TRENDS IN AIRLINE PASSENGER TRIP DELAYS (2007 – 2009)

Lance Sherry (Ph.D.), Guillermo Calderon-Meza (Ph.D. Candidate), Ashwin Samant (M.Sc.)
Center for Air Transportation Systems Research, George Mason University, Fairfax, VA.

Abstract

Delays in arrival of airline passengers should be *the* on-time performance metric of the airline passenger transportation system (not flight delays). A passenger trip can experience arrival delays, relative to the ticketed arrival time, as a result of a delayed flight, as well as a diverted flight, cancelled flight, denied boarding, and/or missed connection. This paper describes the results of analysis of annual passenger trip delays for U.S. domestic airline flights from 2007 to 2009. These results are based on estimated itineraries and load factors, and actual airline (flight) on-time performance data available from government websites.

From 2007 to 2009, there has been a 32% decline in annual passenger trips. The airlines have responded by cutting back flights by 14% and reducing seat capacity. Total passenger trip delay dropped 43% during this period in part due to fewer trips and in part due to reduced congestion. Cancelled flights accounted for 39% of the total trip delays, delayed flights contributed 44% of the total, and missed connections contributed 16%.

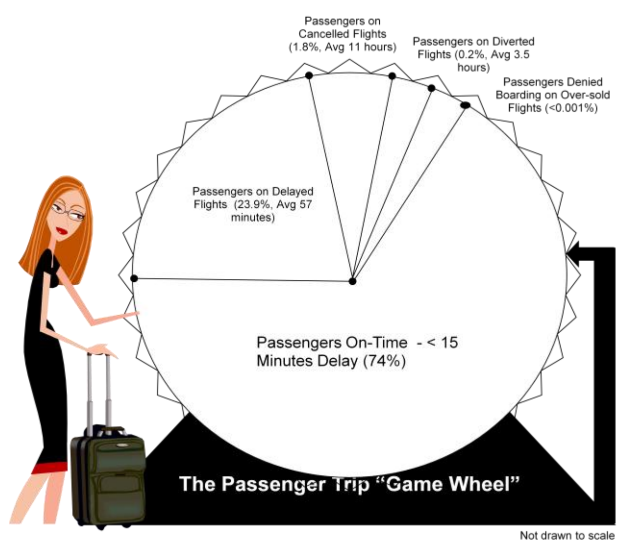
Despite the reduction in total trip delays, the passenger experience did not improve. In 2009, 18 out of 100 passengers experienced a trip disruption of, on average, 105 minutes. In contrast, in 2007, 22 out of 100 passengers experienced a trip disruption of, on average, 116 minutes. Passengers on cancelled flights, dependent on load factors and frequency of service for rebooking, experienced the highest average trip delays of approximately 10 hours.

The continued poor passenger trip performance is indicative of the limitations of the *design* of the transportation system that relies on reserve capacity to compensate for poor reliability in flight performance. The implications of this limitation are discussed.

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 citizens and the productivity of firms. Air transportation plays a 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 locations (Donohue & Shaver, 2008).

Delays in arrival and the lack of predictable travel times introduce additional costs to the conduct of business and leisure travel. These costs accrue when consumers 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.



Passenger trip experience is represented as spinning a game-wheel with probability of being delayed due to a delayed flight, cancelled flight, diverted flight, denied boarding, or missed connection

Figure 1

How bad is the situation? This paper describes the results of an analysis of passenger trip delays, not flight delays, estimated using publicly available airline transportation statistics from the Bureau of Transportation Statistics (bts.gov). The algorithms for this computation have evolved from single airline hub itinerary analysis (Bratu & Barnhart, 2005), to all airline single segment flight (i.e. direct itineraries only) analysis with direct only rebooking strategies (Wang & Sherry, 2006; 2007), to all airline single segment flights (i.e. direct itineraries only) with connecting rebooking strategies and diverted flight routes (Sherry & Calderon-Meza, 2008). This paper describes the results using a version of the algorithm that now includes itineraries for direct as well as connecting trips.

The passenger trip experience can be summed up as a game-wheel, shown in Figure 1, in which the passenger trip has a probability of being delayed due to a delayed flight, diverted flight, cancelled flight and/or a missed connection. The consequence of each one of these options is a trip delay ranging from 56 minutes for a delayed flight to an overnight stay (15 hours).

This paper describes the results of an analysis of passenger trip delays for domestic airlines service from 2007 to 2009.

- In 2009, 308M passenger trips were taken. This is a reduction of 32% since 2007.
- In response to the decreased demand, the airlines reduced service by 14%. The number of airports served has remained constant, but airlines have reduced frequency of service between O-D pairs, reduced average seats per flight, and increased hub itineraries.
- During this period, total passenger trip delays dropped 43%. This reduction is due to the decrease in the number of trips as well as the reduction in congestion from fewer flights.
- Cancelled flights accounted for 39% of the total trip delays. Delayed flights contributed to 44% of the total, and missed connections, 16%.

Despite the reduction in total trip delays, passenger experience did not improve:

- In 2009, 18 out of 100 passengers experienced a trip disruption of, on average, 105 minutes. In contrast, in 2007, 22 out of 100 passengers experienced a trip disruption of, on average, 116 minutes.
- Passengers on cancelled flights (1.1%), dependent on load factors and frequency of service for rebooking, experienced the highest average trip delays of approximately 10 hours.

These results indicate a limitation in the design of the airline transportation system. The underlying design principle of the *passenger transportation service* is that passengers can be transferred to alternate flights and to alternate routes in response to disruptions in the scheduled flight 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. Neither of these performance requirements have been routinely satisfied in 2009. 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 organized as follows: Section 2 provides an overview of Passenger trip Delays, Section 3 provides a description of the methodology used to generate Passenger Trip Delay Statistics from publicly available data. Section 4 provides a detailed summary of Passenger Trip Delay statistics for 2008. The implications of these results and future work are discussed in Section 5.

Passenger Trip Delays

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

Passenger Trip Delay = Actual Passenger Time of Arrival – Ticketed Time of Arrival

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

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

The trip delays experienced by passengers on delayed flights and on diverted flights are proportional to the magnitude of the delay of these flights. The trip delays experienced by passengers that have to be re-booked due to cancelled flights, denied boarding, or missed connections are a function of the frequency and load factors (i.e. seats available) on other flights to the ticketed destination. As the frequency of the flights decreases and/or the load factor of candidate re-booked flights increases, the "reservoir" of seat capacity is reduced and the trip delay experienced by these passengers increases non-linearly.

Methodology for Estimating Passenger Trip Delays

Figure 2 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), Sherry & Wang, (2007), Sherry & Calderon-Mesa (2008), and Zhu (2007).

Data Sources

Three sets of data are required for the analysis. Publicly available data from the Bureaus of Transportation Statistics is used (BTS, 2009).

First, the Passenger Itineraries are described by combining the O/D pair itineraries, and the passengers per itinerary, in the DB-1B data-base with the flight segments in the AOTP data-base. The result is O/D and O/H/D ticket itineraries with passenger counts. For an alternate formulation of passenger trip itineraries see Zhu (2007).

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.

Third, 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.

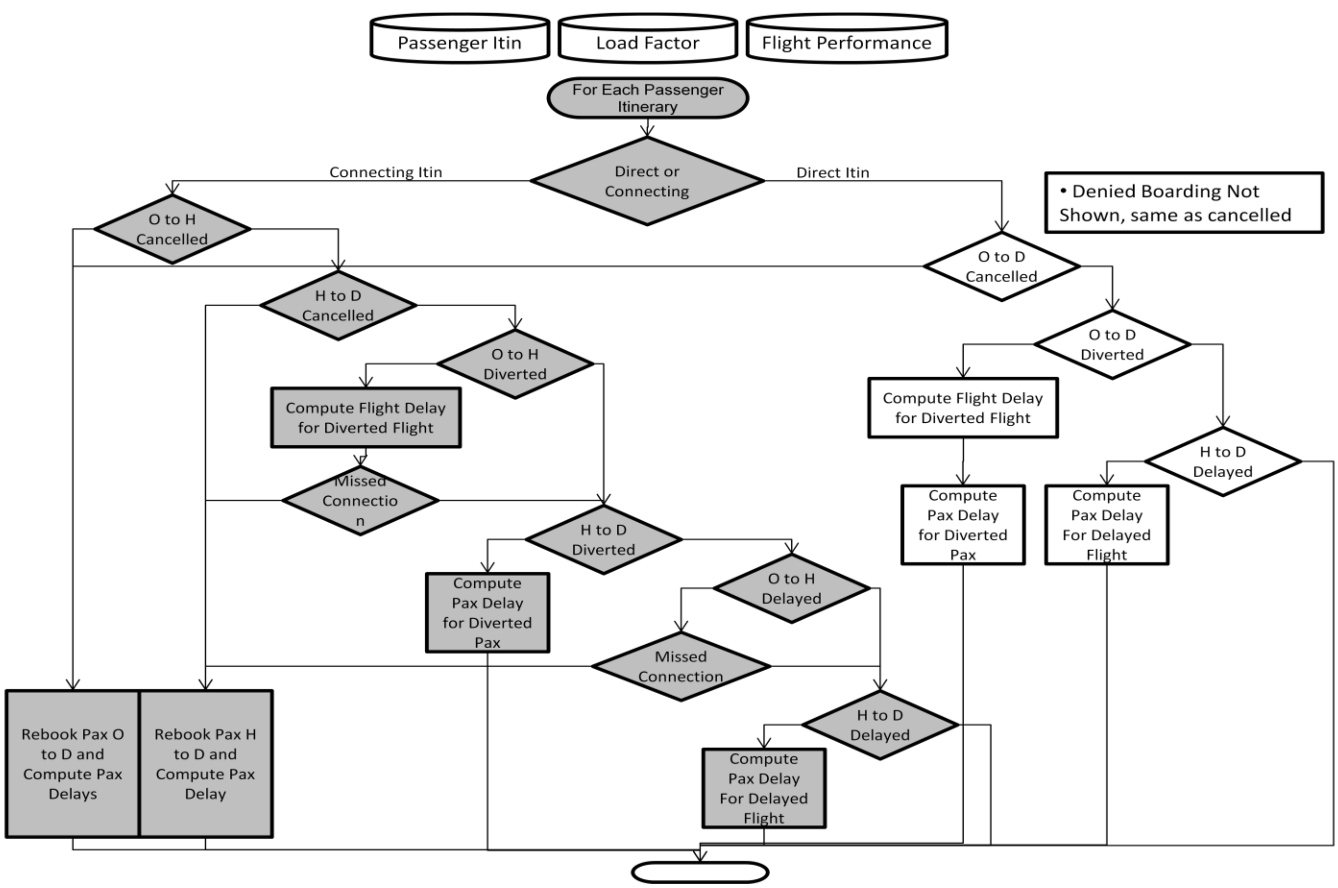
Extensive pre-processing of the BTS data for reasonableness and frequency is also performed. This ensures that issues with data quality are identified and reported to BTS. In addition, data from BTS is compared with data from other publicly available data sources (e.g. ASPM and ASQP) to ensure reasonableness.

Algorithm

The algorithm, summarized in Figure 2, processes each O-D and O-H-D itinerary starting with the first ticketed itinerary in the period under investigation to the last ticketed itinerary of the period.

The algorithm branches depending on whether the itinerary is direct or connecting. For connecting itineraries the following rules apply:

1. If the Origin-to-Hub flight is cancelled, then rebook the passengers to the Destination on the first available direct or connecting flights, update load factors, and compute the passenger trip delay.
2. If the Hub-to-Destination flight is canceled, then rebook the passengers to the Destination on the first available direct or connecting flights, update load factors, and compute the passenger trip delay.
3. If a passenger is denied boarding on the Origin-to-Hub flight, then rebook the passengers to the Destination on the first available direct or connecting flights, update load factors, and compute the passenger trip delay. It is assumed that if a passenger is boarded on a the O-H leg, they will not be denied boarding on the H-D leg.
4. If the Origin-to-Hub flight is diverted, then compute the estimated delay for the diversion and check if the passengers miss their connection at the Hub. If the passengers miss their connection at the Hub, then rebook the passengers to the Destination on the first available direct or connecting flights, update load factors, and compute the passenger trip delay.
5. If the Hub-to-Destination flight is diverted, compute the passenger trip delay.



Summary of algorithm used to estimate passenger trip delays.

Figure 2

6. If the Origin-to-Hub flight is delayed, then check if the passengers miss their
7. connection at the Hub. If the passengers miss their connection at the Hub, then rebook the passengers to the Destination on the first available direct or connecting flights, update load factors, and compute the passenger trip delay.
8. If the Hub-to-Destination flight is delayed, then compute the estimated delay for the diversion and compute the passenger trip delay.

For direct itineraries the following rules apply:

9. If the Origin-to-Destination flight is cancelled, then rebook the passengers to the Destination on the first available direct or connecting flights, update load factors, and compute the passenger trip delay.
10. If a passenger is denied boarding on the Origin-to-Destination flight, then rebook the passengers to the Destination on the first available direct or connecting flights, update load factors, and compute the passenger trip delay.
11. If the Origin-to-Destination flight is diverted, then compute the estimated delay for the diversion and compute the passenger trip delay.
12. If the Origin-to-Destination flight is delayed, compute the passenger trip delay.

Limitations

The results reported in this paper are estimates based on aggregate monthly load factors for each flight and 10% samples passengers on each itinerary. These estimates do not account for time-of-day and day-of-week differences. In this way the results over-estimate delays for off-peak flights and under-estimate the delays for peak period flights. When the difference between peak and off-peak load factors is not excessive and the number of peak and off-peak flights are not out of balance, any errors wash-out.

Results

This section describes the results of the analysis of passenger trip delays for the period 2007 to 2009.

Capacity Reduction in Response to the Economic Downturn

In 2006 and 2007, the U.S. Gross Domestic Product (GDP) increased 2.7% and 2.1% respectively resulting in increased demand for air transportation. In 2007, the domestic airline passenger transportation system provided 453 million passenger trips via 7.5 million flights through 276 airports. The average frequency of service of between O-D pairs was 4 flights per day. See Table 1 for statistics.

In 2008, the GDP flattened out with only a 0.4% increase. The stalled economy resulted in demand for 5% fewer passenger trips. The airlines adapted to the reduction in demand by reducing service with 6% fewer flights yielding an average frequency of service on 3.7 flights per day.

In 2009 the GDP declined -2.4% resulting in significant reduction in demand: -29% fewer

PASSENGER TRIP DEMAND AND CAPACITY	2007	2008	2009	Change 07 to 08	Change 08 to 09
Passenger Itineraries (M)	453	432	308	-5%	-29%
Direct (M)	316	298	209	-5.5%	-30%
Connecting(M)	137	134	96	-3%	-26%
% Connect	30	31	32	+2%	+4%
Flights (millions)	7.4	7.0	6.4	-6%	-8%
Frequency of Service (average flights per day)	4	3.7	3.4	-7.5%	-8%

Airlines responded to reduced demand for travel (-5% in 2008, and -29% in 2009) with reduction in flights (-6% and -8%), yielding reduced frequency of flights and a slight shift from direct itineraries to connecting itineraries.

Table 1

passengers trips. The reduction in demand was met by an 8% reduction in flights with an average frequency of service of 3.3 flights per day.

During this contraction of service, airlines continued to provide scheduled service to all airports served in 2007. Reductions in service took the form of reduced frequency and a slight shift from direct itineraries to connecting itineraries. In 2007, 30% of all passengers flew on connecting itineraries. In 2009, 32% of the passengers were on connecting itineraries.

Annual Passenger Trip Delay Statistics

In 2007, passengers accrued delays (due to delayed flights, diverted flights, rebooking for cancelled flights, rebooking for denied boarding and rebooking for missed connections) of 262 million hours (29,873 years). This trip delay experienced by the average passenger was 25 minutes.

In 2008, when the number of flights dropped by 6%, the total trip delays experienced by passengers, dropped 11% to 233 million hours (26,605 years). The trip delay experienced by the average passenger was 24 minutes, a 6% drop from 2007.

In 2009, when the number of flights was off by another 8%, the total trip delays experienced by passengers dropped 36% to 148.5 million hours (16,957 years). The trip delay experienced by the average passenger was 16 minutes, a 32% drop from 2008.

Table 2 summarizes the Total Trip Delay statistics.

TOTAL PASSENGER TRIP DELAYS	2007	2008	2009	Change 07 to 08	Change 08 to 09
Total Passenger Trip Delays (million hours)	261.6	233	148.5	-11%	-36%
Average Passenger Trip Delay (minutes)	25	24	16	-6%	-32%

Total Passenger Trip Delays declined in proportion with reduction in the number of passenger itineraries. The trip delay spread out over all the passengers also dropped proportionately.

Table 2

Disrupted Passenger Trip Delay Statistics

Disrupted passengers are passengers who experience a trip disruption from any of the following: delayed flight, diverted flight, and rebooking for cancelled flight, denied boarding and missed connection. The percentage of passengers experiencing disrupted trips and the average delay experienced by the passengers is summarized in Table 3.

In 2007, 22% of the passengers experienced a disrupted trip. Despite the 6% reduction in flights that occurred in 2008, 20% of the passengers experienced a disrupted trip. The additional 8% reduction of flights in 2009, did provide passengers some relief. In 2009, 17% of the passengers experienced disrupted flights.

DISRUPTED PASSENGERS	2007	2008	2009	Change 07 to 08	Change 08 to 09
% Passengers	22%	20%	17%	-10%	-16%
Total Passengers Disrupted (millions)	138.5	118.4	93.3	-15%	-21%
Average Disrupted Passenger Trip Delay (minutes)	110	110	92	-	-10%

Statistics for Passengers experiencing disrupted trips. Despite the reduction in number of flights in 2008, and 2009 (-6%, -8%), the percentage of passengers experiencing disrupted flights remained approximately the same at one in five passengers.

Table 3

Contribution of each Type of Disruption

The percentage of passengers affected by each type of disruption is summarized in Table 4.

The majority of the passengers experience disruptions to trips due to delayed flights: 18% in 2007, 16.5% in 2008, and 14% in 2009. The year-over-year change in passengers experiencing delayed flights is proportional to the reduction in passengers trips.

% OF PASENGERS ON …	2007	2008	2009	Change 07 to 08	Change 08 to 09
Delayed Flights	18%	16.5 %	14%	-14.5%	-9.8%
Cancelled Flights	1.7%	1.6%	1.1%	-9%	-31%
Diverted Flights	0.2%	0.3%	0.2%	+7.8%	-5.8%
Missed Connections	1.7%	1.5%	1.3%	-13%	-14%

Percentage of passengers experiencing trip delay by type of disruption.

Table 4

Cancelled flights and missed connections affect between 1% and 2% of the passengers. The year-over-year reductions are proportional to the reduction in number of passengers. The exception is the number of passengers affected by cancelled flights, which dropped 31% from 2008 to 2009.

The average delay experienced by passengers for each type of disruption is summarized in Figure 5.

AVERAGE TRIP DELAY	07	08	09	Change 07 to 08	Change 08 to 09
Passengers on Delayed Flights (mins)	57	57	52	-1.4%	-10%
Passengers on Cancelled Flights (mins)	653	644	588	-1.3%	-8.6%
Passengers on Diverted Flights (mins)	40	37	49	-6.2%	-31.2%
Passengers with Missed Connections (mins)	133	129	130	-2.8%	-7.2%

Average trip delay experienced by each passenger by cause of trip delay.

Table 5

Passengers on delayed flights experienced delays of approximately 1 hour. The reduction in flights in 2009 (-8%) yielded only a 10% reduction in passenger trip delays.

Passengers on cancelled flights experienced delays of approximately 10 hours. These delays are the result of delays accrued by waiting for the rebooked flight. The load factors on later flights serving the same O-D pair, and frequency of service between the O-D pairs, determines the magnitude of the delay for these passengers. The magnitude of the delay did not change as the transportation system adapted from 2207 to 2009.

Passengers on missed connections experienced an average delay of approximately 2 hours. The magnitude of the delay did not change as the transportation system adapted.

Table 6 provides an overview of the contributions of each type of disruption to the total trip delay. Passengers on cancelled flights contribute to the total delay as much as passengers on delayed flights. Only approximately 2% of the passengers experience cancelled flights, but their individual trip delays are on average 10 times greater than trip delays on delayed flights resulting in the assymetry in contribution to total trip delay.

% OF TOTAL PASSENGER TRIP DELAY	2007	2008	2009	Change 07 to 08	Change 08 to 09
Passengers on Delayed Flights (mins)	41%	42%	44%	2%	5%
Passengers on Cancelled Flights (mins)	45%	45%	39%	0%	-14%
Passengers on Diverted Flights (mins)	0%	0%	1%	12%	69%
Passengers with Missed Connections (mins)	13%	12%	16%	-7%	32%

% Total Passenger Trip Delay for each type of disruption. 2% of the passengers experience disruption due to cancelled flights, same as contribution to delayed flights.

Table 6

One of the largest contributors to Passenger Trip Delays are cancelled flights that require an overnight stay. Table 7 shows the number and percentages of passengers that experienced this sub-class of disruption.

% OF TOTAL PASSENGER TRIP DELAY	2007	2008	2009	Change 07 to 08	Change 08 to 09
Passengers required to stay overnight	1.6	1.3	0.6	-18.8%	-53.8%
% of Total Itineraries	0.4%	0.3%	0.2%		
% of Cancelled Itineraries	14.6%	13.8%	9.9%		

Number and percentage of passengers required to overnight when rebooked.

Table 7

Conclusions

The statistics for passenger trip disruptions, described in this paper, illustrate a weakness in the design of the passenger transportation system. Despite a reduction in the number of passengers, resulting in a reduction in the number of flights, that in turn, yielded a reduction in the annual total passenger trip delay, approximately one out of every five passengers experienced a disruption in service. The magnitude of these delays remained unchanged from 2007 to 2009.

The underlying design premise of the airline transportation system, is that disruptions in service can be absorbed by a reserve capacity (i.e rebook passengers on a later flight).

When service reliability is high, or when service reliability is degraded but reserve capacity is available, the system can meet a minimum standard of passenger trip delay performance.

Over the last decade, the airlines have continued to improve their ability to dynamically match capacity with demand resulting in high load factors. The high load factors, along with reduced frequency of service, has eliminated the "reservoir" of seat capacity for dealing with disrupted passenger service.

Since this mode of transportation has a monopoly in rapid, affordable long distance haulage, and because the combined forces shaping the industry have resulted in the design limitation in passenger transportation service, government intervention may be required to ensure the interests of the consumers.

First government consumer protection records need to capture the *performance of the passenger transportation service*. On-time performance of flights is an inadequate proxy for passenger trip delay, as on-time flights does not account for cancelled flights (39% of the total passenger trip delay), or missed connections (16% of the total passenger trip delays). What is not measured, cannot be improved.

Second, an industry-government-public debate should ensue to establish financially and socially responsible *passenger trip delay standards*. Without the standards, it is difficult to assess performance.

Third, targeted mitigation strategies can be developed to meet the established standards. Some solutions can be achieved through the introduction of new technologies (e.g. NextGen), others will require direct (e.g. airport capacity limits and auction of slots) or indirect regulations. Actions that do not directly address the on-time flight performance, flight cancellation rates, or reserve seat capacity will not improve the passenger trip experience.

References

[1] Donohue, G.L. & R. Shaver (2008) "Terminal chaos: Why U.S. air travel is broken and how can we fix it," AIAA, Washington D.C.

[2] Bratu, S., Barnhart, C. (2005). An Analysis of Passenger Delays Using Flight Operations and Passenger Booking Data. *Journal of Transportation and Statistics, Number 1, Volume13, 1-27*

[3] Bureau of Transportation and Statistics (2009). Airline On-Time Performance Data, Form 41 Traffic T-100 Domestic Segment Data, DB1_B Coupon Data. Available: http://www.transtats.bts.gov.

[4] Wang, D., L. Sherry (2006) Passenger Trip Metric for Air Transportation. In proceedings of the 2nd International Conference on Research in Air Transportation - ICRAT 2006.
[5] Sherry, Lance, D. Wang (2007) Air Travel Consumer Protection: Metric for Passenger On-Time Performance. Transportation Research Record, Transportation Research Board of the National Academies, Volume 2007, pages 22-27.
[6] Sherry, L. & Calderon-Meza, G. (2008) Passenger Trip Delays in the U.S. Airline Transportation System. In Proceedings International Conference on Research in Air Transportation (ICRAT-2008), Fairfax, VA, 2008
[7] Zhu, Y. (2007) Evaluating Airline Delays: The Role of Airline Networks, Schedules and Passenger Demands. Masters Thesis, MIT, Cambridge, Massachusetts. Advisor: Cynthia Barnhart

Acknowledgements

Thank you to Peg Young, (BTS), Thea Graham, Dan Murphy, Joe Post, Dave Chin, Kimberly Noonan (FAA), Natalia Alexandrov, Mike Madson, Maria Consiglio (NASA), Poornima Balakrishna, Ben Levy (Sensis Corp.), Chris Brinton (Mosaic ATM), Gregg Wollard (MWAA), Taryn Lewis, Norm Fujisaki, Terry Thompson, Jerome Lard, Arash Yousefi (Metron Aviation), John Ferguson, David Schaar, Mariecl Medina, Vivek Kumar, Yimin Zhang, and Akshay Belle. Funding for this research was provided by the FAA DTFAWA-08-F-GMU, NASA NRA NNH06ZEA001N, and internal GMU Research Foundation Funds.

Email Addresses

lsherry@gmu.edu

2010 Integrated Communications Navigation and Surveillance (ICNS) Conference

May 11-13, 2010