PASSENGER TRIP DELAY STATISTICS FOR 2010

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Abstract:

The *raison d'etre* of the Airline Passenger Transportation System (APTS) is the rapid, affordable, and safe transportation of passengers (and cargo). The top-level performance measure of the system is passenger trip delay, defined as the difference between ticketed passenger arrival time and actual passenger arrival time. Passenger trip delay accounts for delays caused by cancelled flights, missed connections and diversions, as well as delayed flights. Algorithms developed to estimate passenger itineraries and passenger trip delay statistics using publicly available data, were used to generate passenger trip delay statistics for 2010.

In 2010 an estimated 421 million passengers ticketed on 46.8 million itineraries were transported on 8.7 million flights. Passenger on-time performance was 78.7%. The average delay for a disrupted passenger was 67 minutes. The total trip delay experienced by passengers in 2010 was 11,669 years. The largest contributors to total passenger trip delays were: passengers on direct itineraries disrupted by delayed flights - 32%, passengers on connecting itineraries disrupted by cancelled flights - 23%, connecting itineraries disrupted by delayed flights - 16%, and missed connections - 14%.

Since 2007, annual passenger trip delay is down 26%, however in 2010 1-in-5 passengers experienced a trip disruption (compared to 1-in-4 in 2007) with an average delay for disrupted passengers of 67 minutes (73 minutes in 2007).

These results highlight the important role the “structure” of the airline network, in addition to on-time flight performance, plays in determining passenger trip reliability. These results have important implications for modernization and consumer protection initiatives.

Introduction

The Airline Passenger Transportation Systems (APTS) is a mass-transit system. It is unique in that it provides service through complex interactions between airlines, air navigation service providers (ANSPs), airports, and their supply chains. The markets served and schedules (i.e. frequency of service and seat capacity) are determined by the airlines based on the ANSP and airport infrastructure available. The operational performance is determined by the interaction between all of the stakeholders in the presence of operational uncertainties (e.g. weather. equipment). As a consequence, no single entity can manage, or have responsibility for, the performance of the overall passenger transportation service.

Despite the lack of ownership, the top-level performance measure of the APTS is passenger trip delays. Passenger trip delays are defined as the difference between ticketed passenger arrival time and actual passenger arrival time. This measure of performance accounts for disruptions due to cancelled flights, missed connections and diversions, as well as flight delays. In this way, this performance measure extends beyond the boundaries of flight operations and air traffic control, whose performance is measured by flight-centric measures of performance.

This transportation service is a key enabler of the U.S. economy, providing rapid, affordable, safe transportation to people and lightweight cargo. When all categories of trip disruptions are taken into account, the cost in lost productivity to the U.S. economy in 2007 was estimated at $32B. For this reason measuring, understanding, and addressing the causes of passenger trip delays is critical to improving economic productivity and initiatives to modernize the air transportation system.

This paper describes the results of analysis of passenger trip delay statistics for 2010. Previous papers report passenger trip delay statistics for 2007 through 2009 (Sherry et al, 2007; 2008; 2010). The statistics are generated using two algorithms that operate on publicly available data provided by the Bureau of Transportation Statistics (BTS, 2011). The first algorithm generates an estimate of the passenger itineraries. The second algorithm uses the estimated passenger itineraries and historic on-time flight performance data to estimate the passenger trip delay statistics.

The main passenger trip delay statistics for 2010:

- 421M passengers were transported on 46.8M itineraries serviced by 8.7M flights.
- Passenger trip on-time was 78.7% with an average delay for a disrupted trip of 67 minutes. The total passenger trip delay for 2010 was equivalent to 11,669 years.
- 49% of the total passenger trip delays were the result of delayed flights (average trip delay 37 minutes), 33% cancelled flights (average trip delay 4.9 hours), 14% missed connections (average trip delay 4.4. hours).
- 67% of the passengers were on direct itineraries, 33% on connecting itineraries.

- Passengers on direct itineraries (67%) were disrupted 12.9% of the time experiencing an average delay of 51 minutes. Passengers on connecting itineraries (33%) were disrupted 8.3% of the time experiencing an average delay of 93 minutes.

- The contribution to total passenger trip delays was: direct itineraries disrupted by delayed flights 32%, connecting itineraries disrupted by cancelled flights 23%, connecting itineraries disrupted by delayed flights 16%, connecting itineraries disrupted by missed connections 14%, and direct itineraries disrupted by cancelled flights 11%.

These results highlight the importance of the "structure" of the airline network in determining passenger trip reliability. In comparison to 2007, the 11% reduction in scheduled flights has reduced congestion and improved flight on-time performance yielding a 26% improvement in total passenger trip delays (15,841 years in 2007 to 11,669 years in 2010). However, the likelihood of a passenger trip disruption has changed from one-in-four in 2007 to one-in-five in 2010. Also, the average delay experienced by disrupted passengers has improved by only 6 minutes from 73 minutes in 2007 to 67 minutes in 2010.

These results have important implications for the modernization initiatives and consumer protection schemes. In addition to flight on-time performance, passenger trip delays are determined in large part by the airline network itinerary structures, aircraft size, load factors, frequency of service, and banking structures. To effect sustainable change, these factors must be taken into account.

This paper is organized as follows: the next section provides an overview of the relationship between flights, itineraries, and disruptions, and provides definitions of passenger trip delay statistics. The following section summarizes the algorithms and data used for the analysis. The Results section provides a detailed accounting of the passenger trip delay statistics by disruption type and by itinerary type (direct vs. connecting). The Conclusions section discussed the impact of these results on modernization initiatives and consumer protection schemes.

Flights, Itineraries and Disruptions

Airlines provide the transportation service by scheduling and selling tickets for carrying passengers between origin and destination (O/D) pairs. To maximize utilization of assets (e.g. aircraft, crews, gate agents, etc.), airlines operate a time-space network of flights that is synchronized with the ticketed schedule and the availability of aircraft and labor.

The building block of airline transportation is a *fligh*t between an origin and destination airport. A flight is defined by a unique date, flight number, an origin/destination, a scheduled departure time, a scheduled arrival time, an actual departure time, and an actual arrival a time. A flight is also defined uniquely by the available seats, load factor, and by its performance status: on-time, delayed, cancelled, diverted.

Feasible sequences of flights to ferry passengers from an origin to a destination are known as *passenger itineraries*. A passenger itinerary is defined uniquely by a single flight (e.g. AAL 123) or by a sequence of flights (e.g. UAL 345 & UAL 456), along with the number of passengers on the itinerary. A passenger itinerary supported by a single flight is classified as *direct itinerary*. A passenger itinerary supported by more than one flight is classified as a *connecting itinerary*. Each passenger itinerary is also uniquely classified by an itinerary status: on-time, delayed, rebooked due to missed connection, rebooked due to cancellation, and diverted.

Networks and Itineraries

Airlines schedule flights to operate in a time-space network of flights such that aircraft and crews can be positioned to operate the flights in contiguous manner throughout the day. A well designed network of itineraries will maximize revenue by meeting passengers travel demands, and minimize costs by using the most cost-effective aircraft, keeping the aircraft utilized as much as possible, and minimizing the impact of disruptions.

By definition, each flight in the network will have passengers with direct and connecting itineraries on board. For example, a Delta flight from Washington, D.C. (DCA) to Atlanta (ATL), will have passengers flying on a direct itineraries from DCA to ATL, as well as passengers flying on connecting itineraries from DCA to DEN, MEM, LAX, …, all connecting at ATL. The number of passengers on each flight is the sum of all the passengers on each of the passenger itineraries that form that flight.

Relationship between Flight Disruptions and Itinerary Disruptions

A flight can be disrupted as follows: delayed, cancelled, or diverted. For each of the class of flight disruptions there exists both a probability of disruption and a magnitude of the average flight delay. When flights are disrupted, passenger itineraries are disrupted. The relationship between a flight disruption and a passenger itinerary disruption is summarized in Table 1. The likelihood of a disruption of direct itineraries is a function of the likelihood of the disruptions of flights only. The magnitude of the disruption for passengers on direct itineraries is a function of

Itinerary Type	Type of Itinerary Disruption	Type of Flight Disruption	Probability of Itinerary Disruption	Magnitude of Itinerary Disruption (Average)
Direct	Delayed	Arrival of flight O-D is delayed (more than 15 minutes)	Based on Probability of Delayed Flight (typical = 0.3)	Based on Average delay for delayed flights
	Cancelled	Flight O-D is cancelled (typical 0.02)	Based on Probability of Cancelled Flight (typical 0.02)	Based on Availability of Seats on subsequent flights and Time to next flight
Connecting	Delayed	Arrival of flight H-D is delayed (more than 15 minutes)	Based on Probability of Delayed Flight (typical 0.3)	Based on Average delay for delayed flights
	Cancelled	Flight O-H is cancelled *or* flight H-D is cancelled	Twice probability of Cancelled Flight (typical 2 * 0.02)	Based on Availability of Seats on subsequent flights and Time to next flight
	Missed Connection	Flight O-H is delayed such that passengers miss connection to H-D	A function of connecting times and airline policies regarding holding flights (typical 0.02)	Based on Availability of Seats on subsequent flights and Time to next flight

The relationship between flight disruptions and passenger itinerary disruptions. Also describes the characteristics of the passenger trip delays. O- Origin, H-Hub, D-Destination.

Table 1

the flight delay for delayed itineraries, and a function of the availability of seats and time to next flight for passengers rebooked for cancelled itineraries.

The likelihood of a disruption of connecting itineraries is a function of the likelihood of the disruptions of flights as well as the structure of the connections. Connecting itineraries that are delayed reflect the likelihood and magnitude for a delayed flight between the hub and the destination. Connecting itineraries that are cancelled are a function of the cancellation rates for the flights inbound to the hub and outbound from the hub. The magnitude of the disruption for passengers is a function of availability of seats and time to next flight for passengers rebooked on cancelled itineraries. The probability of a missed connection on a connecting itinerary is a function of the likelihood for the delay of flights that are inbound to the hub, with a magnitude of delays that extends beyond the connecting window and the airline policy for coordinating inbound and outbound banks by holding flights. Analysis of historic data indicates a probability of a missed connection at 0.02.

Passenger Trip Delay Metrics

Reliability in passenger transportation is measured by the difference between ticketed scheduled arrival time and the actual arrival time. This measure takes into account delays accrued by passengers due to delayed and diverted flights, as well as rebooking due to cancelled flights and missed connections.

There are three main metrics used to capture the passenger trip reliability (Bratu & Barnhart, 2005; Wang & Sherry, 2006, Sherry & Wang, 2007; Sherry & Calderon-Meza, 2008; Zhu, 2007; Sherry, Samant, Calderon-Meza, 2010):

1. Annual Total Passenger Trip Delays
2. Percentage of Passengers Disrupted
3. Average Trip Delay for Disrupted Passengers

Annual Total Passenger Trip Delays represents the cumulative delays experienced by passengers. These delays include disruptions due to delayed flights, cancelled flights, diverted flights and missed connections. This is a holistic metric of the magnitude of the trip delay phenomenon and is used to estimate lost economic productivity.

The Percentage of Passengers Disrupted represents the likelihood of a disruption due to delayed flights, cancelled flights, diverted flights or missed connections. The Average Trip Delay for Disrupted Passengers provides a measure of the magnitude of the delays experienced by disrupted passengers. These two metrics are used to assess the reliability of the airline in providing the transportation service from a passenger standpoint.

When the Percentage of Passengers Disrupted is multiplied to the Average Trip Delays for Disrupted Passengers, the result is an expectation, or a measure of the expected trip delay experienced by a passenger selected at random from the pool of all passengers.

3 Passenger Itinerary (PI) and Passenger Trip Delay (PTD) Algorithms

The Passenger Trip Delay statistics are generated through two sequential processes: (1) Generate Passenger Itineraries, and (2) Compute Passenger Trip Delays. The first process generates an estimate of the passenger itineraries. The second process uses the itineraries and the flight performance to estimate the passenger trip delays. The data used and the algorithms are described in this section.

Data Sources

Data for the analysis is derived from three publicly available government data-bases from the Bureau of Transportation Statistics (BTS, 2011):

(1) The Airline Origin and Destination Survey (DB1B) Market: is a 10% sample of airline tickets from reporting carriers for each quarter.
(2) The Air Carrier Statistics (Form 41 Traffic) T100 data-base contains domestic non-stop segment data reported by both U.S. and foreign air carriers, including carrier, origin, destination, aircraft type, available capacity, and load factor. Data is aggregated on a monthly basis.
(3) The Airline On-Time Performance (AOTP) data-base contains on-time arrival data for non-stop domestic flights by major air carriers. The data is provided on a flight-by-flight basis for each day.

Passenger Itinerary Generation

The Passenger Itinerary Generation algorithm generates the passenger itineraries and estimates the number of passengers on each itinerary. There are three stages in generation of the passenger itineraries. First, the DB1B provides a list of the generic itineraries flown by passengers (e.g. DCA-ATL-DEN). Itineraries with more than 2 segments account for 2.5% of the itineraries in 2011 and are ignored for this analysis. Only itineraries with more than 0.5 passengers per day were considered in this analysis.

Second, the for each generic itinerary, the AOTP data-base is used to identify specific passenger itineraries for each day. For example, on a given day, AOTP identified two flight itineraries that provide service on DCA-ATL-DFW: (1) DL-417 DCA-ATL departing at 9am and arriving at 11:00am and DL-471 ATL-DFW departing at 12:25pm and arriving 1:45pm, (2) DL-1137 DCA-ATL departing at 8pm and arriving at 9:55pm connecting to DL-1697 ATL-DFW departing at 10:40pm and arriving at midnight.

Third, the DB1B is used in conjunction with the T100 to estimate the number of passengers in on each individual itinerary and flight. The DB-1B provides an estimate of the total passengers per quarter on each itinerary. For each DB1B generic itinerary (e.g. DCA-ATL-DFW) the 10% sample for each quarter is multiplied by 10 (to generate an estimate the total quarterly passengers), then divided by 90 days to estimate the total passengers per day on each itinerary. For example, DB1B estimates that 360 passengers flew an itinerary DCA-ATL-DFW during a specified quarter (i.e. 90 days). This amounts to 4 passengers per day on this itinerary.

This data is then used to estimate the percentage of passengers on a given passenger itinerary. The passenger count on individual itineraries is divided by the sum of the total passengers that share each O-D, O-H, H-D segment. This yields the percentage of passengers on each X-Y segment of the itinerary. For example, on a given day, the passengers travelling on DL-1137 with an itinerary DCA-ATL-DFW accounted for 3% of the total number of passengers on that flight. Similarly passengers originating at DCA and terminating at ATL (direct itinerary) accounted for 15% of the total number of passengers on DL-1137.

The T100, with an estimate of the total passengers on each individual flight, is used in conjunction with the percentage of passengers on each itinerary, to generate an estimate of the number of passengers on each passenger itinerary. On direct itineraries 10 passengers are added to account for a bias in under estimation of passengers on DB1B direct itineraries. On connecting itineraries, passengers are allocated evenly between the different itineraries up to the actual load factor from T100. For example, the average number of passengers on DL-1137 DCA-ATL was 122 and the percentage of passengers with itinerary DCA-ATL-DFW was 3%. Out of the 122 passengers, 4 passengers travelled on that itinerary. Likewise, the percentage of passengers with a direct DCA-ATL itinerary was 15% generating 19 passengers on DL-1137.

See Barnhart, Fearing and Vaze (2010) for description of alternate algorithm for passenger itinerary estimation.

Passenger Trip Delay Computation

The algorithm for estimating Passenger Trip Delays uses the Airline On-Time Performance (AOTP) data-base to compute passenger trip delays. The AOTP data-base contains on-time arrival data for non-stop domestic flights.

The Passenger Trip Delay Algorithm is summarized in Figure 1. For each day in the period under analysis, each passenger itinerary is processed. If the itinerary is a connecting itinerary, the algorithm follows the left branch (shaded). If the passenger itinerary is a direct itinerary, the algorithm follows the right branch. The algorithm checks for cancelled flight, diverted flight and delayed flight, rebooking and/or assigning passenger delays as described above. For more details on the algorithm, see Sherry et al. (2010).

Limitations and Validation

Absent proprietary data of actual passenger itineraries, the estimate is based on publicly available data and is intended to provide a representative estimate of the actual passenger itineraries. Sources of error include: (1) missing itineraries from the DB1B 10% sample, (2) aggregated quarterly DB1B passenger data, (3) aggregated monthly average load factors from T100, and (4) the simplified algorithm that divides the number of passengers between the available flights. The algorithm used in this analysis does not make distinctions between time-of-day and day-of-week.

By way of validation, a comparison of the total flights per year from AOTP to total flights per year in the passenger itineraries showed a difference of 2,133 flights per day, equivalent to 10% of the total flights. In comparison to Barnhart et al (2010), the total number of itineraries generated by this method is short 13%. The total passengers in the Passenger Itineraries generated by this method is 6% lower than the total passengers in the T100 data but 21% higher than the total passengers in (Barnhart et. al., 2010).

The passenger trip delay algorithm is accurate for delayed flights. Diversion delays are estimated based on a round trip to nearest airport with appropriate runway length. Rebooking itineraries are generated based on the average monthly load factor rebooking on the original ticketed airline, unless the passenger cannot be accommodated on the same day, in which case the passenger is rebooked on competing airlines.

4 2010 PASSENGER TRIP DELAY STATISTICS

In 2010, an estimated 421 million passengers were transported on 46.8M itineraries using 8.7M flights (Table 1).

TABLE 1: Flight, Itinerary, and Passenger Statistics

Metric	Direct + Connecting
Flights	8,701,205
Itineraries	46,850,298
Passengers	421,011,740

Twenty five percent of the itineraries were disrupted impacting 21.3% of the passengers. That is one-in-five passengers experienced a disrupted itinerary. Each passenger on a disrupted itinerary experienced an average delay of 67 minutes. The total annual delay experienced by passengers in 2010 was 11,669 years.

The difference between disrupted itineraries (24.7%) and the disrupted passengers (21.3%) is an indication of the airline's attempts, when possible, to manage itineraries to minimize passenger disruptions.

TABLE 2: Disrupted Itinerary Statistics

Metric	Direct + Connecting	% of Total
Disrupted Itineraries	11,582,643	24.7%
Passengers on Disrupted Itineraries	89,583,460	21.3%
Total Trip Delay for Passengers on Disrupted Itineraries (Years)	11,669	
Average Trip Delay for Passenger on Disrupted Itineraries (Minutes)	67	

The following two sections breakdown the passenger trip delays by disruption category and by itinerary type (direct or connecting).

Passenger Trip Delays by Disruption Category

Itineraries are disrupted by delayed flights, cancelled flights, diverted flights and missed connections. In 2010, the largest contributor to total passenger trip delays were itineraries disrupted by delayed flights that accounted for 48.8% of the total passenger trip delays. Itineraries disrupted by cancelled flights accounted for 33% of the total passenger trip delays, itineraries disrupted by missed connections, 14%, and itineraries disrupted by diverted flights 4.1%. (Table 3).

TABLE 3: Passenger Trip Delays by type of Itinerary Disruption

Metric	Direct + Connecting	% of Total
Delayed Itineraries	9,395,087	20.1%
Passengers on Delayed Itineraries	78,841,086	18.7%
Total Trip Delay for Passengers on Delayed Itineraries (Years)	5,692	**48.8%**
Average Trip Delay for Passengers on Delayed Itineraries (Minutes)	37	
Cancelled Itineraries	782,104	1.7%
Passengers on Cancelled Itineraries	6,587,328	1.6%
Total Trip Delay for Passengers on Cancelled Itineraries (Years)	3,869	**33.2%**
Average Trip Delay for Passengers on Cancelled Itineraries (Minutes)	299	
Missed Connection Itineraries	808,264	1.7%
Passengers on Missed Connection Itineraries	3,193,977	0.8%
Total Trip Delay for Passengers on Missed Connection Itineraries (Years)	1,634	**14.0%**
Average Trip Delay for Passengers on Missed Connection Itineraries (Minutes)	265	
Diverted Itineraries	101,374	0.2%
Passengers on Diverted Itineraries	961,069	0.2%
Total Trip Delay for Passengers on Diverted Itineraries (Years)	475	4.1%
Average Trip Delay for Passengers on Diverted Itineraries (Minutes)	260	

In 2010, delayed flight disrupted 20.1 % of the itineraries. These itineraries carried 18% of the 21.3% of the disrupted passengers, accruing 5,692 years of passenger trip delays. The average trip delay for passengers on itineraries disrupted by delayed flights was 37 minutes.

The effect of itineraries disrupted by cancelled flights or missed connections, in which passengers delays are accrued by rebooking, exhibits an asymmetry between the number of passengers affected and the magnitude of the contribution to total passenger trip delays. Although only 1.7% of the itineraries were disrupted by cancelled flights, affecting 1.6% of the passengers, the contribution towards the total passenger trip delay was 33%. The small percentage of passengers affected experienced an average rebooking delay of 4.9 hours. The combination of a high average trip delay and small number of disrupted passengers yielded a significant portion of the total passenger trip delays.

Likewise, although trip delays for itineraries disrupted by missed connections accounted for 14% of the total trip delays, only 1.7% of the itineraries were disrupted by missed connections, affecting 0.8% of the passengers. However with the average trip delay for passengers on itineraries disrupted by missed connections at 4.4 hours, these unlikely events add up fast.

Note that a widely held intuition that airlines tend to cancel flights or allow missed connections for flights with low load factors is supported by the data. Whereas 1.7% of the itineraries were disrupted by cancelled flight, 1.6% of the passengers were affected. Likewise for missed connections, 1.7% of the itineraries were disrupted, but on 0.8% of the passengers.

Itineraries disrupted by diverted flights accounted for 0.2% of the itineraries, affecting 0.2% of the passengers. The average trip delay for passengers on itineraries disrupted by diversions was estimated at 4.3 hours.

Trip Delays by Itinerary Type (Direct or Connecting)

The airline itinerary network is dominated by connecting itineraries. Connecting itineraries account for 87% of the itineraries with direct itineraries accounting for 13% (Table 4). In 2010, 33% of the passengers were transported on connecting itineraries, while 67% of the passengers were transported on direct itineraries. That is for every one passenger on a connecting itinerary, there are two passengers on a direct itinerary. This asymmetry plays a key role in determining performance by itinerary type.

TABLE 4: Passenger Trips by Itinerary Type (Direct, Connecting)

Metric	Direct	% Total	Connecting	% Total
Flights	8,701,205			
Itineraries	6,128,665	13.1%	40,721,633	86.9%
Passengers	282,070,114	67.0%	138,941,626	33.0%

Direct itineraries were operated with better performance than connecting itineraries, yet due to the asymmetric distribution of passengers to direct (67%) and connecting (33%) itineraries the contribution to total passenger trip delays was roughly equal. Direct itineraries contributed 46% of the total passenger trip delays (Table 5). Connecting itineraries contributed 54% of the total passenger trip delays.

Passengers on connecting itineraries were approximately 6 times more likely to be disrupted (21.1%) than passengers on direct itineraries (3.6%). Passengers on direct itineraries experienced an average delay of 51 minutes, almost half the average delay experienced by the passengers on connecting itineraries of 93 minutes.

Although direct itineraries were less likely to be disrupted (3.6%), these itineraries ferried two out of every three passengers (67%) with an average trip delay of 51 minutes generating 46% of the total trip delay. Connecting itineraries, experiencing a higher rate of disruptions (21.1%), hauled fewer passengers (33%) with an average trip delay of 93 minutes. Connecting itineraries generated 54% of the total passenger trip delay.

TABLE 5: Passenger Trip Disruptions by Itinerary Type (Direct, Connecting)

Metric	**Direct**	**% Total**	**Connecting**	**% Total**
Disrupted Itineraries	1,684,552	3.6%	9,898,091	21.1%
Passengers on Disrupted Itineraries	54,494,521	12.9%	35,088,939	8.3%
Total Trip Delay for Passengers on Disrupted Itineraries (Years)	5,367	46.0%	6,302	54.0%
Average Trip Delay for Passenger on Disrupted Itineraries (Minutes)	51		93	

Passenger trip delay statistics for direct itineraries are listed in Table 6, and for connecting itineraries in Table 7. Direct itineraries disrupted by delayed flights contributed the largest amount to total passenger trip delays (32%). This was followed by connecting itineraries disrupted by cancelled flights 23%, connecting itineraries disrupted by delayed flights 16%, connecting itineraries disrupted by missed connections 14%, and direct itineraries disrupted by cancelled flights 11%.

As shown in Table 6, of the 3.6% of direct itineraries that were disrupted, 2.4% of the disruptions were the result of delayed flights, 0.1% were the result of cancelled flights, and less than 0.1% were diverted flights.

The 2.4% of the direct itineraries disrupted by delayed flights, ferry half (12.2%) of the passengers on disrupted flights (21.3%). These passengers, experienced an average trip delay of 38 minutes, generated 32.4% of the total trip delays.

Although only 0.1% of the direct itineraries were disrupted by cancelled flights, the average trip delays experienced by the 0.5% of the passengers on direct itineraries was 4.6 hours. This type of disruptions contributed only 10.6% to the total passenger trip delays for 2010.

The higher percentage of passengers disrupted by cancelled flights (0.5%), than itineraries disrupted by cancelled flights (0.1%), indicates that the airlines were ambivalent to load factors when dealing with mechanical problems leading to cancelled flights, or when selecting flights for cancellations due to tactical reason.

TABLE 6: Disruptions on Direct Itineraries by Itinerary Disruption

Metric	**Direct**	**% Total**
Delayed Itineraries	1,114,485	***2.4%***
Passengers on Delayed Itineraries	51,510,418	***12.2%***
Total Trip Delay for Passengers on Delayed Itineraries (Years)	3,786	***32.4***%
Average Trip Delay for Passengers on Delayed Itineraries (Minutes)	38	
Cancelled Itineraries	59,689	0.1%
Passengers on Cancelled Itineraries	2,284,938	0.5%
Total Trip Delay for Passengers on Cancelled Itineraries (Years)	1,237	10.6%
Average Trip Delay for Passengers on Cancelled Itineraries (Minutes)	277	
Diverted Itineraries	14,564	0.031%
Passengers on Diverted Itineraries	699,165	0.2%
Total Trip Delay for Passengers on Diverted Itineraries (Years)	344	3.0%
Average Trip Delay for Passengers on Diverted Itineraries (Minutes)	260	

Connecting itineraries contributed 54% of the total passenger trip delays (Table 7). Connecting itineraries that were disrupted by cancelled flights generated the largest percentage of passenger trip delays (22%), followed by delayed itineraries (16.3%), missed connections (14%), and diverted itineraries (1.1%).

In 2010, 1.7% of the itineraries (direct and connecting) were disrupted by cancelled flights (Table 3). Of those disruptions, 1.5% of the itineraries were connecting itineraries. These disruptions affected only 1% of the disrupted passengers, but with an average trip delay for rebooking of 5.2 hours, these disruptions generated 22.6% of the total passenger trip delay. Both modernization and consumer protect initiatives need to consider this contribution to the total passenger trip delays.

Delays and missed connections contributed 16.3% and 14% respectively to total passenger trip delays. The 17.7 % of the connecting itineraries disrupted by delayed flights, ferry 6.5% of the 21.3% of the disrupted passengers and generate 16.3% of the total passenger trip delays. These passengers experienced an average trip delay of 36 minutes.

Missed connections generated 1.7% of disrupted itineraries affecting 0.8% of the disrupted passengers. The average trip delay for rebooking of 4.4 hours generated 14% of the total trip delay.

TABLE 7: Disruptions on Connecting Itineraries by Itinerary Disruption

Metric	Connecting	% Total
Delayed Itineraries	8,280,602	***17.7%***
Passengers on Delayed Itineraries	27,330,668	***6.5%***
Total Trip Delay for Passengers on Delayed Itineraries (Years)	1,905	16.3%
Average Trip Delay for Passengers on Delayed Itineraries (Minutes)	36	
Cancelled Itineraries	722,415	1.5%
Passengers on Cancelled Itineraries	4,302,390	1.0%
Total Trip Delay for Passengers on Cancelled Itineraries (Years)	2,633	***22.6%***
Average Trip Delay for Passengers on Cancelled Itineraries (Minutes)	***311***	
Missed Connection Itineraries	808,264	1.7%
Passengers on Missed Connection Itineraries	3,193,977	0.8%
Total Trip Delay for Passengers on Missed Connection Itineraries (Years)	1,634	14.0%
Average Trip Delay for Passengers on Missed Connection Itineraries (Minutes)	265	
Diverted Itineraries	86,810	0.2%
Passengers on Diverted Itineraries	261,904	0.1%
Total Trip Delay for Passengers on Diverted Itineraries (Years)	130	1.1%
Average Trip Delay for Passengers on Diverted Itineraries (Minutes)	260	

5 CONCLUSIONS

The results for 2010 yield important insights into the operation of the APTS. In comparison to 2007, the annual total passenger trip delay has decreased by 26% from a high of 15,841 years in 2007 to 11,669 in 2010 (Table 8). In large part these reductions are the result of an 11.5% percent reduction in the number of flights over this period, and several airline cost reduction initiatives (e.g. rolling banks with longer turn-around times) that benefited passenger trip reliability.

Despite these improvements, the passenger trip experience has not change proportionally since

2007. In 2010, one-out-of-five passengers experienced a disrupted itinerary, a modest improvement from 2007 when one-out-of-four passengers experienced a disrupted itinerary. Also, the average delay experienced by disrupted passengers improved 6 minutes from a high of 73 minutes in 2007, to 67 minutes in 2010.

TABLE 8: Trends 2007 - 2010

Metric	2007	2010
Flights	**9,839,578**	**8,701,205**
Total Passenger Trip Delays (Years)	15,841	11,669
% Passengers on Connecting Itineraries	30.3%	33%
% Passengers on Disrupted Itineraries	25.7%	21.3%
Average Trip Delay for Passengers on Disrupted Itineraries (mins)	73	67

This analysis establishes important distinctions between the disruptions to itineraries due to delayed flights and disruptions to itineraries due to cancelled flights or missed connections. In the former, performance is determined by the on-time reliability of flights and the magnitude of flight delays. In the latter, performance is determined by the response to the itinerary disruption by rebooking passengers on alternate itineraries. The "structure" of the network in the form of frequency of service, time connecting between flights, aircraft size, and load factor, determines the robustness in response to itinerary disruptions that require rebooking passengers (not just the reliability of the flights). For example, for a 51 airport hub-and spoke network, Sherry (2011) estimated that under certain circumstances a 10% increase in load factor could nullify the benefits of 5% improvement in on-time performance. For more complete discussion of these topics see Sherry (2011).

Impact of ATC Modernization Initiatives on Passenger Trip Performance

Initiatives to modernize Air Traffic Control will create additional capacity and improve productivity to increase effective-capacity. These changes will yield (at least in the short-term) direct reductions in flight delays. This will directly improve the performance of passenger itineraries disrupted by delayed flights. Increased capacity will have a secondary effect of possibly reducing cancelled flights (at least those cancelled due for "tactical" reasons). Although this will improve the performance of passenger itineraries for cancelled flights, the effect of the rebooking of passengers is dependent on the schedule and flight load factors.

In addition, care must be taken to carefully state assumptions in the benefits analysis for ATC modernization. Shifts in itineraries, frequency of service, aircraft size and load factors can have a significant impact on passenger trip delay. As shown in Sherry (2011), in certain circumstances, a 10% increase in load factor can nullify the benefits in passenger trip delay of a 5% improvement in on-time performance.

Passenger Bill of Rights

A Passenger Bill of Rights is governmental rule-making that sets service standards for airline passengers. The European Union (EU) established a common set of rules for airlines registered in member states for compensation and assistance of passengers in the event of cancellations, long delays and denied boarding. In short, the EU's Air Passenger Rights mandates compensation for passengers in the event of denies boarding based on distance of flight. In the event of long delays, passengers must be provided services, meals, hotel accommodation or the option for reimbursement. Financial compensation for a cancelled flight is due unless the airline has informed passengers of the flights' cancellation 14 days prior to the flight, or if the passengers have been rerouted close to their original travel times. Airlines are exempt from compensation should the cancellation be due to extraordinary circumstances.

The U.S. Passenger Bill of Rights includes only provisions for denied boarding and for extended delays (> 2 hours) on the tarmac. This bill of rights does not mandate compensation for delays and cancellations. Based on the passenger itinerary analysis, the absence of cancellations and missed connections in the bill are significant omissions, as these factors are significant contributors to individual total passenger trip delays.

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