AIR TRAVEL CONSUMER PROTECTION: A METRIC FOR PASSENGER ON-TIME PERFORMANCE

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Abstract:

The *raison d'etre* for the national Air Transportation System (ATS) is the movement of passengers and cargo. As a consequence, passenger trip time performance is positively correlated with passenger satisfaction, airfare elasticity, and airline profits. Regulatory consumer information available to airline passengers provides measures of trip performance using the percentage of on-time flights (e.g. 15-OTP metric). Researchers have shown that these "flight-based" metrics are poor proxies for passenger trip time performance. First these metrics do not include the trip delays accrued by passengers rebooked due to cancelled flights (which accounts for 40% of the overall passenger trip delays). Second, the metric does not quantify the magnitude of the delay (only the likelihood) and thus fails to provide the consumer with a useful assessment of the impact of a delay (such as missed connections on next mode of transportation).

This paper describes a new consumer protection metric (Expected Value of Passenger Trip Delay – EV-PTD) that accounts for: (i) cancelled flights, and (ii) *both* the probability of delay and the magnitude of the delay. The EV-PTD for all 1030 routes between OEP-35 airports in 2005 ranged from 11.5 minutes (best) to 155 minutes (worst). The average route EV-PTD was 35 minutes. By treating passenger trip delay as a random variable it can be shown that the transportation process is not a "fair" game and that passengers and service providers (e.g. airlines, air traffic control, airports) cannot "beat" the system until the variance is significantly reduced. The implications of these results and the use of the EV-PTD metric by consumers for purchasing tickets and for consumer protection are discussed.

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1 INTRODUCTION

Passenger trip time is an important property of the air transportation system. Passenger trip time informs passenger choices of flights, airlines, and airports, and has been positively correlated with customer satisfaction and brand loyalty that drives airline profits [1, 2]. Conversely, poor service reliability on specific routes has been shown to lead to reduced airfares on these routes [3].

Contrary to popular opinion, the airlines are under no legal obligation to operate a scheduled flight on a given day and are not required to compensate passengers for "damages" when flights are delayed or canceled [7].

As a consequence, passengers must apply *caveat emptor* in selecting airlines and airports while purchasing tickets. The most complete consumer information is made available by the Department of Transportation (DOT) Office of Aviation Enforcement and Proceedings (OAEP) in a monthly report -. *Air Travel Consumer Report (ATCR).* This report is "designed to assist consumers with information on the quality of services provided by the airlines." In addition to data on mishandled bags, overbooking, and passenger complaints, the report includes measures of the percentage on-time performance of arrivals of flights within 15 minutes of the schedule arrival time. This metric is known as the 15-OTP. The report also provides the percentage of cancelled flights. Similar consumer information can be found in the monthly Airline Quality Rating (AQR) Report [8] and in traveler survey data such as the J.D. Power Airport Satisfaction Report [12].

Researchers have shown that these types of "flight-based" metrics are poor proxies for the passenger trip experience [4, 5, 9, 10, 11]. First, these metrics fail to account for the trip delays experienced by passengers when they are re-booked on a later flight due to a cancelled flight or missed connection. For example, Wang [5] estimated that 40% of the total trip delays accrued by passengers on single segment flights between OEP-35 airports in 2005 were the result of delays due to cancelled flights. Delayed flights contributed to the remaining 60% of total trip delays.

Second, these metrics fail to describe the magnitude of delay experience by the passenger when a flight is not on-time. These delays are not negligible. Bratu & Barnhart [4] used proprietary airline data to study passenger trip times from the hub operations of a major U.S. airline. This study showed that that flight-based metrics are poor surrogates for passenger delays for hub-and-spoke airlines as they do not capture the effect of missed connections and flight cancellations. For example, for a 10 day period in August 2000, Bratu & Barnhart [4, page 14] cite that the 85.7% of passengers that are not disrupted by missed connections and cancelled flights arrive within one hour of their scheduled arrival time and experience an average delay of 16 minutes. This is roughly equivalent to the average flight delay of 15.4 minutes for this period. In contrast, the 14.3% of the passengers that are disrupted by missed connections or cancelled flights experienced an average delay of 303 minutes.

This paper describes a new metric – Expected Value of Passenger Trip Delay (EV-PTD) – that is designed to account for: (i) delays experienced by passengers due to delayed flights plus cancelled flights, and (ii) *both* the probability of passenger trip delay and the magnitude of the delay. This metric correctly treats passenger trip delays as a random variable.

Analysis of delay data for 1030 routes between OEP-35 airports in 2005, showed:

- Passenger On-Time Percentage (15-POTP) for each route ranged from 44% to 97%, with an average on-time percentage of 77%.
- Average delays in excess of 15 minutes experienced by passengers on delayed and cancelled flights on each route ranged from 33 minutes to 298 minutes, with an average delay of 87 minutes.
- 90th percentile delays experienced by passengers on delayed and cancelled flights on each route ranged from 89 minutes to 1925 minutes, with an average delay of 887 minutes
- Expected Value of Passenger Trip Delay (EV-PTD) yielded an expected value for trip delay on each route ranging from 11 minutes to 154 minutes, with an average of 35 minutes.

The EV-PTD metric, successfully combines the probability of a delay with the magnitude of the delay, to provide a useful assessment of performance of the air transportation system on each route. Consumers can use the 15-POTP, the 90th percentile delay, and the EV-PTD metric, along with their own utility function to make informed travel choices related to mode choice as well as route and time-of-day..

It is recognized that these metrics represent "holistic" metrics of the performance of the "integrated" air transportation system. Improving these metrics is beyond the ability of individual enterprises in the supply chain (e.g. airlines, Air Traffic Control, airports, etc.). Improvement demands an integrated and cooperative solution.

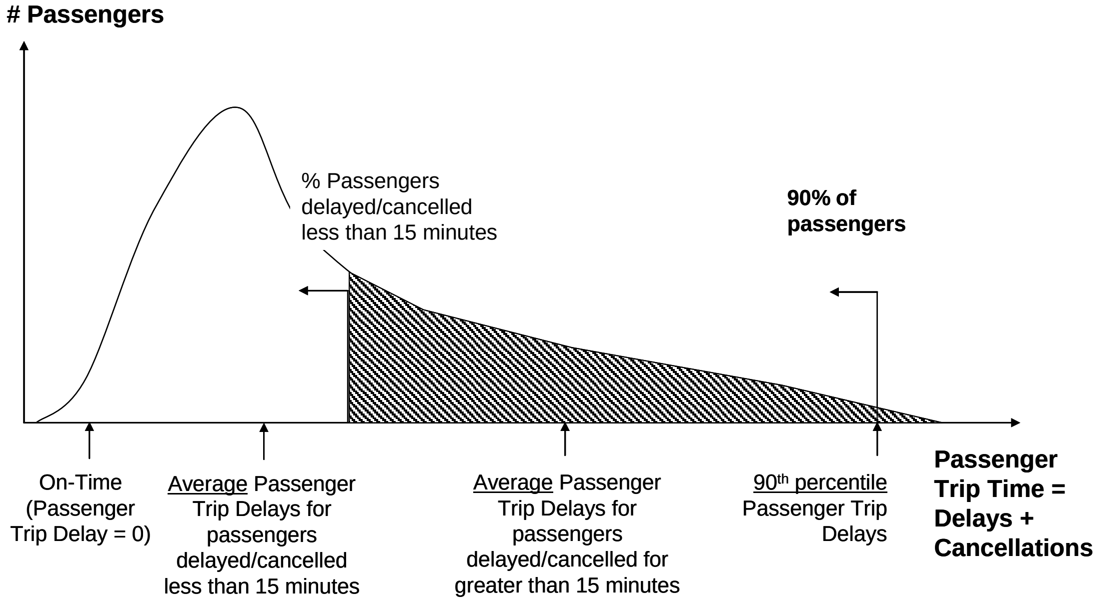
Section 2 of the paper provides an overview of passenger trip delays statistics and the computation of expected passenger trip delay. Section 3 describes the method for computing the passenger trip delay metrics. Section 4 describes the results of an analysis of the EV-PTD for delay data on 1030 routes between OEP-35 airports. Section 5 discusses the implications of these results.

2 STATISTICS OF PASSENGER TRIP DELAYS

The underlying behavior of passenger delays is represented by the heavy right-tailed distribution shown in Figure 1. This distribution shows, for a given route, the number of passenger trips that arrived at the destination gate in each 5 minute bin. The distribution in passenger trip delays occurs due to variation in flight times caused by the presence of headwinds, weather and the resulting flight distance, aircraft type, and. airline specified cruise speeds. The passenger trip delays may also the result of airline operations such as mechanical delays, gate utilization, and holding for connecting passengers. On routes departing or arriving at congested airports, the delays may also be a result of traffic congestion.

The Passenger On-Time Percentage (15-POTP) represents the percentage of passengers that arrive within 15 minutes of the scheduled arrival time. Typical values range from 50% to 98%. The 90th percentile represents the passenger trip delay that accounts for 90% of all passengers.

Individual passengers experience an average trip delay dependent on the window in which they arrive: (i) average delay for the trips within 15 minute window (typically 3 to 8 minutes), (ii) average delay for delayed and cancelled passengers, and (iii) average delay for delayed and cancelled passengers in excess of 90th percentile. In 2005, the average delay for those trips with delays in excess of 15 minutes on the OEP-35 routes ranged from 33 minutes (Salt Lake City – Tampa Bay) to 298 minutes (Philadelphi – Newark), with an average of 87 minutes. The 90th percentile delays ranged from 89 minutes (St Louis to San Diego) to 1925 minutes (Honolulu to Seattle) with an average delay of 468 minutes.



Distribution of Passenger Trip Delays on a Route. Heavy right-tailed distribution reflects weather and other uncertainties that result in flight delays plus delays experienced by passengers due to cancelled flights. Average delays for three trip delay segments are shown.
Figure 1.

Expected Value of Passenger Trip Delays (EV-PTD)

Analysis of random phenomena (e,g. roulette wheel) is accomplished by the computation of an Expected Value. The Expected Value represents the average amount one "expects" to win or lose per bet if bets with identical odds are placed over a large number of repetitions. Mathematically, the Expected Value of a random variable is the sum of the probability of each possible outcome of the experiment multiplied by its payoff (or cost). A game or situation in which the Expected Value for the player is zero (no net gain nor loss) is called a "fair game." A game or situation in which the Expected Value is negative is not a fair game and over time will result in losses to the player that will approach the Expected Value.

The concept of Expected Value can be applied to passenger trip delay distributions. Passenger trips arriving with 15 minutes of schedule occur with the probability of the on-time percentage (i.e. 15-POTP) and with average delay for trips in this window. Passenger trips arriving in excess of 15 minutes of schedule occur with probability of one minus 15-POTP percentage minus 10 percent (for 90th percentile) and experience trip delay of the average for this window. Passenger trips arriving in excess of the 90th percentile occur with probability of 10% and experience trip delay of average for this window. The calculation is as follows:

Probability of Event		Payoff or Cost		Expected Value
P(Trip Delay < 15 minutes) = On-Time %	*	Average Trip Delay for Trips < 15 minutes	=	EV1
P(Trip Delay > 15 minutes and < 90th percentile) = 1-On-Time %-10%	*	Average Trip Delay for Trips > 15 minutes but less than 90th percentile delays	=	EV2
P(Trip Delay > 90th percentile delay) = 10%	*	Average Trip Delay 90th percentile delays	=	EV 3

Expected Value of Passenger Trip Delays (EV-PTD) = EV1 + EV2 + EV3

In this manner, the choice of routes can be treated as a random phenomenon with a cost (i.e. duration of delay). The Expected Value for a route represents the delays that should be expected by a passenger if the route were flown a large number of times.

The degree of asymmetry of the delay distribution is the most significant factor in determining the value of EV-PTD. For example, 90th percentile delays that are very large, will result in very large values for EV-PTD.

3 METHOD FOR COMPUTING PASSENGER TRIP DELAYS

The data used in this study was derived from two publicly available data-bases:

1. Airline On-Time Performance (AOTP) Database [6]– This database provides departure delays and arrival delays for non-stop domestic flights by major air carriers. The data also includes additional information such as origin and destination airports, flight numbers, cancelled or diverted flights. Each record in the data-base represents one flight.
2. Air Carrier Statistics (known as T-100) Database [6] – This database provides domestic non-stop segment data by aircraft type and service class for passengers, freight and mail transported. It also provides available capacity, scheduled departures, departures performed and aircraft hours. Each record in the data-base represents monthly aggregated data for a specific origin/destination segment.

One thousand and thirty routes were identified between OEP-35 airports. These routes each experienced in excess of 50 flights during the time period under investigation.

Estimating Passenger Trip Delays on Each Route

Passenger trip delays on each route were estimated using an algorithm to compute the Estimated Total Passenger Trip Delay (ETPTD) for each passenger on single segments flights [5]. The algorithm includes trip delays that are a result of delays caused by re-booking passengers on later flights due to cancelled flights and/or delays incurred by flight delays.

ETPTD is computed using two algorithms to process the data from the data-bases described above: (Algorithm 1) TPTD due to Delayed Flights, and (Algorithm 2) Estimated TPTD due to Cancelled Flights.

Algorithm 1: Total Passenger Trip Delay (TPTD) due to Delayed Flights

TPTD due to Delayed Flights is computed by processing the data for each flight in the AOTP database for a given route and specified period (e.g. 365 days) to compute the *delay time for the flight*. This time is them multiplied to the average number of passengers for this flight (from the T-100 data-base) to derive the *passenger delay time for the flight*.. The *total passenger delay time for delayed flights* is computed by summing the *passenger delay time for the flight* for all the flight for the specified period.

Algorithm 2: Estimated Total Passenger Trip Delay (TPTD) due to Cancelled Flights

Estimated TPTD due to Cancelled Flights is computed based on the assumption that a passenger displaced by a cancellation will be rebooked on a subsequent flight operated by the same carrier with the same origin/destination pair. The passenger will experience a trip time that now includes both the flight delay of the re-booked flight plus the additional time the passengers must wait for the re-booked flight. The ability to re-book passengers on subsequent flights is determined by the load-factor and aircraft size of the subsequent flights. In general, passengers from a cancelled flight will be relocated to 2 or 3 different flights due to limited empty seats on each available flight.

The process is as follows. The algorithm processes data for each flight in the AOTP database for a given route and a specified period (e.g. 365 days). For each flight that is listed as cancelled, the algorithm checks the T-100 data-base for the average aircraft size and average passengers loaded for the cancelled flight as well as the aircraft size and load factor for the next available flights operated by the same carrier on the same route segment. Passengers for the cancelled flight are then “re-booked” on these subsequent available flights up to 15 hours from the scheduled departure time of the cancelled flight. The 15 hours upper-bound is derived from Bratu & Barnhart (2005) and reflects an estimate of the upper bound of passenger trip delays due to cancelled flights. Also it should be noted that the algorithm described in this paper allows passengers to be re-booked on flights operated by subsidiary airlines (e.g. American Airline (AA) and it’s subsidiary American Eagle (MQ)), but not on other airlines. The delay time accrued by waiting for the re-booked flight is added to the delay time for the re-booked flight.

Approximations in Algorithm

The original research on passenger trip time by Bratu & Barnhart [4] was conducted using data from a major U.S. airline that included the exact itinerary of individual passengers and the load factors of each flight. This data is proprietary to the airline and is also subject to civil liberties laws. To overcome this limitation, the algorithm developed by Wang [5] and summarized above makes three assumptions:

(1) The algorithm estimates passenger load factors based on publicly available monthly average data for each carrier on each route. When the algorithm "re-books" passengers from cancelled flights it assumes the load factor for each route flown by each carrier in that month is the average load factor for that flight. Analysis of a sample of cancelled flights indicates that the average load factor on cancelled flights is equal to the average load factors on non-cancelled flights and that this assumption is statistically valid.

(2) The algorithm only re-books passengers on single segment flights. The algorithm does not re-book passengers with a connecting flight to their original destination. Accounting for alternative routing would be possible but adds significant complexity to the algorithm. This is a subject for further research.

(3) The algorithm only re-books passengers on flights operated by the same airline or it's subsidiaries. Accounting for re-booking on other airlines is possible within the constraints of the existing algorithm but is not consistently practiced. For example, it is understood that some Low Cost Carriers do not have the infrastructure to handle coupons from other airlines. At this time, the algorithm sets an upper-bound for delays due to cancelled flights of 15 hours. This value was chosen based on previous work by Bratu & Barnhart and reflects the behavior that passengers with extensive delays would be re-booked on other airlines. This is an area for future research.

Statistical Data

Table 1 provides a summary of the data generated by this analysis.

Origin	Destination	15 – POTP (%)	Average Passenger Trip Delay for Passengers on Delayed or Cancelled Flights (mins)	90th Percentile Passenger Trip Delays (mins)	Passenger Expected Trip Delay
ATL	BOS	0.68	98.3	908	45.9
ATL	BWI	0.72	93.2	890	41.3
ATL	CLE	0.74	133.5	911	49.1
ATL	CLT	0.72	86.3	909	39.3
ATL	CVG	0.79	81.3	901	32.6
ATL	DCA	0.76	88.4	894	36.1

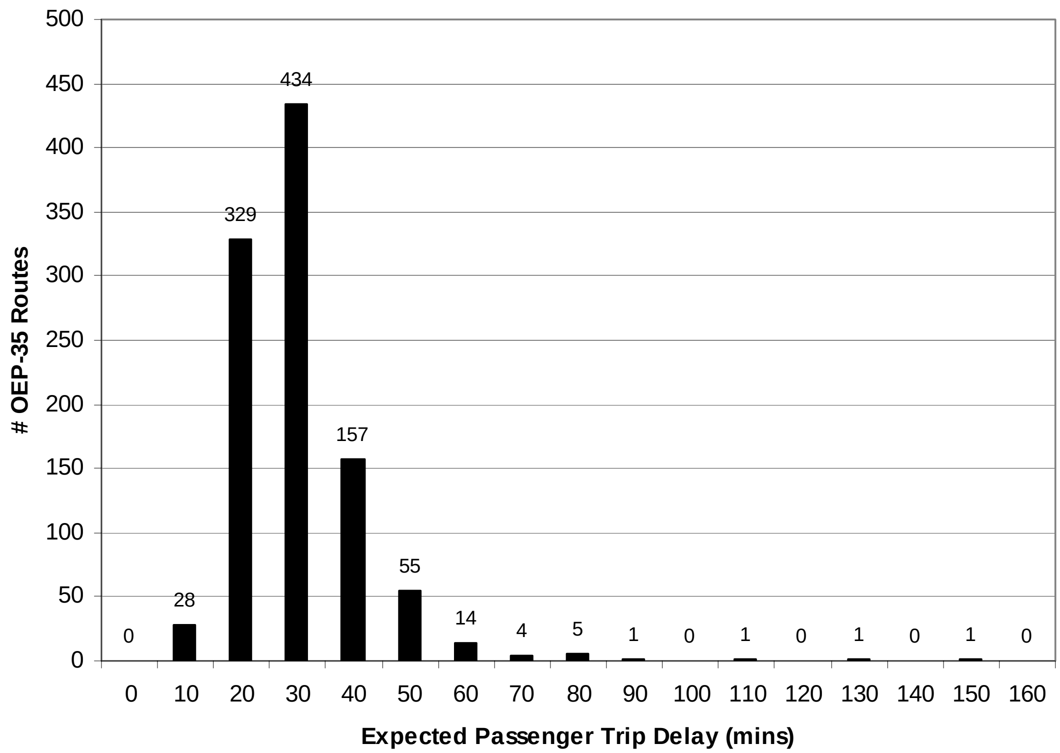
ATL	DEN	0.75	79.3	900	34.8
ATL	DFW	0.74	79.8	958	36.5
ATL	DTW	0.73	108.3	903	43.9
ATL	EWR	0.63	113.3	898	56.5

Sample statistics for Passenger Trip Delays
Table 1

4 EXPECTED VALUE OF TRIP DELAYS (EV-PTD)

Expected Value of Passenger Trip Delay (EV-PTD) was computed for each of the 1030 routes between OEP-35 airports. The distribution of EV-PTD for all the routes is shown in Figure 2. The overall statistics for all the routes are listed in Table 2.

The distribution is heavy right-tailed with 26 outlier routes (2.4%) with EV-PTD in excess of 60 minutes. The majority of routes yield a EV-PTD of less than 60 minutes. The average EV-PTD across all routes is -35 minutes with a standard deviation of 11.6 minutes. The 90th percentile EV-PTD is -45 minutes. The 10th percentile is -24.7 minutes.



Distribution of EV-PTD for all routes between OEP-35 airports.
Figure 2.

	Passenger On-Time Percentage (15-POTP)	Average Passenger Trip Delay > 15 mins (mins)	90th Percentile Passenger Trip Delays (mins)	Passenger Expected Trip Delay
Average	0.77	86.6	886.9	35.1
Std Deviation	0.07	30.2	155.8	11.6
90th percentile	0.85	121.13	900	48.5
10th percentile	0.67	54.83	879	24.7

Summary statistics for EV-PTD over all routes between OEP-35 airports.
Table 2.

The average Passenger On-Time Percentage (15-POTP) ranged from 44% to 99% with an average of 77%. Average delays in excess of 15 minutes experienced by passengers on delayed and cancelled flights on each route ranged from 33 minutes to 298 minutes, with an average delay of 87 minutes. 90th percentile delays experienced by passengers on delayed and cancelled flights on each route ranged from 99 minutes to 1925 minutes, with an average delay of 887 minutes. Correlation between passenger percentage on-time (15-POTP) and passenger trip delays in excess of 15 minutes was poor (less than 50%) due to the large spread of delays. For example routes that experienced 15-POTP of 80% had average trip delays in excess of 15 minutes ranging between 25 minutes and 150 minutes. Correlation between % cancelled flights and average trip delays in excess of 15 minutes also exhibited poor correlation due to the range of delays for each level of cancellations.

The 2.4% of the routes experiencing EV-PTD in excess of 60 minutes are listed in Table 3. Removing the "outlier" routes, dropped the average EV-PTD from -35 minutes to -33.9 minutes. This indicates that these routes do not affect the system-wide EV-PTD significantly.

Route	EV-PTD (minutes)	Route	EV-PTD (minutes)
Baltimore - Newark	81	New York/JFK - Detroit	82.7
Baltimore – New York/JFK	60.3	New York/JFK - Minneapolis	62.9
Charlotte – New York/JFK	71.3	New York/JFK – Chicago/O'Hare	113.6
Cincinnati - Newark	63.8	New York/JFK – Philadelphia	95.4
Detroit - Newark	62.9	New York/JFK – Pittsburgh	61.5
Detroit – New York/La Guardia	60.9	New York/La Guardia - Detroit	64.1
Newark – Baltimore/Washington	77.7	Chicago/O'Hare – New York/JFK	62.5
Newark - Cincinnati	60.8	Philadelphia - Newark	154.6
Newark - Detroit	64.1	Philadelphia – New York/JFK	87.2
Newark – Washington/Dulles	68.0	Philadelphia – New York/La Guardia	63.7
Newark - Philadelphia	139.2	Pittsburgh - Newark	81.4
New York/JFK - Cleveland	65.7	St Louis - Philadelphia	71.9
New York/JFK - Charlotte	80.9	Washington/Dulles - Newark	69.3

"Outlier" routes experiencing EV-PTD of greater than 60 minutes.
Table 3

5 CONCLUSIONS

These results have significant implications for the way passengers think about air transportation and should inform route choices, as well as the way consumer protection for airline travelers is provided. This paper proposes a new set of data to serve as consumer protection for airline travelers.

(1) Expected Value of Passenger Trip Delays (EV-PTD) – a composite metric that reflects the randomness of delays. This metric is computed from the 4 metrics below (#2 - #5)

(2) Passenger On-Time Performance (15-POTP) – percentage of passengers that arrive within 15 minutes of schedule. Includes delays accrued from re-booking on cancelled flights as well as delays from flights.

(3) Average Passenger Delay for Passengers within 15 minutes of schedule – includes passenger delays from cancelled flights as well as delayed flights.

(4) Average Passenger Delay for Passengers arriving <u>not</u> within 15 minutes of schedule – includes passenger delays from cancelled flights as well as delayed flights. Does not include passenger delays beyond 90^{th} percentile (see below).

(5) 90^{th} percentile passenger delay – delay experienced by the 90^{th} percentile passengers

Winning the Passenger Trip Delay "Game"

By treating the performance on the OEP-35 routes as random phenomena, one can begin to understand the likelihood and magnitude of outcomes. The expected value represents the average amount one "expects" to win/lose per bet if bets with identical odds are repeated many times. A game or situation in which the expected value for the player is zero (no net gain nor loss) is called a "fair game."

As is evidenced, by the EV-PTD values for each route and for the system as whole, air transportation is not a "fair game." The system operates in favor of large delays whose costs that are borne primarily by passengers and secondarily by the enterprises that provide the service such as airlines, Air Traffic Control, airports and their supply chains. There appears no way for any of the players on these routes to systematically "beat the odds."

In large part, the excessive costs of the system are the result of the significant asymmetries in both passenger on-time percentage and in average delays experienced by passenger with trips in excess of 15 minute delays on all routes (not just at congested airports).

Informed Passenger Choices

When passengers purchase an airline ticket they have made a commitment to a specific flight. This flight has historically exhibited a degree of randomness in it's on-time performance and delay statistics. For example, an origin-destination pair that exhibits a EV-PTD -25.7 minutes provides a significantly more robust performance than a flight on an origin-destination pair with a EV-PTD of -51.4 minutes. As a consequence, from the passenger perspective, the choice of route is akin to “rolling the dice” with the “odds” associated with each route. One way to start to mitigate this effect is to use the EV-PTD to make choices of routes (i.e. airport pairs) between two markets.

As passenger choices of flights between large metropolitan areas have expanded consumers choices of departure and arrival airport have increased. For example, Boston, New York, Washington D.C., San Fransisco, Los Angeles, and South Florida are all serviced by multiple airports. The choice of airport pairs provides the passenger with an additional degree of freedom in selecting flights.

Table 4 summarizes the EV-PTD between routes between Washington D.C. and Chicago. The table illustrates a 2X improvement in performance of the best route (Washington D.C./National - Chicago/Midway with EV-PTD = -25.7 minutes) over the worst-route (Washington D.C./Dulles - Chicago/Midway with EV-PTD = -51.4). The table also illustrates that intuition about one airport being less congested than another are not reflected in the data. Baltimore to Chicago has similar performance independent of which Chicago airport is selected. Likewise Midway as a destination airport has the best and worst EV-PTD.

Route	EV-PTD (minutes)
Washington D.C./National - Chicago/Midway	25.7
Baltimore – Chicago/O’Hare	27.2
Baltimore – Chicago/Midway	34.1
Washington D.C./Dulles - Chicago/O’Hare	37.4
Washington D.C./National - Chicago/O’Hare	41.1
Washington D.C./Dulles - Chicago/Midway	51.4

EV-PTD for 6 route options between Washington D.C. and Chicago markets.
Table 4.

Consumer Protection for Airline Travelers Against the System

The traditional view of consumer protection – the one adopted by the Department of Transportation – is to provide a comparison of flight-based services provided by the airlines to the passengers. This approach is based on the premise that the difference in service is derived only by the performance of the airlines. This view of consumer protection fails to recognize the effect of the integrated system, composed of airlines, airports, air traffic control, employment contracts, government funding systems, etc. This data illustrates the importance of consumer protection against the system (not just the enterprise).

This paper has demonstrated a metric for consumer protection for airline travel that captures the integrated performance of all the agents. This metric will enable passengers to make choices about the air transportation system, not just the airlines. Whereas EV-PTD is top-level composite metric, the elements of EV-PTD should also be provided (15-POTP, average delay for passengers with trip delay less than 15 minutes, average delay for passengers with trip delay greater than 15 minutes, and 90th percentile delay).

It is recognized that these metrics represent "holistic" metrics of the performance of the "integrated" air transportation system. Improving these metrics is beyond the ability of individual enterprises in the supply chain (e.g. airlines, Air Traffic Control, airports, etc.). Improvement demands an integrated and cooperative solution.

In addition, the data should be presented in a way to enable comparison of routes between markets.

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