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TRENDS IN AIRLINE PASSENGER TRIP DELAYS:
EXPLORING THE DESIGN OF THE PASSENGER AIR TRANSPORTATION SERVICE

Lance Sherry
lsherry@gmu.edu
703-993-1711

Guillermo Calderon-Meza
gcaldero@gmu.edu
703-993-1711

George Donohue
gdonohue@gmu.edu
703-993-2093

Fax: 703-993-1521
Center of Air Transportation and Systems Research
Department of Systems Engineering and Operations Research
George Mason University
4400 University Dr.
Engineering Building, Room 4507
Fairfax VA 22030

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1 **Abstract:**

2
3 This paper describes an analysis of the year-over-year trends in Passenger Trip Delays. In 2008 there was a
4 5.1% reduction in the number of passenger trips from 2007, along with a 6% reduction in the number of flights.
5 This yielded a 13.1% reduction in the annual total passenger trip delays over 2007. Despite the improved total
6 delay performance, in 2008, one out of four passengers experienced a trip disruption due to a delayed flight,
7 cancelled flight, diverted flight, or denied boarding. Further the trip delay experienced by disrupted passengers
8 remained largely unchanged from 2007. Passengers on delayed flights experienced an average of 58 minutes in
9 trip delay. Passengers rebooked due to cancelled flights experienced an average delay of 10.6 hours.

10 The failure to improve the passenger experience, even during a reduction in the operations in 2008 is
11 indicative of an inherent flaw in the design of the *passenger transportation service*. The underlying design
12 principle is that when flights are delayed or cancelled, passengers can be transferred to alternate flights or re-
13 routed. This design approach is satisfactory when flight operations are predictable *or* when load factors are low
14 and a “reservoir” of seat-capacity exists to handle disruptions. In the twenty-first century, the air transportation
15 system has been optimized to eliminate excess seats, and experiences an on-time flight performance
16 predictability around 70%. The result – systemic passenger trip delays. A discussion of the underlying
17 structural issues and mitigation strategies is provided.

I. INTRODUCTION

Regional and economic productivity is derived, in part, from the speed and cost of introducing ideas and products to improve the quality of life of consumers and the productivity of firms. Air transportation plays major role in the conduct of economic transactions through rapid, affordable transportation of passengers and lightweight/high-value cargo between geographically distant and/or remote location (Donohue & Shaver, 2008). Even in a period of economic down-turn and increased travel costs, respondents to the Orbitz for Business 2008 Year End Survey (Orbitz, 2009) identified the fundamental importance of travel to their business model.

Flight delays and the lack of predictable travel times introduce additional costs to the conduct of business and leisure travel. Unpredictable travel times requires passenger consumers to insert “time padding” into their trip schedules such as leaving a day early and/or selecting flights with off-peak (i.e. early) travel times. Although this phenomenon has generated a cottage industry of “delay entrepreneurs” that offer alternate forms of communication (e.g. video-conferencing), alternate modes of transportation (e.g. trains, air-taxi), and flight delay and cancellation strategies (e.g. insurance), the costs to economic productivity is significant.

Whereas the design of the airline flight network has been explicit and has been optimized to achieve economies of scale and matching passenger demand with the required capacity, the design of the *passenger transportation service* has been an emergent property. The underlying design principle of the *passenger transportation service* is that passengers can be transferred to alternate flights and to alternate routes to mitigate disruptions in the flight transportation service. This design principle provides satisfactory performance when: (i) flight operations exhibit high reliability resulting in distributed minor disruptions to passengers, and (ii) the reserve seat-capacity on alternate flights and routes can absorb the disrupted passengers. At the turn of the twenty-first century neither of these performance requirements are satisfied. On-time flight performance is around 70% *and* passenger load-factors and flight frequency have been optimized to eliminate reserve seat-capacity. As a result, concentrated disruptions in the airline’s flight network cannot be absorbed any longer and passenger trip delays are at their highest levels in the history of air transportation.

This paper is the next in a series of papers presented at the Transportation Review Board and other industry conferences, that provides a description of the performance of the air transportation system with regard to Passenger Trip Delays over the past year (see Wang & Sherry, 2006; Sherry & Wang, 2007; Calderon-Mesa & Sherry, 2008). A summary of the Passenger Trip Delay statistics from 2008 is provided below:

- 610 million passenger trips were taken in 2008, a reduction in passenger trips of 5.1% compared with 2007.
- Airlines operated 7 million flights in 2008, a reduction in the number of flights of 6% compared with 2007
- The reduction in flights was achieved by cutting frequency of service in off-peak periods (not by eliminating service at airports) resulting in continued congestion at the major airports during peak operations
- Passengers accumulated 27,504.3 years in passenger trip delays in 2008, a reduction of 13.1% from 2007

Despite the reduction in total annual passenger trip delays, structural issues with the passenger transportation service persist.

- One out of four passengers experienced a trip disruption due to a delayed flight, cancelled flight, diverted flight, or denied boarding.

- 1 • Trip delays experienced by disrupted passengers was largely unchanged from 2007 averaging 101
2 minutes in 2008.
 - 3 ○ Passengers on delayed flights experienced an average delay of 58 minutes.
 - 4 ○ Passengers rebooked due to cancelled flights experienced an average delay of 10.6 hours.

5 This data illustrates the flaw in the design of the passenger transportation system. Despite a reduction in the
6 number of passengers and the number of flights that yielded a reduction in the annual total passenger trip delay,
7 one quarter of the passengers experienced a disruption in service. The magnitude of these delays remained
8 unchanged from 2007 to 2008. In the 2008, as the airlines reduced frequency of service (to match passenger
9 demand), high passenger load factors along with fewer flights between O/D pairs eliminated the “reservoir” of
10 seat capacity for dealing with disrupted passenger service. As a consequence, airlines exhibited a preference to
11 take longer flight delays (rather than cancel flights), and passengers experienced longer disruptions when re-
12 booked due to cancelled flights.

13 Since this mode of transportation has a monopoly in rapid, affordable long distance haulage, and because
14 the combined forces shaping the industry have resulted in a flawed passenger transportation service,
15 government intervention may be required to ensure the interests of the consumers. First government consumer
16 protection records need to capture the performance of the passenger transportation service. What is not
17 measured, cannot be improved. Second, an industry-government-public debate should ensue to establish
18 financially and socially responsible passenger trip delay standards. Third, targeted mitigation strategies can be
19 developed to meet the established standards. Some solutions can be achieved through the introduction of new
20 technologies, others will require direct or indirect regulations.

21 This paper is organized as follows: Section 2 provides an overview of Passenger trip Delays, Section 3
22 provides a description of the methodology used to generate Passenger Trip Delay Statistics from publicly
23 available data. Section 4 provides a detailed summary of Passenger Trip Delay statistics for 2008. The
24 implications of these results and future work is discussed in Section 5.

25 II. BACKGROUND – PASSENGER TRIP DELAYS

26 Passenger Trip Delay is defined as the difference between the actual time of arrival of the passenger and the
27 ticketed time of arrival.

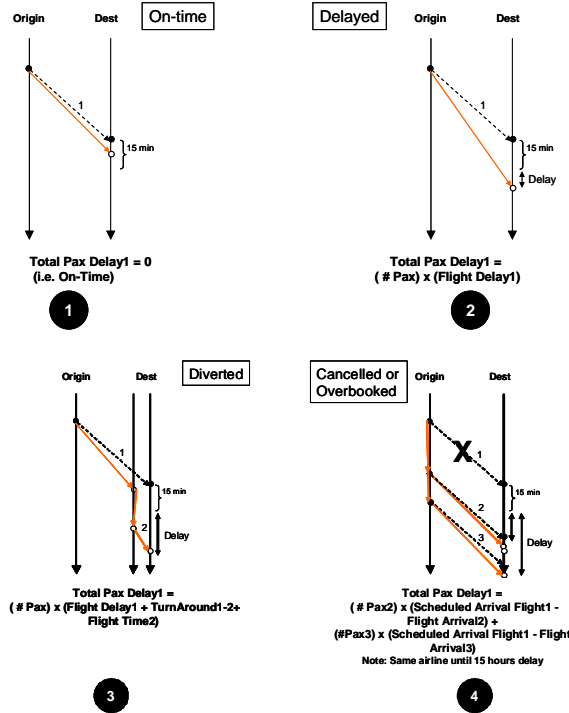
$$28 \text{ Passenger Trip Delay} = \text{Actual Pax Time of Arrival} - \text{Ticketed Time of Arrival}$$

29 Passenger Trip Delay can occur as a result of one or more of the following scenarios:

- 30 1. Passenger arrives on-time on the ticketed flight (i.e. less than 15 minutes after ticketed arrival time).
- 31 2. Passenger arrives late on the ticketed flight (i.e. greater than 15 minutes after ticketed arrival time).
- 32 3. Passenger arrives late when the ticketed flight is diverted.
- 33 4. Passenger arrives late after being re-booked on a later flight when the ticketed flight is cancelled.
- 34 5. Passenger arrives late, when the passenger is denied boarding on the ticketed flight and is re-booked on
35 a later flight.
- 36 6. Passengers on connecting itineraries arrive at the connecting airport late, miss the ticketed next leg in
37 their itinerary, and are re-booked on a later flight.

38 Scenarios 1, 2, 3, and 4 are illustrated in the Time-Space diagrams in the Figure 1. Scenario 5 is a variant on
39 Scenario 4.

1 The trip delays experienced by passengers on late flights and on diverted flights are proportional to the
 2 magnitude of the delay of these flights. The trip delays experienced by passengers that have to be re-booked
 3 due to cancelled flights, denied boarding, or missed connections are a function of the frequency and load factors
 4 (i.e. seats available) on other flights to the ticketed destination. As the frequency of the flights decreases and/or
 5 the load factor of candidate re-booked flights increases, the “reservoir” of seat capacity is reduced and the trip
 6 delay experienced by these passengers increases non-linearly. This phenomenon is illustrated in Figure 2



Passenger Trip Delay (solid) is determined by one of the scenarios described in Space-Time diagrams
 Figure 1

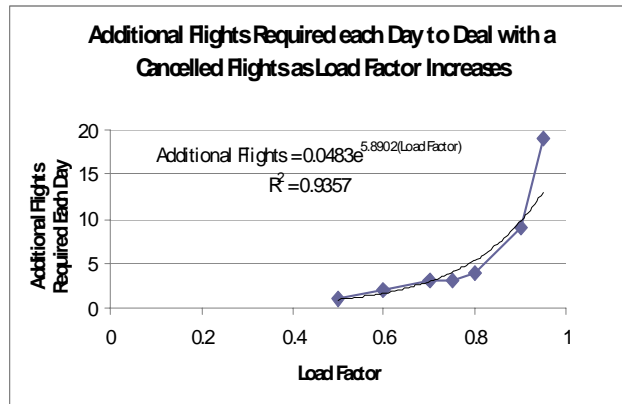
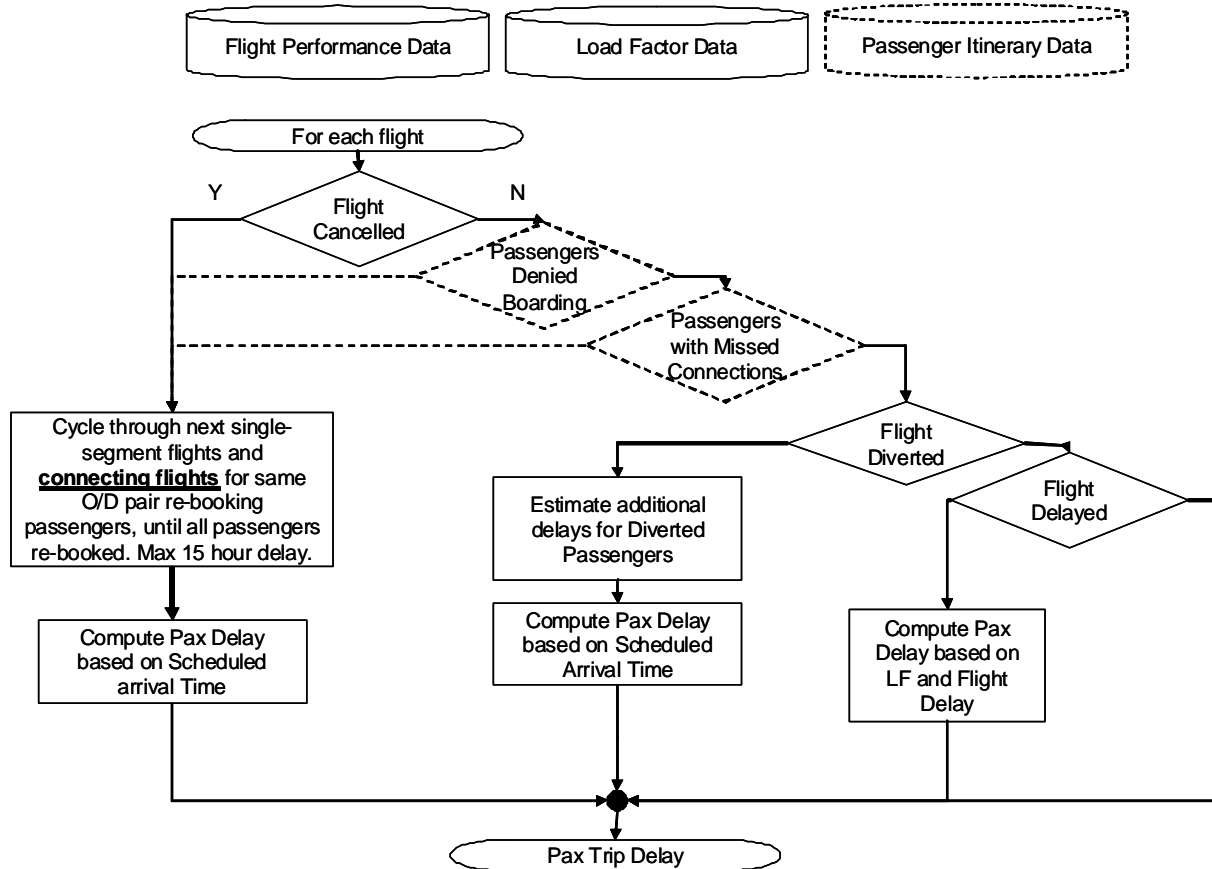


Chart identifies the number of additional flights (y-axis) required to re-book passengers from a cancelled flight as the load factor of the cancelled flight and candidate re-booked flights increases. Assumes homogeneous load factor and seats per flight.

Figure 2

III. METHODOLOGY FOR ESTIMATING PASSENGER TRIP DELAYS

Figure 3 provides an overview of the algorithm for the computation of Passenger Trip Delay for each of the scenarios described in Section 2. The algorithm is based on the work of Bratu and Barnhard (2005), Wang and Sherry (2006), Calderon-Mesa and Sherry (2008), and Zhu & Barnhard (2009).



Data-sources and Algorithm used to compute Passenger Trip Delays. Dashed elements identify limitations of the algorithm that are under development and described in Section X.4

Figure 3

Data Sources

Three sets of data are required for the analysis. First, airline flight performance data is required to determine flight delays for each individual flight, as well as any diversions and cancellations of individual flights. This information is derived from the BTS Airline On-Time Performance (AOTP) data-base which includes data from mandatory “Form 41” reporting for all airlines that provide service with more than 1% of total enplanements in a year.

Second, the Load Factor and Seat Size of flights serving each airport are derived from the BTS T-100 data-base. This information is in the form of aggregated, average monthly load factors and seat sizes for each airport pair. This data-set does not distinguish flight operations according to day-of-week and time-of-day. This is a limitation of the data-source and has been the subject of research to develop algorithms/functions to account for differences between peak and non-peak operations using proprietary samples of de-identified airline passenger itinerary data.

1 To take into account delays due to missed connections (scenario #6), passenger itinerary data identifying the
2 segments flown by each passenger, including connections, is required. This information is not currently
3 available publicly, but is the subject of on-going research.

4 Extensive pre-processing of the BTS data for reasonableness and frequency is also performed. This ensures
5 that issues with data quality are identified and reported to BTS. In addition, data from BTS is compared with
6 data from other publicly available data sources (e.g. ASPM and ASQP) to ensure reasonableness.

7 *Algorithm*

8 The algorithm processes each individual flight starting with the first flight in the period under investigation
9 to the last flight of the period. Following the algorithm in Figure 3, if the flight was *cancelled*, the passengers
10 are re-booked onto subsequent flights between origin and destination operated by the same airline or its
11 subsidiaries. Passengers are re-booked on direct (i.e. single segment) flights, as well as connecting flights (i.e.
12 two segment flights). To reflect airline policies of “maximizing capture of revenue,” passengers that cannot be
13 accommodated within 15 hours of their ticketed departure time on the same airline are considered to be
14 rebooked on a different airline and assigned a trip delay of 15 hours. Passengers that cannot be accommodated
15 on any flight within 15 hours of their ticketed departure time are assumed to switch modes of transportation and
16 are also assigned a penalty of 15 hours. The derivation of the 15 hour limit can be found in Bratu and Barnhard
17 (2005).

18 Passengers that are *Denied Boarding* or that *Miss Connections* are treated in the same manner as Passengers
19 on Cancelled flights and are rebooked on subsequent flights with the same rules and 15 hour limit. The absence
20 of the source for this data prohibits use of this part of the algorithm.

21 The Passengers Trip Delay for passengers on *Diverted* flights is estimated based on flying time to nearby
22 airports and turn-around time for specific aircraft. This estimate is typically on the high side for flights that do
23 not dock at a gate or refuel during a diversion, and on the low side for flights that are delayed in excess of re-
24 fueling time due to lack of access to their intended destination as a result of runway closures, reduced visibility,
25 etc.

26 The Passengers Trip Delay for passengers on *Delayed* flights is computed based on the reported flight
27 delays.

28 *Limitations*

29 The results reported in this paper are subject to two limitations in the availability of data. First, passenger
30 load factors in all calculations were drawn from the BTS T-100 data-base and reflect aggregated monthly load
31 factors. They do not account for time-of-day and day-of-week differences. In this way the results over-estimate
32 delays for off-peak flights and under-estimate the delays for peak period flights. When difference between peak
33 and off-peak load factors is not excessive and the number of peak and off-peak flights are not out of balance,
34 the results wash-out. Second, itineraries are treated as single segment flights. Passenger trip delays due to
35 missed connections are not computed. Previous research evaluating the sensitivity of the percentage of
36 connecting passengers using a simulation and assumptions on passengers flows (Wang & Sherry, 2006),
37 indicates that the contribution of missed connections to Total Passenger Trip Delays is approximately 10% of
38 the Total Annual Passenger Trip Delay.

39 IV. RESULTS

40 Total passenger trips taken in 2008 was down 5.1% over 2007. This reduction in trip demand was met by a
41 reduction in the supply of seats by the airlines (-6%). The number of airports with service remained constant,
42 but the frequency of service was reduced. Flights were typically eliminated at off-peak hours,

	2008	2007	% Change 2007 to 2008
Passenger Trips	610,236,061	642,719,733	-5.1%
Flights	7,007,835	7,453,156	-6.0%
Average Frequency of Flights between O/D Pairs	4.26	4.57	-6.8%
Airports Served	264	267	-1.1%
Total Passenger Trip Delays (Years)	27,504	31,923	-13.8%
Total Passenger Trip Delays (Hours)	240,937,580	279,650,046	-13.8%
Average Passenger Trip Delay (Mins)	23.7	26.1	-2.4 minutes

Statistics for Passenger Trips in 2008 compared with 2007.

Table 1

1
2 leaving peak-hour operations at the congested major airports remained unchanged. These results are
3 summarized in Table 1.

4 Total trip delays accumulated by all passengers in 2008 was 27,504 years - down 13.8% over 2007. Despite
5 the reduction in total annual passenger trip delays, the average trip delay, over all the passengers in 2008 was
6 23.7 minutes, only slightly down from 26.1 minutes in 2007. Is this a paradox? Can a reduction in total
7 passenger delay of 13.1% yield only 2.4 minute improvement for the average passenger?

8 Table 2 summarizes the details of the passenger experience. One in four passengers (23.4%) experienced a
9 disruption in their trips in 2008. This percentage, albeit high for a service industry, was down from 27.3% in
10 2007. On average, disrupted passengers experienced 101 minutes of trip delay.

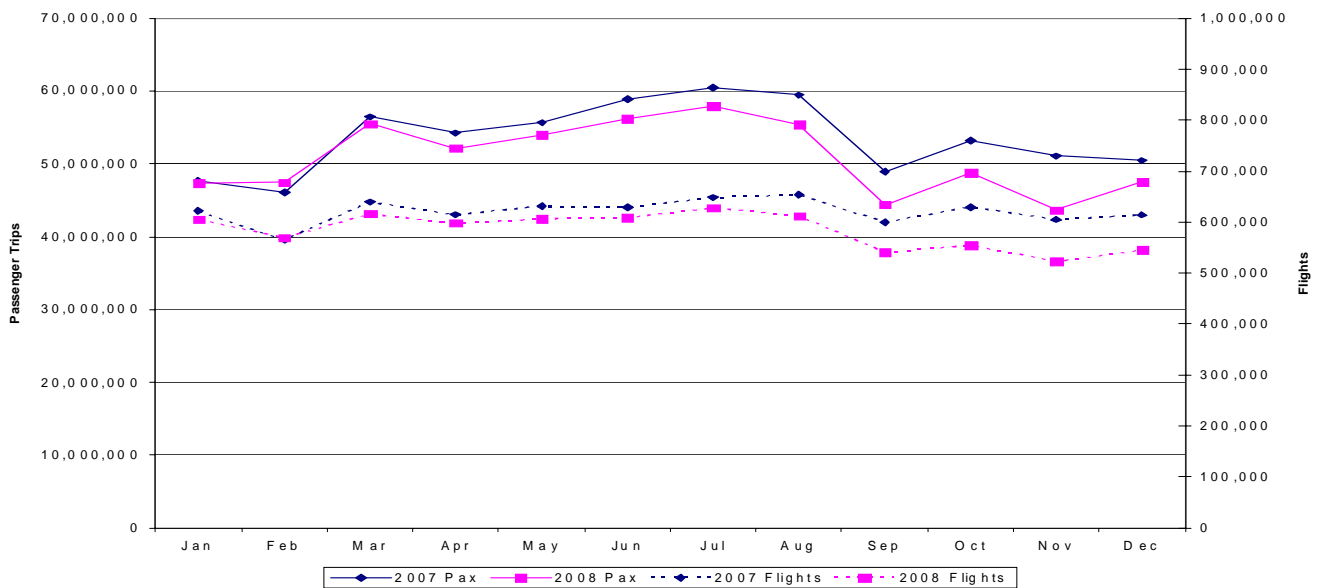
11 The two main contributors to passenger trip delays were delays due to delayed flights (52% of total) and trip
12 delays due to cancelled flights (44% of total). Twenty two percent (21.6%) of passengers experienced trip
13 delays due to delayed flights. On average, these passengers experienced 57.7 minutes of delay in 2008,
14 compared with 66.4 minutes in 2007. Passengers re-booked due to cancelled flights (1.6%), experienced delays
15 of 10 hours and 36 minutes in 2008, compared with 10 hours and 48 minutes in 2007.

	Percentage Passengers			Average Passenger Trip Delays		
	2008	2007	% Change 2007 to 2008	2008	2007	% Change 2007 to 2008
Passenger Experiencing Trip Delay (> 15 mins)	23.4%	27.3%	-14.1%	101.1 mins	100.8 mins	No Change
Passengers on Delayed Flights	21.6%	23.9%	-9.6%	57.7 mins	66.4 mins	-8.7 mins
Passengers on Cancelled Flights	1.6%	1.8%	-9.8%	10.6 hrs	10.8 hrs	-12 mins
Passengers on Diverted Flights	0.3%	0.2%	7.6%	3.75 hrs	3.75 hrs	No Change
Passengers Denied Boarding on Oversold Flights	<0.001% (1.1 in 10,000)	<0.001% (1.12 in 10,000)	No Change	3.1 hrs	3 hrs	+ 6 mins

Statistics for Passenger Trip Delays in 2008 compared with 2007.

Table 2

Seasonal trends in passenger trip demand and the number of flights are shown in Figure 4. The solid lines, referenced to the left axis, represent the passenger trips taken in each month in 2008 and 2007. The dashed lines, referenced to the right axis, represent the number of flights operated in each month. As the year progressed and the impact of the economic downturn affected travel, the number of passenger trips and number of flights in 2008 diverged from 2007 statistics. The airlines, as a whole, were very effective in cutting capacity



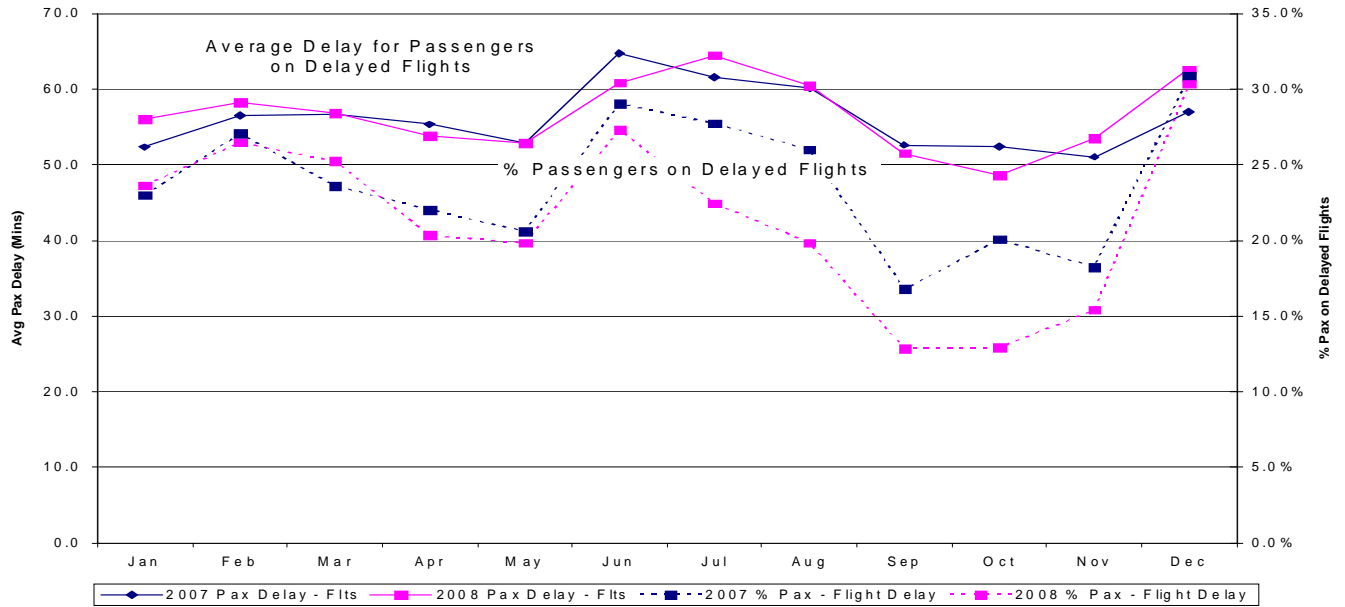
Seasonal trends in passenger trip demand and flights by month. Solid lines, referenced to the left axis, represent the passenger trips taken in each month. Dashed lines, referenced to the right axis, represent the number of flights operated in each month. Divergence of 2008 demand and supply from 2007 evident as year progressed.

Figure 4.

to keep load-factors high.

The role of delayed flights in passenger trip delays is documented in Figure 5. The average passenger trip delay experienced by passengers on delayed flights is shown by the solid line and referenced to the left axis. Despite the reduction in the number of flights, in 2008, the passenger trip delay data for passengers on delayed flights tracks the 2007 statistics in the first-half of the year. In the second half of the year, passenger trip delay from delayed flights in 2008 was greater than 2007 in July, November and December.

The percentage of passengers impacted by delayed flights, the dashed lines referenced to the right axis, in 2008 exhibits similar patterns to 2007. In January, February, May and December, the percentage of passengers affected in 2008 is the same as in 2007. In June through November, the percentage of passengers in 2008 is approximately 5% lower in 2008 than in 2007.

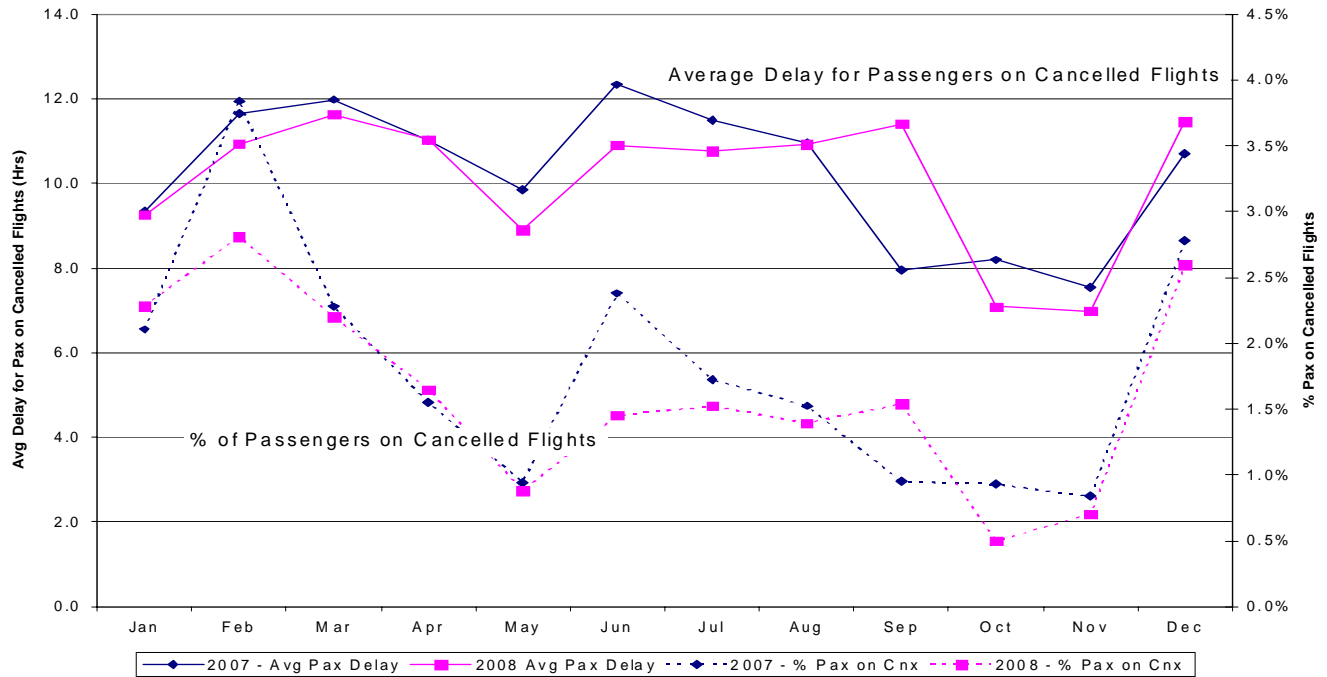


Seasonal trends in passenger trip delay due to delayed flights. Solid lines, referenced to the left axis, represents the average delay experienced by passengers on delayed flights. Dashed lines, referenced to the right axis, represents the percentage of passengers on delayed flights.

Figure 5.

The role of cancelled flights in passenger trip delays is documented in Figure 6. In 2008, the annual percentage of cancelled flights was down from 2.2% in 2007 to 2% in 2008. Likewise the percentage of passengers on cancelled flights was down from 1.8% in 2007 to 1.6% in 2008. The percentage of passengers affected by cancelled flights, the dashed-line referenced to the right-axis, shows lower percentages in 2008 than 2007 in each month except for September when 2008 percentages exceeded 2007.

The average passenger trip delay experienced by passengers that are re-booked due to cancelled flights, shown by the solid line and referenced to the left axis, did not yield reductions in the percentage of cancelled passengers and the delay experienced by these passengers (e.g. September and December).



Seasonal trends in passenger trip delay due to cancelled flights. Solid lines, referenced to the left axis, represents the average delay experienced by passengers rebooked due to cancelled flights. Dashed lines, referenced to the right axis, represents the percentage of passengers on cancelled flights .

Figure 6.

V. CONCLUSIONS & FUTURE WORK

Despite the reductions in the number of flights (-6%) resulting in improvements in the total passenger trip delay (-13.8%), the passenger trip performance of the system did not significantly improve from 2007 to 2008. This is reflected by the percentage of passengers experiencing disrupted trips due to delayed, cancelled, diverted and oversold flights (23.4%), as well as the magnitude of trip delay statistics for passengers on delayed flights (58 minutes) and cancelled flights (10 hours and 36 minutes).

Failure in the Design of the Passenger Transportation Service

The passenger transportation service operates on the premise that flights arrive as scheduled. When disruptions to flight service occur, the system is designed to transfer passengers from one flight to another or to change flight routing to deliver the passengers. When flights operate with a high degree of reliability, or when the reliability of service degrades but the seat-capacity on alternate flights and routes is sufficient to absorb the disrupted passengers, the service functions within tolerable performance limits.

When the reliability in flight service degrades, and the “reservoir” of seat-capacity is low, the reliability of the passenger transportation service falls apart. In 2008, as the airlines reduced frequency of service (to match passenger demand), high passenger load factors along with fewer flights between O/D pairs eliminated the “reservoir” of seat capacity for dealing with disrupted passenger service. As a consequence, airlines exhibited a preference to take longer flight delays (rather than cancel flights), and passengers experienced longer disruptions when re-booked due to cancelled flights.

Designing a Robust Passenger Transportation Service

1 In large part the passenger transportation service was not explicitly designed. Instead it was an emergent
2 property of the evolution of the airline operations that sought economies of scale, and increased revenues
3 through optimization of the airline network. This is evident in the absence of clauses in the airline “contract of
4 carriage” to explicitly deal with disruptions to the passenger transportation service.

5 The result is a system design that allows the airline profit imperative to trump the passenger trip experience
6 for consumers that have no other competitive choices in modes of transportation over long distances and/or to
7 remote locations. High passenger load-factors, achieved by reduced service and fleet mix selection to meet
8 passenger demand, contribute to airline profits. At the same time, high passenger load-factors eliminate any
9 seat-capacity buffer airlines have to handle irregular operations by shifting passengers to alternate flights. As a
10 consequence, airline operations are obliged to delay flights longer to avoid having to rebook passengers. Also,
11 passengers on rebooked flights experience longer delays.

12 The bottom-line is that: (i) air transportation has a monopoly on affordable, rapid transportation over long
13 distance and to remote locations, and (ii) forces in the industry have resulted in the (implicit) design of a
14 passenger transportation service that is disincentivized to restructure operations to compete for consumers
15 based on trip reliability (as is the case in the cargo industry).

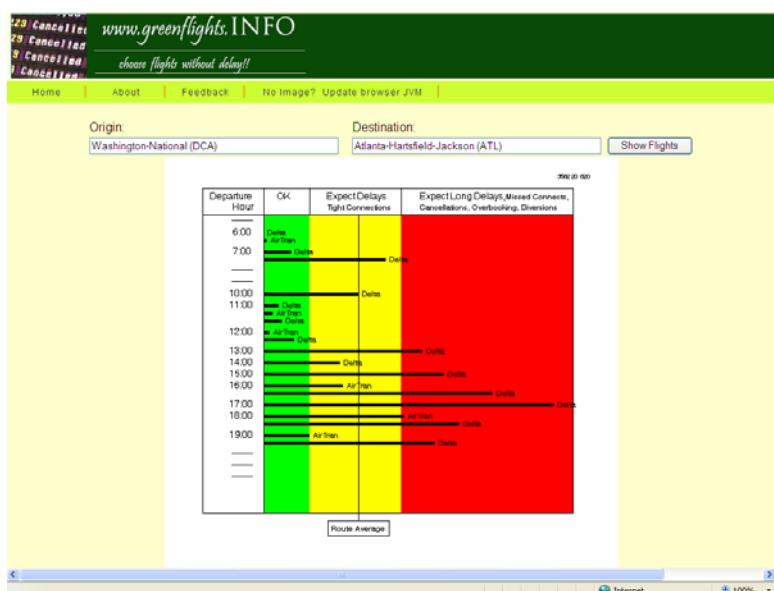
16 The following is a 3 step process for developing rational strategies for mitigation of this phenomenon.

17 1) Measure and report passenger trip reliability. Based on the adage “one cannot improve what one does
18 not measure,” the Bureau of Transportation Statistics should report passenger trip delays. Regulations could be
19 imposed to extend airline Form 41 reporting to include load-factors on individual flights. This data would be
20 de-identified and/or not directly released. Keep in mind the goal is to report passenger trip delay performance,
21 not airline performance or passenger itineraries (which should remain subject to civil liberty restrictions).

22 2) Set Service Standards for Passenger Reliability With the data on passenger trip reliability available, a
23 public debate can occur on acceptable performance tolerances. The result would be a service standard
24 equivalent to the 15 minute On-Time Performance standard for flight delays. Since passenger delays are
25 derived from cancelled flights, diverted flights, missed connections and denied boarding, as well as delayed
26 flights, service standards for airline performance in these other areas would be derived.

27 3) Mitigation Strategies. Until passenger trip delay metrics are used to establish passenger trip service
28 standards, consumer protection regulations will remain absent and airlines will continue to be disincentivized to
29 restructure their operations to compete for consumers based on trip reliability (as is the case in the cargo
30 industry). Because this mode of transportation has a monopoly in rapid, affordable long distance haulage,
31 government regulations may be required to ensure the interests of the consumers when the forces in the industry
32 are conflict with interests of the public

33 Airline policies with regard to delayed, cancelled, or diverted flights are covered in the airline’s “contract of
34 carriage” to which passnegrs give consent at the time of purchase of the ticket. In Europe and the U.S., airlines
35 do not guarantee their schedules and have no legal obligations with respect to reliability of operations to
36 ticketed schedules. Trip delays due to delayed flights and cancelled flights are simply considered a risk of travel
37 and are not required to be compensated on either continent. Financial compensation is provided to passengers
38 denied boarding due oversold flights both in Europe and the U.S.



Passenger Trip Delay information by flight on the GreenFlights.info website

Figure 7

Recent regulations by the European Union, however, have legislated passenger treatment when passengers experience disruptions in transit. In the European Union, passengers on flights delayed more than 5 hours are eligible for a refund of the ticket only on condition that the passenger does not take a flight with an alternate airline. For cancelled flights, an unspecified financial compensation is due the passenger if a flight is cancelled within 14 days of departure, the airline is unable or unwilling to re-route the passenger “close” to the original times, and the airline cannot prove the cancellation is the result of “extraordinary circumstances.”

In the U.S. there is no federal or state legislation regarding passenger treatment in-transit. Airlines have voluntarily adopted “Customer Service Plans” modeled on the Air Transport Association’s 12 Point Customer Service Commitment. These commitments include: notifying passengers of known flight delays and cancellations, and meeting customers’ essential needs during long on-aircraft delays (see http://www.airlines.org/customerservice/passengers/Customers_First.htm). Passengers also have the right to report complaints to the Aviation Consumer Protection Division, of the U.S. Department of Transportation (see <http://airconsumer.ost.dot.gov/escomplaint/es.cfm>).

There are three sources of information consumers can use to assess the reliability of a flight. First, on request from the consumer, the U.S. airlines are obliged to provide the on-time performance code for any flights under consideration. A one-digit code is provided in the reservations computer that shows how often that flight arrived on time (within 15 minutes) during the most recent reported month. For example, an “8” means that flight arrived within 15 minutes of the scheduled arrival time between 80% and 89.9% of the time. Second the Aviation Consumer Protection Division, of the U.S. Department of Transportation publishes monthly reports with summary statistics of on-time performance of flights by airlines and service to/from airports. This report also includes the “Hall of Shame” that identifies flights that are consistently delayed or cancelled. Both of these sources of information are limited to flight delay statistics (not passenger trip delay statistics).

Historic passenger trip delay data for passengers ticketed on individual flights is provided on the website www.Greenflights.info. This website, maintained by graduate students at George Mason University’s Center for Air Transportation Systems Research, uses the algorithm and data sources described in this paper to provide estimated trip performance for each flight. See Figure 7.

1 For other ideas on mitigation strategies see Donohue and Shaver (2008).

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