Characterization of Ground Delay Program Duration

Deepak Kulkarni

1. Introduction

Traffic Management Specialists strategically manage the flow of air traffic in the presence of system disruptions such as heavy volume, weather, and equipment outages using various traffic management initiatives (TMI). (FAA, 2010) Ground delay program (GDP) is one of the traffic flow initiatives that is used by Traffic Flow Managers. (FAA, 2008) This program is usually implemented in response to events such as adverse weather, a large number of aircraft going to an airport, an aircraft incident, and a closed runway. GDP can affect various parts of the airspace in the United States and Canada. GDPs are assigned a "scope" and to a specific "center" or tier. For instance, in the case of a GDP at Newark Airport, controllers could institute delays for just ZNY (New York Center) or each center touching ZNY. Sometimes the delay may affect centers on the second tier, that is, each center adjacent to the first tier. Sometimes the scope of the GDPs is set by mileage; that is, all departures that are less than certain distance from the affected center can be included in the GDPs. The duration of these programs can be several hours, and average delay minutes can vary as conditions change in the affected airspace. Each aircraft flying to the affected area is assigned an EDCT (Expect Departure Clearance Time). If conditions worsen, the controllers may also revise the GDP to increase its duration. When conditions improve, the controllers begin running compressions. This is when the ATC facility can accept more traffic. This causes other EDCT times to change and decrease delays. If conditions improve sufficiently, the controllers may also cancel an ongoing GDP. Given the uncertainties about weather and traffic conditions, initially planned GDP duration often turns out to be an underestimate or an overestimate of the actual GDP duration. This, in turn, results in avoidable airborne or ground delays in the system. Therefore, better models of actual duration have the potential of reducing delays in the system. The overall objective of this study is to develop such models based on logs of GDPs.

TMIs are logged by Air Traffic Control facilities with The National Traffic Management Log (NTML) which is a single system for automated recoding, coordination, and distribution of relevant information about TMIs throughout the National Airspace System. (Brickman, 2004; Yuditsky, 2007) We use 2008-2009 GDP data from the NTML database for the study reported in this paper. NTML information about a GDP includes the initial specification, possibly one or more revisions, and the cancellation. A GDP can be characterized by a number of important factors including the following:

Initial Planned Duration: Duration of the GDP specified in the initial announcement of the GDP.

Overall Planned Duration: Overall duration for which the GDP was planned.
Actual Duration: Actual duration of the GDP.
Lead Time: The duration between initial time of announcement of the GDP and the time of the start of the GDP.
Early Cancel Time: The duration between the planned time for ending the GDP and the actual time when it ended.
Affected Flights: Number of Flights affected by the GDP.
Planned AAR: Airport Arrival Rate planned during GDP.
Start Time Of Day: Hour of the day when the GDP starts.
Weather Cause: Cause of the GDP.

In the next section, we describe general characteristics of actual duration. In the third section, we develop models of actual duration in terms of quantitative variables. In the fourth section, we describe categorical variables that influence actual duration. The final section is a conclusion.

2. Actual Duration

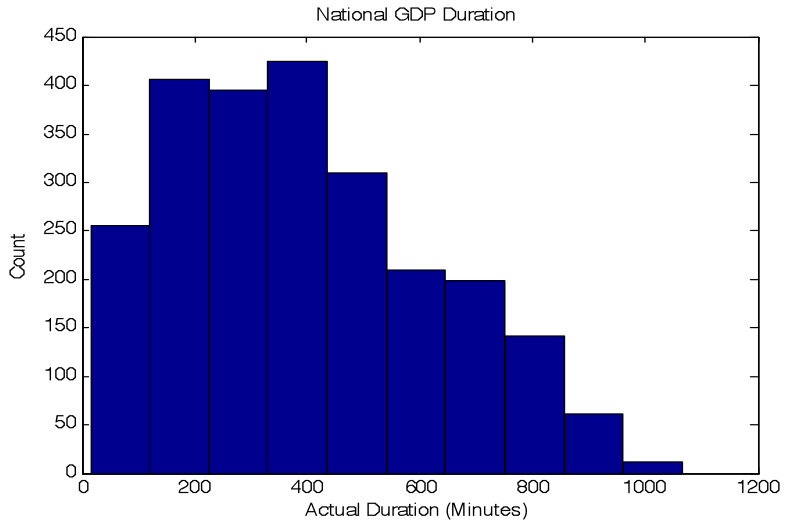

Figure 1. Actual Duration

The mean and the standard deviation of actual duration for all airports in the national airspace are 395 minutes and 228 minutes respectively. A histogram of actual duration is shown in Figure 1. Table 1 shows the mean and the standard deviation of actual duration as well as the percent share of GDPs at airports with the highest number of GDPs. Eight airports listed in the table account for 79% of the GDPs in the country. These airports can be grouped into New York area airports (JFK, LGA, and EWR) and the rest (SFO, PHL, ORD, BOS, and ATL). In this paper, we will refer to these groups as NY and non-NY. The mean duration of GDPs varies from 301 minutes to 602 minutes among these eight major airports. These results are similar to those reported by Cook (2010).

Airport	% Share of GDP	Mean Actual duration (Minutes)	Std. Dev. Actual Duration (Minutes)
EWR	15	522	169
LGA	11	602	220
JFK	12	344	141
SFO	13	301	244
PHL	8	431	240
ORD	8	439	247
BOS	6	366	182
ATL	4	393	220

Table 1. Actual Duration at Selected Airports

Table 2 shows percentage share of all causes of GDPs. Weather causes account for 79% of the GDPs. Among all causes, low ceiling and wind result in the most number of GDPs. Rios (2010) gives a more detailed breakdown of GDP causes at major airports.

Cause	% Share of the GDPs
Low Ceiling	31
Non-weather Causes	21
Rain	1
Snow	5
Thunderstorms	13
Low Visibility	5
Wind	25

Table 2. Percentage Share of Different GDP Causes

3. Actual Duration Models in Terms of Quantitative Attributes

In this section, we develop quantitative models of actual duration at major airports. Table 3 lists coefficients of correlation of actual duration with relevant parameters. Figures 2 and 3 show corresponding scatter-plots in the case of EWR. Table 3 shows a number of quantitative variables that have strong correlation with actual duration. These are initial size of demand list, initial number of affected flights, and initial planned duration. In contrast, early cancel time and lead time have weak correlation with actual duration.

Airport	All	NY	non-NY	EWR	LGA	JFK	SFO	PHL	ORD	BOS	ATL
Early Cancel Time	-.24	-.10	-.24	-.19	-.20	-.13	-.18	-.20	-.32	-.44	-.36
Lead Time	-.14	-.24	-.07	.07	.02	-.10	.04	.09	.12	-.13	.07
Initial Size of Demand List	.52	.89	.52	.85	.90	.80	.74	.69	.73	.74	.77
Initial Number Of Affected Flights	.58	.86	.57	.80	.90	.75	.75	.70	.73	.72	.77
Initial Planned Duration	.82	.90	.75	.84	.91	.78	.75	.73	.75	.73	.74

Table 3. Correlation of Actual Duration with Various Parameters

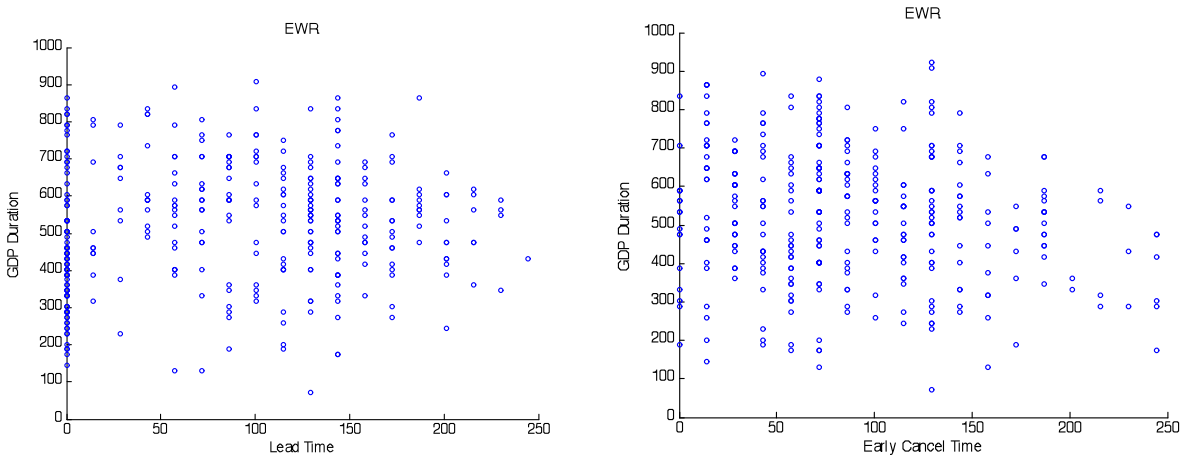

Figure 2. Lead Time and Early Cancel Time vs. Actual Duration at EWR

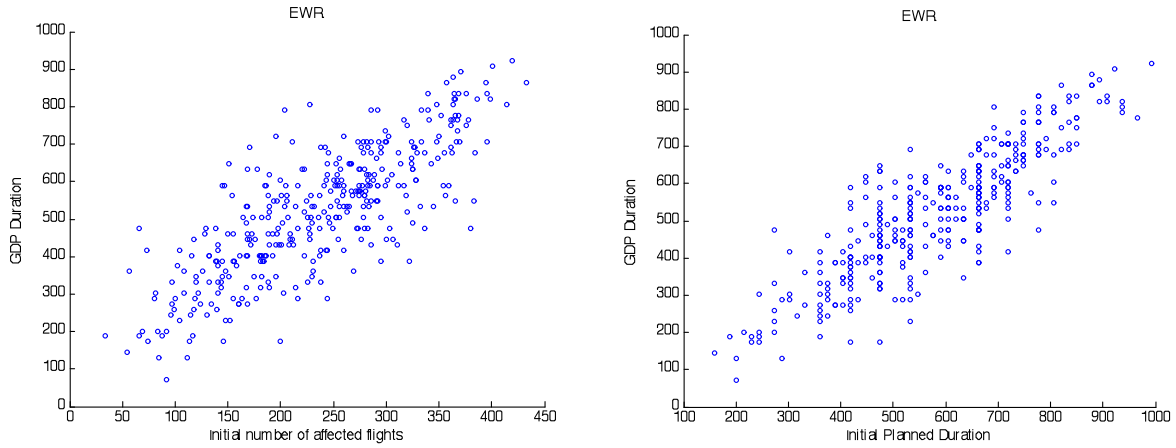

Figure 3. Initial Planned Duration and Initial Number of Affected Flights Vs. Actual Duration at EWR

Table 4 shows information about the models of actual duration in terms of initial planned duration for major airports. Correlation coefficients between actual duration and initial planned duration listed in the fourth column of the table vary from .71 to .91 among different airports. This shows a generally strong correlation between actual duration and initial duration. The last column in the table lists the correlation coefficients of multiple linear regression of actual duration with initial planned duration, initial size of demand list, initial affected flights and lead time. Its values show that more complex multiple linear regression models show very small improvement in ability to predict actual duration as compared to the models in the second column. The third column in Table 4 lists interval estimates of the intercepts in these models. For most airports, the intercept interval in the third column includes 0 and one cannot reject the null hypothesis that intercept is zero. For NY group and SFO, the intercepts do not include 0, but includes a value very close to 0. Therefore, "*actual duration = k * initial planned duration*" can be used as a simple linear model for actual duration. This model can be characterized by the ratio of actual duration and initial planned duration. For the sake of brevity, we will use the term "actual to planned ratio" to refer to the ratio of actual duration and initial planned duration. Box-plots, mean values and 95% confidence interval (CI) estimates of actual to planned ratios at various airports are shown in Table 5 and Figure 4. Size of the interval depends both on variations in the values of a parameter as well as the amount of data. Thus, the estimate of the mean ratio for all airports is based on far more data as compared to the corresponding estimate for an individual airport. Therefore, the interval of this estimate would be narrower. The mean value is the highest for EWR and is generally high for New York airports. On the other hand, it is low for BOS. Airport is not a relevant factor to ratio in the non-NY group under ANOVA test with p = .08 whereas it is a relevant factor to actual to planned ratio in the NY group with p = .00.

Airport	Model in Terms of Initial Planned Duration	Interval Estimate of Intercept	r	r for multiple linear regression
ALL	.87x - 27	(-42, -11)	.82	.83
NY	.81x -18	(-42, 7)	.75	.76
non-NY	.9x - 24	(-41, -7)	.90	.91
EWR	.89x + 1	(-30,34)	.86	.87
LGA	.95x - 60	(-101, 25)	.91	.91
JFK	.79x + 3	(-17, 45)	.79	.81
SFO	.89x – 37	(-80, -6)	.76	.77
PHL	.79x + 18	(-32,90)	.71	.72
ORD	.79 x - 12	(-60, 70)	.72	.74
BOS	.8x - 39	(-110, 24)	.73	.75
ATL	.91 x - 60	(-148,26)	.76	.78

Table 4. Models of Actual Duration in Terms of Initial Planned Duration

Airport	All	Non-NY	NY	EWR	LGA	JFK	SFO	PHL	ORD	BOS	ATL
Mean	.81	.76	.86	.90	.84	.81	.75	.82	.76	.70	.78
Lower Bound	.79	.74	.84	.88	.83	.79	.70	.76	.71	.66	.71
Upper Bound	.82	.79	.87	.92	.86	.84	.80	.89	.81	.74	.84

Table 5. Actual to Planned Ratio at Different Airports

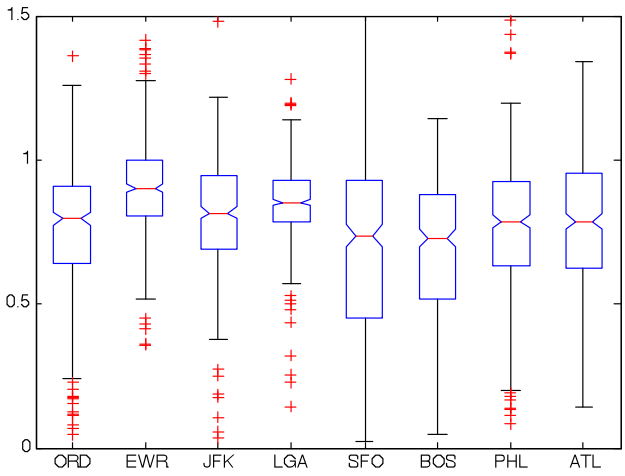

Figure 4. Actual to Planned Ratio at Major Airports

4. Influence of Categorical Variables on Actual to Planned Ratio

In this section, we examine how categorical variables can influence the actual to planned ratio. Table 6 shows p-values under ANOVA test of the influence of the time of day, the GDP cause, the season and the month on the actual to planned ratio. We use alpha to be .05 for determining relevance of a factor. The time of day is a relevant factor at all airports. The GDP cause is a relevant factor at most airports whereas the month and the season are generally not relevant factors at most airports. There are some exceptions to this pattern. For example, season and month are relevant factors at SFO. Figure 5 shows box-plots of EWR actual to planned ratio for different GDP causes. Figure 4 shows box-plots of EWR actual to planned ratio for different months and times of day.

Airport	GDP Cause	Month	Season	Time of Day
All	.00	.05	.32	.00
NY	.00	.39	.30	.00
non-NY	.27	.19	.08	.00
EWR	.01	.27	.36	.34
LGA	.00	.30	.37	.00
JFK	.08	.42	.32	.00
SFO	.04	.01	.02	.13
PHL	.15	.53	.91	.09
ORD	.27	.10	.09	.50
BOS	.00	.58	.09	.01
ATL	.07	.09	.32	.41

Table 6. P-value of ANOVA Test of Relevant Factors

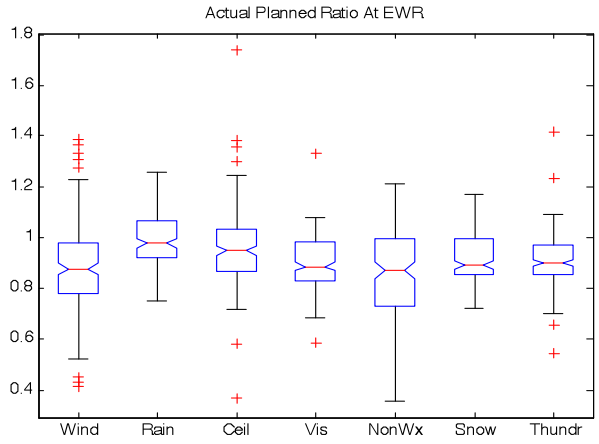

Figure 5. Impact of GDP Cause on EWR Actual Planned Ratio

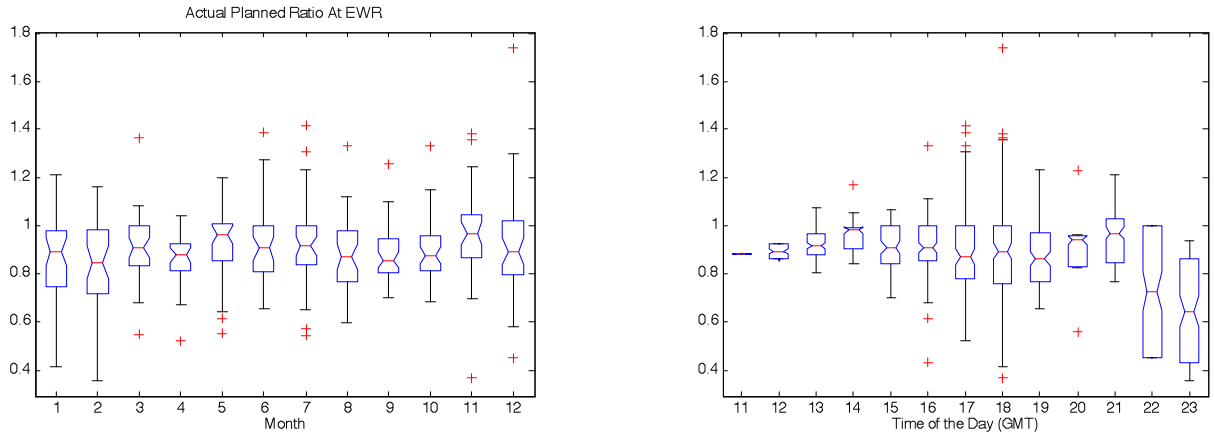

Figure 6. Influence of Month and the Time of Day on Actual Planned Ratio at EWR

Cause	All Mean	All CI	NY Mean	NY CI	Non-NY Mean	Non-NY CI	EWR Mean	EWR CI
Wind	.83	.82,.85	.85	.84,.87	.76	.74,.79	.87	.85,.90
Rain	.87	.76,.98	.98	.88,1.08	.81	.66,.97	.99	.87,1.12
Low Ceiling	.81	.78,.84	.88	.86,.91	.78	.75,.82	.95	.92,.99
Low Visibility	.83	.75,.91	.88	.84,.93	.78	.63,.93	.90	.83,.97
Non-weather	.66	.74,.80	.80	.77,.84	.68	.63,.75	.86	.80,.92
Snow	.71	.68,.87	.83	.74,.93	.74	.60,.88	.93	.85,1.02
Thunderstorm	.72	.73,.81	.87	.83,.91	.69	.63,.75	.91	.85,.97

Table 7. Impact of GDP Cause on Actual to Planned Ratio

Table 7 shows mean actual to planned ratios for different combinations of GDP causes and airports. As the data used for these estimates is smaller than that used for Table 5, the widths of intervals is larger. Furthermore, data used for the estimates varies significantly within the table. For example, amount of cases of rain caused by EWR GDPs are very few and the width of the CI estimate is .25. On the other hand, there are a large number of wind-caused GDPs and, therefore, the width of CI estimates for these for all airports is just .03. Consideration of interval estimates helps us in correctly comparing the estimates of means under differing conditions. In addition to the GDP cause, another factor influencing actual to planned ratio is the start time of the planned GDP. Table 8 shows that there is significant variation in actual to planned ratio for LGA and for different airport groups depending on the GDP Start Time.

Start Time (GMT)	All Mean	All CI	NY Mean	NY CI	Non-NY Mean	Non-NY CI	LGA Mean	LGA CI
12 to 14	.89	.85,.94	.90	.88,.92	.89	.81,.97	.89	.87,.89
15 to 18	.82	.79,.84	.87	.85,.89	.78	.73,.82	.81	.77,.86
19 to 21	.80	.79,.82	.85	.83,.87	.74	.70,.77	.84	.79,.88
22 to 24	.70	.67,.73	.78	.75,.81	.58	.53,.63	.70	.65,.75

Table 8. Impact of GDP Start Time on Actual to Planned Ratio

5. Conclusion

GDP is an important traffic flow initiative that is used by Traffic Flow Managers to reduce the impact of disruptions. Inaccurate estimation of actual duration results in significant avoidable delays in the system. Therefore, better models of actual duration have a potential of reducing delays in the system. We use 2008-2009 GDP data from the NTML database to develop such models. Actual duration was found to have a strong correlation with initial planned duration, size of demand list and number of affected flights. Furthermore, the intercept term in the linear

model of actual duration in terms of Initial Planned Duration is not significant. Therefore, the actual duration model can be characterized by the ratio of actual and planned duration. We also found that the time of Day and GDP cause influence the value of this ratio for most airports.

References

Brickman, B. and Yuditsky, T., "Improving the Usability of an Automated Tool for the Recording, Coordination and Communication of Traffic Management Initiatives," Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting, 2004, pp 46-50.

Cook, L., "Translating Weather Information (Convective and Non-convective) Into TFM Constraints," NASA NRA Report, August 2010.

FAA, Order JO 7110.65S. Air Traffic Control, February 2008.

FAA, Order 7210.3W. Facility Operation and Administration, February 2010.

Rios, J., "Aggregate Statistics of National Traffic Management Initiatives," ATIO Conference, Toronto, Canada, 2010.

Yuditsky, T. and Brickman, B., "Benefits Analysis for the National Traffic Management Log," Technical Report, Federal Aviation Administration, July 2007.