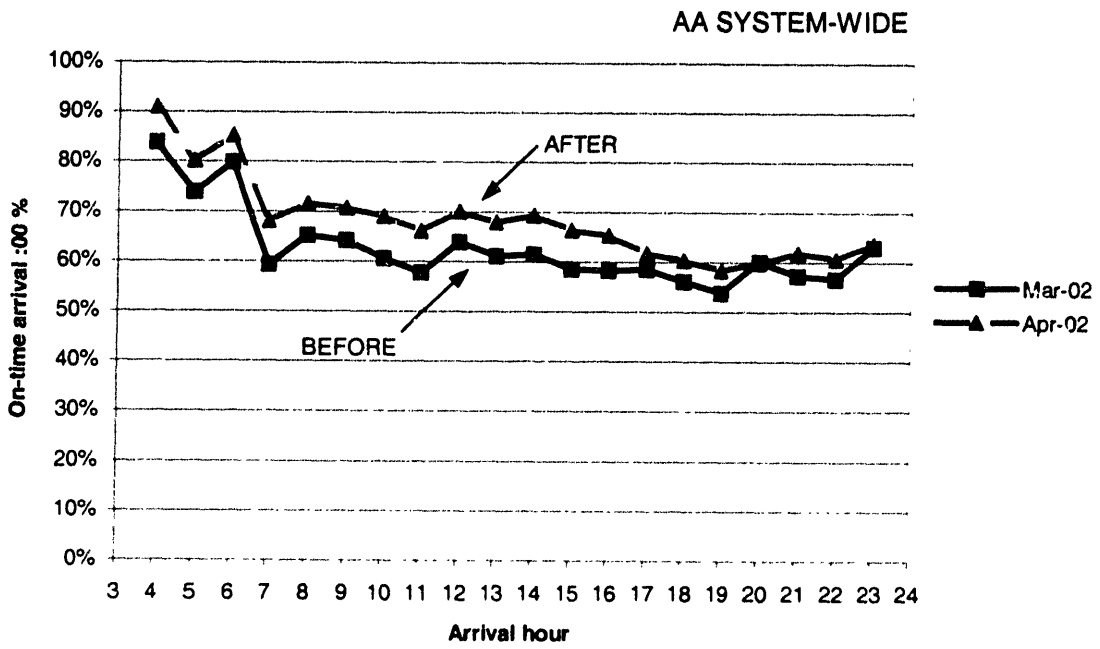

Figure B.9 American Airlines Arrival On-Time :00%, System-wide for All Domestic Airports

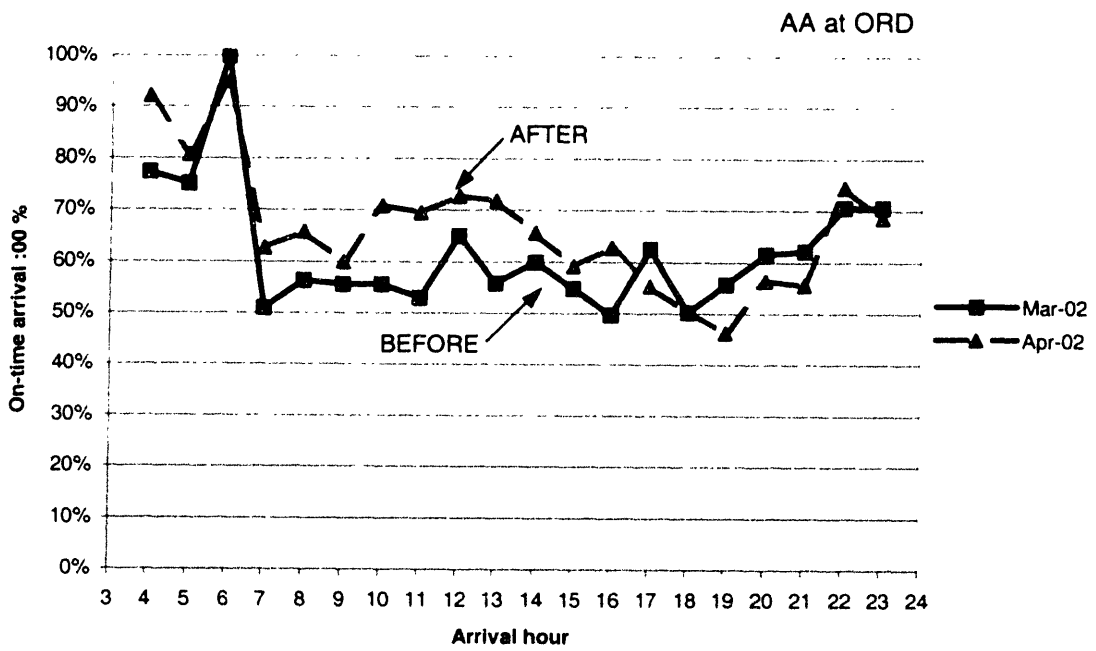

Figure B.10 American Airlines Arrival On-Time :00%, for All Flights at ORD