

Thisisafunnygroupname's Project Report

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[DELETE ALL TEXT IN BRACKETS AND TEMPLATE COMMENTS IN CODE WHEN FINISHED]

Introduction

[Write a quick introduction]

Project Description

[Write about the project, our project objectives, and the questions we seek to answer]

Through this data analysis, we aim to answer the 5 following questions:

1. Have flight delays improved over time overall?
 - What about with individual airlines?
2. Do busy destinations tend to have more or less delays?
3. Is the weather correlated with flight delays?
 - How has this changed over time?
4. Is the time of the year correlated between flight delays (holidays or rainy season)?
5. Which airlines have the least delays?
 - How has this changed over time?

Research Questions

[REPLACE WITH QUESTION #1]

Data Exploration and Visualization

```
# reuse/refine the plot made in the proposal
```

[Discuss the visualization. What are some important takeaways? What could we possibly find interesting insights in judging from the plot? Any possible reasons for these insights? Talk about how your visualization leads to your analysis]

Data Analysis/Modeling/Predictions

```
# code for testing your hypotheses/models  
  
# DON'T FORGET TO CHECK NECESSARY ASSUMPTIONS FOR PERFORMING ANALYSES  
# there are plenty of premade functions to test assumptions, just search them up
```

[Discuss your results. Don't forget that no results is still an important conclusion, with plenty to discuss! What are some important takeaways? Any possible explanations for these takeaways? How can we apply this new found knowledge?]

Do busy destinations tend to have more or less delays?

Data Exploration and Visualization

```
important_airports <- destination_stats |>  
  arrange(desc(avg_delay)) |>  
  slice(c(1:5, (n()-4):n())) |>  
  bind_rows(  
    destination_stats |>  
      arrange(desc(busyness)) |>  
      slice(1:5) # 5 busiest  
  ) |>  
  distinct(dest, .keep_all = TRUE)  
  
#for the correlation and p value  
cor_test <- cor.test(destination_stats$busyness, destination_stats$avg_delay)  
correlation <- cor_test$estimate  
p_value <- cor_test$p.value  
  
ggplot(destination_stats, aes(x = busyness, y = avg_delay)) +  
  geom_point(aes(size = total_flights, color = avg_delay), alpha = 0.5) +  
  
  #linear fit line  
  geom_smooth(method = "lm", color = "red", se = FALSE) +
```

```

#floating text for important airports
geom_text_repel(
  data = important_airports,
  aes(label = paste(dest, name.y)),
  size = 3,
  box.padding = 0.5
) +

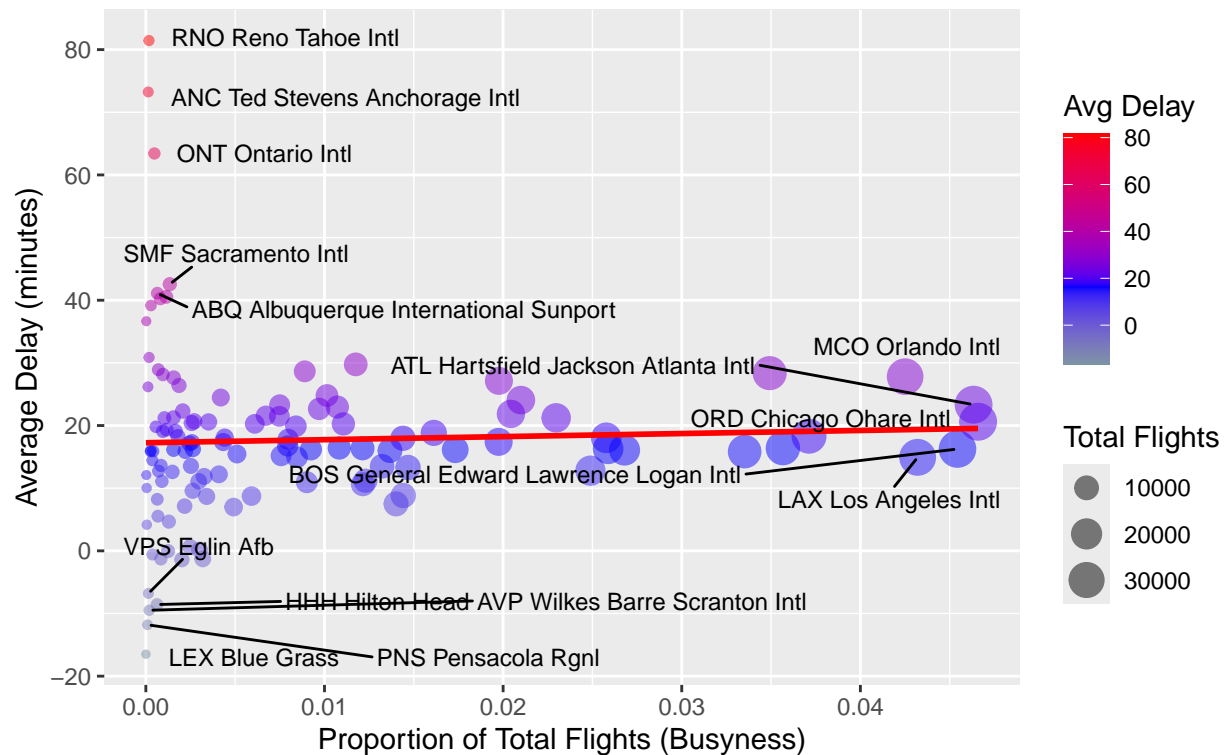
#add colors to visualise delay better
scale_color_gradient2(
  low = "green", mid = "blue", high = "red",
  midpoint = median(destination_stats$avg_delay)
) +
labs(
  x = "Proportion of Total Flights (Busyness)",
  y = "Average Delay (minutes)",
  title = "Flight Delays vs. Destination Busyness",
  subtitle = sprintf(
    "Correlation: %.2f (p = %.3f)",
    correlation,
    p_value
  ),
  size = "Total Flights",
  color = "Avg Delay"
)

```

```
## 'geom_smooth()' using formula = 'y ~ x'
```

Flight Delays vs. Destination Busyness

Correlation: 0.04 ($p = 0.662$)



[Discuss the visualization. What are some important takeaways? What could we possibly find interesting insights in judging from the plot? Any possible reasons for these insights? Talk about how your visualization leads to your analysis]

Data Analysis/Modeling/Predictions

```
model <- lm(avg_delay ~ busyness, data = destination_stats)
bptest(model) # p > 0.05 = homoscedastic
```

```
##
## studentized Breusch-Pagan test
##
## data: model
## BP = 5.4403, df = 1, p-value = 0.01968
```

```
shapiro.test(residuals(model))
```

```
##
## Shapiro-Wilk normality test
##
## data: residuals(model)
## W = 0.86554, p-value = 6.72e-09
```

```
#accounting for heteroscedasticity (obust standard error)

#accounting for normality (np regression)
model_gam <- gam(avg_delay ~ s(business), data = destination_stats)
summary(model_gam)
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## avg_delay ~ s(business)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  17.670      1.282   13.79  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##             edf Ref.df      F p-value
## s(business)   1      1 0.192  0.662
##
## R-sq.(adj) = -0.00701  Deviance explained = 0.167%
## GCV = 195.52  Scale est. = 192.17      n = 117
```

[Discuss your results. Don't forget that no results is still an important conclusion, with plenty to discuss! What are some important takeaways? Any possible explanations for these takeaways? How can we apply this new found knowledge?]

[REPLACE WITH QUESTION #3]

Data Exploration and Visualization

```
# reuse/refine the plot made in the proposal
```

[Discuss the visualization. What are some important takeaways? What could we possibly find interesting insights in judging from the plot? Any possible reasons for these insights? Talk about how your visualization leads to your analysis]

Data Analysis/Modeling/Predictions

```
# code for testing your hypotheses/models
```

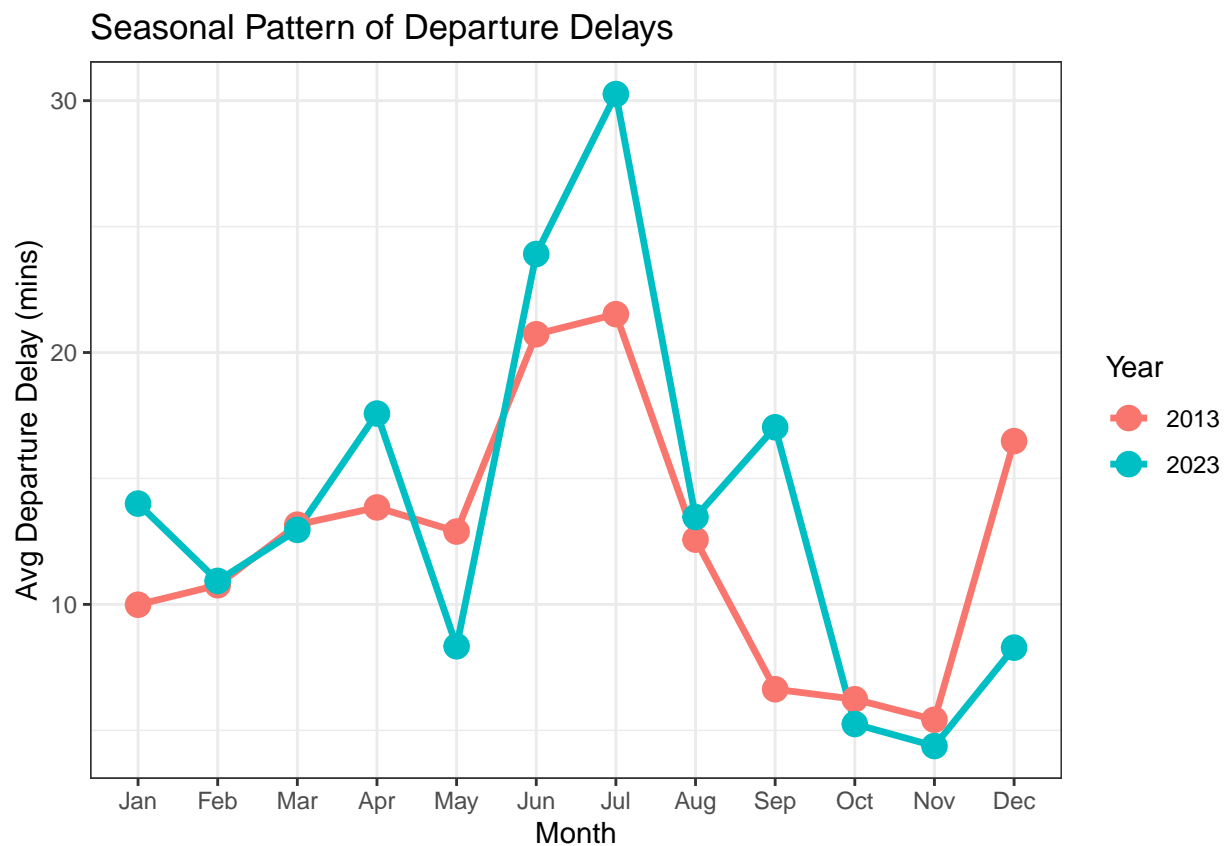
```
# DON'T FORGET TO CHECK NECESSARY ASSUMPTIONS FOR PERFORMING ANALYSES # there are plenty of premade fun
```

[Discuss your results. Don't forget that no results is still an important conclusion, with plenty to discuss! What are some important takeaways? Any possible explanations for these takeaways? How can we apply this new found knowledge?]

Does time of year affect flight delays?

Data Exploration and Visualization

```
flights_clean %>%  
  # get month from time_hour  
  mutate(month = month(time_hour, label = TRUE)) %>%  
  group_by(month, year) %>%  
  # compute average departure delay for that month  
  summarise(avg_dep_delay = mean(dep_delay), .groups = 'drop') %>%  
  # plotting departure delays by month  
  ggplot(aes(x = month, y = avg_dep_delay, group = year, color = factor(year))) +  
  geom_line(linewidth = 1.2) +  
  geom_point(size = 4) +  
  labs(title = "Seasonal Pattern of Departure Delays", x = "Month", y = "Avg Departure Delay (mins)", c  
  theme_bw()
```



This line chart shows how departure delays vary across months for both years. Peaks in certain months could point to holiday seasons, weather events, or seasonal congestion affecting flight performance.

Data Analysis/Modeling/Predictions

```
# constant variance: levene's test for homogeneity of variance across months
leveneTest(dep_delay ~ as.factor(month), data = flights_seasonal)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##           Df F value    Pr(>F)
## group      11  838.66 < 2.2e-16 ***
##           750152
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

[Explain output in a short paragraph 3-4 sentences]

```
# normality, large sample size sensitive to tests, use graph
# TODO: make the QQ plots
```

[Explain output in a short paragraph 3-4 sentences]

```
# durbin-Watson test for autocorrelation/seasonal trend.
anova_model <- aov(dep_delay ~ as.factor(month)*as.factor(year), data = flights_seasonal)
dwtest(anova_model)
```

```
##
## Durbin-Watson test
##
## data:  anova_model
## DW = 1.5254, p-value < 2.2e-16
## alternative hypothesis: true autocorrelation is greater than 0
```

```
# TODO: shouldn't you also run this for the one-way anova too?
```

[Explain output in a short paragraph 3-4 sentences]

```
# run one-way anova
anova_model1 <- aov(dep_delay ~ as.factor(month), data = flights_seasonal)
summary(anova_model1)
```

```
##           Df      Sum Sq Mean Sq F value Pr(>F)
## as.factor(month)    11 2.510e+07 2281673  985.3 <2e-16 ***
## Residuals      750152 1.737e+09    2316
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

[Explain output in a short paragraph 3-4 sentences]

```
# run two-way anova
summary(anova_model)
```

```
##           Df      Sum Sq Mean Sq F value Pr(>F)
## as.factor(month)    11 2.510e+07 2281673  988.0 <2e-16 ***
```



```
## as.factor(year)          1 3.142e+05 314214 136.1 <2e-16 ***
## as.factor(month):as.factor(year) 11 4.460e+06 405440 175.6 <2e-16 ***
## Residuals                750140 1.732e+09 2309
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

[Explain output in a short paragraph 3-4 sentences]

```
# linear model for two-way anova to calculate adjusted r-squared
lm1 <- lm(dep_delay ~ as.factor(month)*as.factor(year), data = flights_seasonal)
summary(lm1)$adj.r.squared
```

```
## [1] 0.0169209
```

[Explain output in a short paragraph 3-4 sentences]

Results and Insights

[Talk about the possible limitations of your part. Explain how your model performed and whether you could've overfitted or underfitted, etc. Make conclusions on your result in context, and give some thoughtful insights on your results, make possible real-world conclusions from your data if possible, ideally a long paragraph]

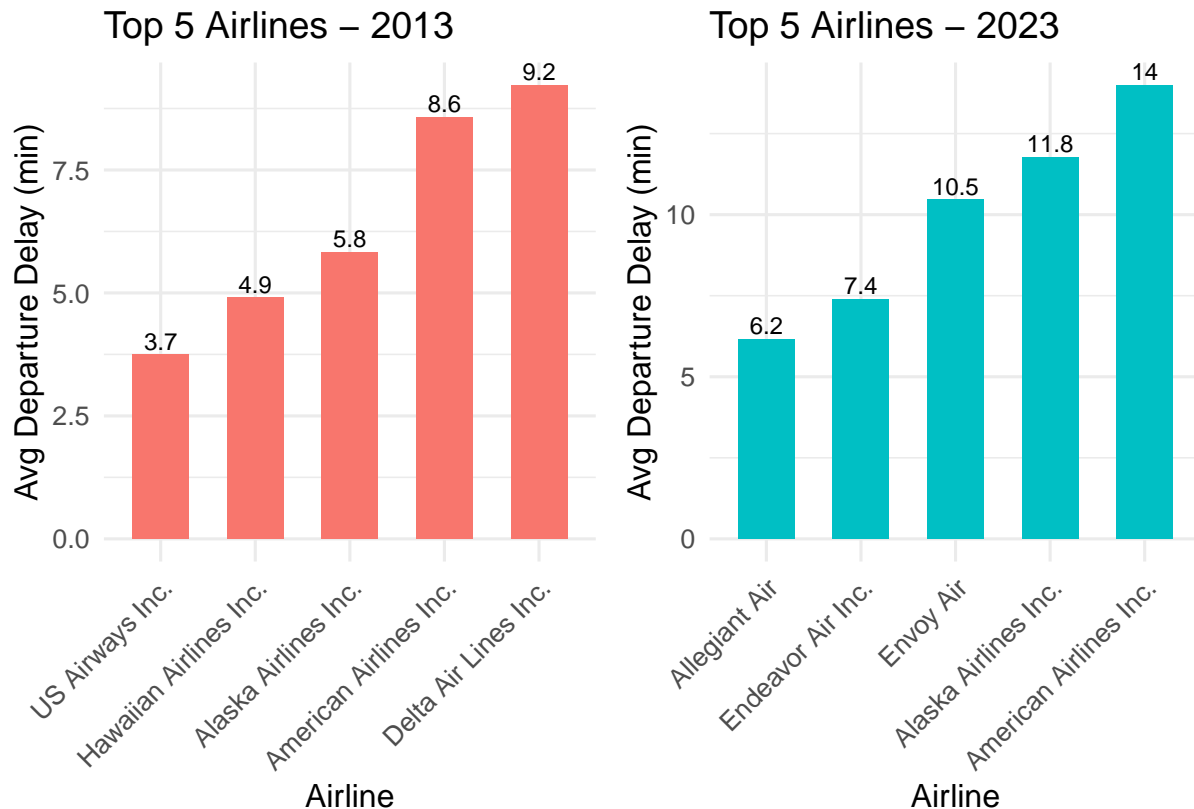
Which airlines have the least delays? How has this changed over time?

Data Exploration and Visualization

```
p1 <- ggplot(top5_2013, aes(x = name.x, y = avg_dep_delay)) +
  geom_col(fill = "#f8766d", width = 0.6) +
  geom_text(aes(label = round(avg_dep_delay, 1)), vjust = -0.3, size = 3) +
  labs(title = "Top 5 Airlines - 2013", x = "Airline", y = "Avg Departure Delay (min)") +
  theme_minimal(base_size = 12) +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

p2 <- ggplot(top5_2023, aes(x = name.x, y = avg_dep_delay)) +
  geom_col(fill = "#00bfc4", width = 0.6) +
  geom_text(aes(label = round(avg_dep_delay, 1)), vjust = -0.3, size = 3) +
  labs(title = "Top 5 Airlines - 2023", x = "Airline", y = "Avg Departure Delay (min)") +
  theme_minimal(base_size = 12) +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

p1 + p2 + plot_layout(ncol = 2)
```



The bar plots show the top 5 airlines with the shortest average departure delays in 2013 and 2023. In 2013, airlines such as US Airways and Hawaiian Airlines had the lowest delays, while in 2023, Allegiant Air and Endeavor Air led in punctuality. A notable insight is that average delays increased overall in 2023, with the lowest still above 6 minutes compared to 3.7 in 2013. Alaska and American Airlines appear in both years, suggesting consistency but also a relative decline in performance. These trends point to changing airline operations and possible external factors, motivating further analysis into statistical significance and underlying causes.

Data Analysis/Modeling/Predictions

```
leveneTest(dep_delay ~ name.x, data = data_2013)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##           Df F value    Pr(>F)
## group      15  256.55 < 2.2e-16 ***
##           327330
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
leveneTest(dep_delay ~ name.x, data = data_2023)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##           Df F value    Pr(>F)
```

```
## group      10 245.08 < 2.2e-16 ***
##          321940
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

[TODO: Interpretation of levene test]

```
summary(anova_2013)
```

```
##              Df      Sum Sq Mean Sq F value Pr(>F)
## name.x        15    6229900  415327    261.8 <2e-16 ***
## Residuals    327330 519243712    1586
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(anova_2023)
```

```
##              Df      Sum Sq Mean Sq F value Pr(>F)
## name.x        10 8.696e+06  869641    265.3 <2e-16 ***
## Residuals    321940 1.055e+09    3278
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 100867 observations deleted due to missingness
```

```
tukey_2013
```

```
## Tukey multiple comparisons of means
## 95% family-wise confidence level
##
## Fit: aov(formula = dep_delay ~ name.x, data = data_2013)
##
## $name.x
##
##              diff              lwr
## Alaska Airlines Inc.-AirTran Airways Corporation -12.7752367 -18.44323814
## American Airlines Inc.-AirTran Airways Corporation -10.0368541 -12.57600225
## Delta Air Lines Inc.-AirTran Airways Corporation -9.3820344 -11.88306168
## Endeavor Air Inc.-AirTran Airways Corporation -2.1664098 -4.80100592
## Envoy Air-AirTran Airways Corporation -8.1606034 -10.73123151
## ExpressJet Airlines Inc.-AirTran Airways Corporation 1.2329451 -1.26280409
## Frontier Airlines Inc.-AirTran Airways Corporation 1.5951905 -4.16727601
## Hawaiian Airlines Inc.-AirTran Airways Corporation -13.7053995 -21.47120637
## JetBlue Airways-AirTran Airways Corporation -5.6384363 -8.13021075
## Mesa Airlines Inc.-AirTran Airways Corporation 0.2929128 -6.03888585
## SkyWest Airlines Inc.-AirTran Airways Corporation -6.0197774 -31.47405119
## Southwest Airlines Co.-AirTran Airways Corporation -0.9443270 -3.66653397
## United Air Lines Inc.-AirTran Airways Corporation -6.5890759 -9.07638042
## US Airways Inc.-AirTran Airways Corporation -14.8612916 -17.46961662
## Virgin America-AirTran Airways Corporation -5.8493384 -8.93218313
## American Airlines Inc.-Alaska Airlines Inc. 2.7383826 -2.44279713
## Delta Air Lines Inc.-Alaska Airlines Inc. 3.3932023 -1.76940243
## Endeavor Air Inc.-Alaska Airlines Inc. 10.6088269 5.38020884
## Envoy Air-Alaska Airlines Inc. 4.6146333 -0.58204630
```

## ExpressJet Airlines Inc.-Alaska Airlines Inc.	14.0081818	8.84813198
## Frontier Airlines Inc.-Alaska Airlines Inc.	14.3704272	7.04899495
## Hawaiian Airlines Inc.-Alaska Airlines Inc.	-0.9301627	-9.91376486
## JetBlue Airways-Alaska Airlines Inc.	7.1368004	1.97867188
## Mesa Airlines Inc.-Alaska Airlines Inc.	13.0681495	5.29068051
## SkyWest Airlines Inc.-Alaska Airlines Inc.	6.7554594	-19.09637628
## Southwest Airlines Co.-Alaska Airlines Inc.	11.8309097	6.55760327
## United Air Lines Inc.-Alaska Airlines Inc.	6.1861608	1.03019013
## US Airways Inc.-Alaska Airlines Inc.	-2.0860549	-7.30148483
## Virgin America-Alaska Airlines Inc.	6.9258983	1.45769186
## Delta Air Lines Inc.-American Airlines Inc.	0.6548197	-0.33185173
## Endeavor Air Inc.-American Airlines Inc.	7.8704443	6.58223632
## Envoy Air-American Airlines Inc.	1.8762507	0.72450766
## ExpressJet Airlines Inc.-American Airlines Inc.	11.2697992	10.29658435
## Frontier Airlines Inc.-American Airlines Inc.	11.6320446	6.34769003
## Hawaiian Airlines Inc.-American Airlines Inc.	-3.6685453	-11.08650598
## JetBlue Airways-American Airlines Inc.	4.3984178	3.43544160
## Mesa Airlines Inc.-American Airlines Inc.	10.3297669	4.42976207
## SkyWest Airlines Inc.-American Airlines Inc.	4.0170768	-21.33323761
## Southwest Airlines Co.-American Airlines Inc.	9.0925271	7.63348839
## United Air Lines Inc.-American Airlines Inc.	3.4477783	2.49642807
## US Airways Inc.-American Airlines Inc.	-4.8244375	-6.05802681
## Virgin America-American Airlines Inc.	4.1875157	2.13268853
## Endeavor Air Inc.-Delta Air Lines Inc.	7.2156246	6.00428491
## Envoy Air-Delta Air Lines Inc.	1.2214310	0.15636007
## ExpressJet Airlines Inc.-Delta Air Lines Inc.	10.6149795	9.74606570
## Frontier Airlines Inc.-Delta Air Lines Inc.	10.9772249	5.71108142
## Hawaiian Airlines Inc.-Delta Air Lines Inc.	-4.3233650	-11.72836362
## JetBlue Airways-Delta Air Lines Inc.	3.7435982	2.88616750
## Mesa Airlines Inc.-Delta Air Lines Inc.	9.6749472	3.79124760
## SkyWest Airlines Inc.-Delta Air Lines Inc.	3.3622571	-21.98426740
## Southwest Airlines Co.-Delta Air Lines Inc.	8.4377074	7.04606880
## United Air Lines Inc.-Delta Air Lines Inc.	2.7929586	1.94860600
## US Airways Inc.-Delta Air Lines Inc.	-5.4792572	-6.63234291
## Virgin America-Delta Air Lines Inc.	3.5326960	1.52516550
## Envoy Air-Endeavor Air Inc.	-5.9941936	-7.34339166
## ExpressJet Airlines Inc.-Endeavor Air Inc.	3.3993549	2.19895058
## Frontier Airlines Inc.-Endeavor Air Inc.	3.7616003	-1.56927454
## Hawaiian Airlines Inc.-Endeavor Air Inc.	-11.5389896	-18.99016159
## JetBlue Airways-Endeavor Air Inc.	-3.4720265	-4.66414501
## Mesa Airlines Inc.-Endeavor Air Inc.	2.4593226	-3.48238426
## SkyWest Airlines Inc.-Endeavor Air Inc.	-3.8533675	-29.21342002
## Southwest Airlines Co.-Endeavor Air Inc.	1.2220828	-0.39736690
## United Air Lines Inc.-Endeavor Air Inc.	-4.4226660	-5.60541309
## US Airways Inc.-Endeavor Air Inc.	-12.6948818	-14.11458810
## Virgin America-Endeavor Air Inc.	-3.6829286	-5.85459572
## ExpressJet Airlines Inc.-Envoy Air	9.3935485	8.34093137
## Frontier Airlines Inc.-Envoy Air	9.7557939	4.45624118
## Hawaiian Airlines Inc.-Envoy Air	-5.5447960	-12.97359109
## JetBlue Airways-Envoy Air	2.5221671	1.47900899
## Mesa Airlines Inc.-Envoy Air	8.4535162	2.53989524
## SkyWest Airlines Inc.-Envoy Air	2.1408261	-23.21266078
## Southwest Airlines Co.-Envoy Air	7.2162764	5.70311757
## United Air Lines Inc.-Envoy Air	1.5715275	0.53909215

## US Airways Inc.-Envoy Air	-6.7006882	-7.99783826
## Virgin America-Envoy Air	2.3112650	0.21766275
## Frontier Airlines Inc.-ExpressJet Airlines Inc.	0.3622454	-4.90139345
## Hawaiian Airlines Inc.-ExpressJet Airlines Inc.	-14.9383445	-22.34156214
## JetBlue Airways-ExpressJet Airlines Inc.	-6.8713814	-7.71329228
## Mesa Airlines Inc.-ExpressJet Airlines Inc.	-0.9400323	-6.82149027
## SkyWest Airlines Inc.-ExpressJet Airlines Inc.	-7.2527224	-32.59872666
## Southwest Airlines Co.-ExpressJet Airlines Inc.	-2.1772721	-3.55940260
## United Air Lines Inc.-ExpressJet Airlines Inc.	-7.8220209	-8.65060886
## US Airways Inc.-ExpressJet Airlines Inc.	-16.0942367	-17.23582916
## Virgin America-ExpressJet Airlines Inc.	-7.0822835	-9.08323463
## Hawaiian Airlines Inc.-Frontier Airlines Inc.	-15.3005899	-24.34408967
## JetBlue Airways-Frontier Airlines Inc.	-7.2336268	-12.49538221
## Mesa Airlines Inc.-Frontier Airlines Inc.	-1.3022777	-9.14885684
## SkyWest Airlines Inc.-Frontier Airlines Inc.	-7.6149678	-33.48767908
## Southwest Airlines Co.-Frontier Airlines Inc.	-2.5395175	-7.91423060
## United Air Lines Inc.-Frontier Airlines Inc.	-8.1842664	-13.44390648
## US Airways Inc.-Frontier Airlines Inc.	-16.4564821	-21.77442245
## Virgin America-Frontier Airlines Inc.	-7.4445289	-13.01059232
## JetBlue Airways-Hawaiian Airlines Inc.	8.0669632	0.66508455
## Mesa Airlines Inc.-Hawaiian Airlines Inc.	13.9983123	4.58180859
## SkyWest Airlines Inc.-Hawaiian Airlines Inc.	7.6856221	-18.70564394
## Southwest Airlines Co.-Hawaiian Airlines Inc.	12.7610725	5.27847412
## United Air Lines Inc.-Hawaiian Airlines Inc.	7.1163236	-0.28405148
## US Airways Inc.-Hawaiian Airlines Inc.	-1.1558921	-8.59781572
## Virgin America-Hawaiian Airlines Inc.	7.8560610	0.23485386
## Mesa Airlines Inc.-JetBlue Airways	5.9313491	0.05157662
## SkyWest Airlines Inc.-JetBlue Airways	-0.3813411	-25.72695423
## Southwest Airlines Co.-JetBlue Airways	4.6941093	3.31916897
## United Air Lines Inc.-JetBlue Airways	-0.9506396	-1.76717741
## US Airways Inc.-JetBlue Airways	-9.2228553	-10.35573197
## Virgin America-JetBlue Airways	-0.2109021	-2.20689351
## SkyWest Airlines Inc.-Mesa Airlines Inc.	-6.3126902	-32.31812884
## Southwest Airlines Co.-Mesa Airlines Inc.	-1.2372398	-7.21830953
## United Air Lines Inc.-Mesa Airlines Inc.	-6.8819887	-12.75986825
## US Airways Inc.-Mesa Airlines Inc.	-15.1542044	-21.08430927
## Virgin America-Mesa Airlines Inc.	-6.1422512	-12.29584497
## Southwest Airlines Co.-SkyWest Airlines Inc.	5.0754504	-20.29385348
## United Air Lines Inc.-SkyWest Airlines Inc.	-0.5692985	-25.91447262
## US Airways Inc.-SkyWest Airlines Inc.	-8.8415142	-34.19885097
## Virgin America-SkyWest Airlines Inc.	0.1704389	-25.24009232
## United Air Lines Inc.-Southwest Airlines Co.	-5.6447489	-7.01157177
## US Airways Inc.-Southwest Airlines Co.	-13.9169646	-15.49331492
## Virgin America-Southwest Airlines Co.	-4.9050114	-7.18217026
## US Airways Inc.-United Air Lines Inc.	-8.2722157	-9.39522661
## Virgin America-United Air Lines Inc.	0.7397374	-1.25067092
## Virgin America-US Airways Inc.	9.0119532	6.87223334
##	upr	p adj
## Alaska Airlines Inc.-AirTran Airways Corporation	-7.10723530	0.0000000
## American Airlines Inc.-AirTran Airways Corporation	-7.49770601	0.0000000
## Delta Air Lines Inc.-AirTran Airways Corporation	-6.88100721	0.0000000
## Endeavor Air Inc.-AirTran Airways Corporation	0.46818626	0.2588732
## Envoy Air-AirTran Airways Corporation	-5.58997532	0.0000000
## ExpressJet Airlines Inc.-AirTran Airways Corporation	3.72869424	0.9492181

## Frontier Airlines Inc.-AirTran Airways Corporation	7.35765699	0.9999012
## Hawaiian Airlines Inc.-AirTran Airways Corporation	-5.93959254	0.0000002
## JetBlue Airways-AirTran Airways Corporation	-3.14666182	0.0000000
## Mesa Airlines Inc.-AirTran Airways Corporation	6.62471146	1.0000000
## SkyWest Airlines Inc.-AirTran Airways Corporation	19.43449648	0.9999871
## Southwest Airlines Co.-AirTran Airways Corporation	1.77787998	0.9985079
## United Air Lines Inc.-AirTran Airways Corporation	-4.10177132	0.0000000
## US Airways Inc.-AirTran Airways Corporation	-12.25296658	0.0000000
## Virgin America-AirTran Airways Corporation	-2.76649374	0.0000000
## American Airlines Inc.-Alaska Airlines Inc.	7.91956231	0.9130741
## Delta Air Lines Inc.-Alaska Airlines Inc.	8.55580699	0.6597668
## Endeavor Air Inc.-Alaska Airlines Inc.	15.83744494	0.0000000
## Envoy Air-Alaska Airlines Inc.	9.81131291	0.1514223
## ExpressJet Airlines Inc.-Alaska Airlines Inc.	19.16823161	0.0000000
## Frontier Airlines Inc.-Alaska Airlines Inc.	21.69185947	0.0000000
## Hawaiian Airlines Inc.-Alaska Airlines Inc.	8.05343939	1.0000000
## JetBlue Airways-Alaska Airlines Inc.	12.29492899	0.0002421
## Mesa Airlines Inc.-Alaska Airlines Inc.	20.84561855	0.0000010
## SkyWest Airlines Inc.-Alaska Airlines Inc.	32.60729501	0.9999526
## Southwest Airlines Co.-Alaska Airlines Inc.	17.10421618	0.0000000
## United Air Lines Inc.-Alaska Airlines Inc.	11.34213157	0.0040746
## US Airways Inc.-Alaska Airlines Inc.	3.12937507	0.9929861
## Virgin America-Alaska Airlines Inc.	12.39410472	0.0015413
## Delta Air Lines Inc.-American Airlines Inc.	1.64149111	0.6434931
## Endeavor Air Inc.-American Airlines Inc.	9.15865228	0.0000000
## Envoy Air-American Airlines Inc.	3.02799377	0.0000028
## ExpressJet Airlines Inc.-American Airlines Inc.	12.24301406	0.0000000
## Frontier Airlines Inc.-American Airlines Inc.	16.91639921	0.0000000
## Hawaiian Airlines Inc.-American Airlines Inc.	3.74941533	0.9487619
## JetBlue Airways-American Airlines Inc.	5.36139409	0.0000000
## Mesa Airlines Inc.-American Airlines Inc.	16.22977181	0.0000002
## SkyWest Airlines Inc.-American Airlines Inc.	29.36739116	0.9999999
## Southwest Airlines Co.-American Airlines Inc.	10.55156588	0.0000000
## United Air Lines Inc.-American Airlines Inc.	4.39912845	0.0000000
## US Airways Inc.-American Airlines Inc.	-3.59084812	0.0000000
## Virgin America-American Airlines Inc.	6.24234286	0.0000000
## Endeavor Air Inc.-Delta Air Lines Inc.	8.42696431	0.0000000
## Envoy Air-Delta Air Lines Inc.	2.28650198	0.0084191
## ExpressJet Airlines Inc.-Delta Air Lines Inc.	11.48389334	0.0000000
## Frontier Airlines Inc.-Delta Air Lines Inc.	16.24336845	0.0000000
## Hawaiian Airlines Inc.-Delta Air Lines Inc.	3.08163359	0.8256179
## JetBlue Airways-Delta Air Lines Inc.	4.60102881	0.0000000
## Mesa Airlines Inc.-Delta Air Lines Inc.	15.55864690	0.0000021
## SkyWest Airlines Inc.-Delta Air Lines Inc.	28.70878158	1.0000000
## Southwest Airlines Co.-Delta Air Lines Inc.	9.82934610	0.0000000
## United Air Lines Inc.-Delta Air Lines Inc.	3.63731114	0.0000000
## US Airways Inc.-Delta Air Lines Inc.	-4.32617141	0.0000000
## Virgin America-Delta Air Lines Inc.	5.54022652	0.0000002
## Envoy Air-Endeavor Air Inc.	-4.64499550	0.0000000
## ExpressJet Airlines Inc.-Endeavor Air Inc.	4.59975923	0.0000000
## Frontier Airlines Inc.-Endeavor Air Inc.	9.09247519	0.5341190
## Hawaiian Airlines Inc.-Endeavor Air Inc.	-4.08781766	0.0000132
## JetBlue Airways-Endeavor Air Inc.	-2.27990790	0.0000000
## Mesa Airlines Inc.-Endeavor Air Inc.	8.40102954	0.9900596

## SkyWest Airlines Inc.-Endeavor Air Inc.	21.50668498	1.0000000
## Southwest Airlines Co.-Endeavor Air Inc.	2.84153257	0.4087417
## United Air Lines Inc.-Endeavor Air Inc.	-3.23991899	0.0000000
## US Airways Inc.-Endeavor Air Inc.	-11.27517544	0.0000000
## Virgin America-Endeavor Air Inc.	-1.51126149	0.0000007
## ExpressJet Airlines Inc.-Envoy Air	10.44616561	0.0000000
## Frontier Airlines Inc.-Envoy Air	15.05534663	0.0000000
## Hawaiian Airlines Inc.-Envoy Air	1.88399901	0.4291506
## JetBlue Airways-Envoy Air	3.56532527	0.0000000
## Mesa Airlines Inc.-Envoy Air	14.36713721	0.0001115
## SkyWest Airlines Inc.-Envoy Air	27.49431290	1.0000000
## Southwest Airlines Co.-Envoy Air	8.72943527	0.0000000
## United Air Lines Inc.-Envoy Air	2.60396293	0.0000215
## US Airways Inc.-Envoy Air	-5.40353811	0.0000000
## Virgin America-Envoy Air	4.40486722	0.0146752
## Frontier Airlines Inc.-ExpressJet Airlines Inc.	5.62588429	1.0000000
## Hawaiian Airlines Inc.-ExpressJet Airlines Inc.	-7.53512692	0.0000000
## JetBlue Airways-ExpressJet Airlines Inc.	-6.02947044	0.0000000
## Mesa Airlines Inc.-ExpressJet Airlines Inc.	4.94142573	0.9999999
## SkyWest Airlines Inc.-ExpressJet Airlines Inc.	18.09328180	0.9998504
## Southwest Airlines Co.-ExpressJet Airlines Inc.	-0.79514154	0.0000080
## United Air Lines Inc.-ExpressJet Airlines Inc.	-6.99343304	0.0000000
## US Airways Inc.-ExpressJet Airlines Inc.	-14.95264418	0.0000000
## Virgin America-ExpressJet Airlines Inc.	-5.08133238	0.0000000
## Hawaiian Airlines Inc.-Frontier Airlines Inc.	-6.25709022	0.0000008
## JetBlue Airways-Frontier Airlines Inc.	-1.97187134	0.0002802
## Mesa Airlines Inc.-Frontier Airlines Inc.	6.54430148	0.9999999
## SkyWest Airlines Inc.-Frontier Airlines Inc.	18.25774339	0.9997879
## Southwest Airlines Co.-Frontier Airlines Inc.	2.83519563	0.9653291
## United Air Lines Inc.-Frontier Airlines Inc.	-2.92462624	0.0000115
## US Airways Inc.-Frontier Airlines Inc.	-11.13854173	0.0000000
## Virgin America-Frontier Airlines Inc.	-1.87846553	0.0005131
## JetBlue Airways-Hawaiian Airlines Inc.	15.46884179	0.0175127
## Mesa Airlines Inc.-Hawaiian Airlines Inc.	23.41481593	0.0000410
## SkyWest Airlines Inc.-Hawaiian Airlines Inc.	34.07688814	0.9998139
## Southwest Airlines Co.-Hawaiian Airlines Inc.	20.24367080	0.0000006
## United Air Lines Inc.-Hawaiian Airlines Inc.	14.51669865	0.0750296
## US Airways Inc.-Hawaiian Airlines Inc.	6.28603144	1.0000000
## Virgin America-Hawaiian Airlines Inc.	15.47726818	0.0354271
## Mesa Airlines Inc.-JetBlue Airways	11.81112157	0.0454046
## SkyWest Airlines Inc.-JetBlue Airways	24.96427209	1.0000000
## Southwest Airlines Co.-JetBlue Airways	6.06904962	0.0000000
## United Air Lines Inc.-JetBlue Airways	-0.13410176	0.0066625
## US Airways Inc.-JetBlue Airways	-8.08997866	0.0000000
## Virgin America-JetBlue Airways	1.78508921	1.0000000
## SkyWest Airlines Inc.-Mesa Airlines Inc.	19.69274851	0.9999818
## Southwest Airlines Co.-Mesa Airlines Inc.	4.74382993	0.9999979
## United Air Lines Inc.-Mesa Airlines Inc.	-1.00410911	0.0060904
## US Airways Inc.-Mesa Airlines Inc.	-9.22409954	0.0000000
## Virgin America-Mesa Airlines Inc.	0.01134248	0.0510145
## Southwest Airlines Co.-SkyWest Airlines Inc.	30.44475420	0.9999987
## United Air Lines Inc.-SkyWest Airlines Inc.	24.77587559	1.0000000
## US Airways Inc.-SkyWest Airlines Inc.	16.51582248	0.9984186
## Virgin America-SkyWest Airlines Inc.	25.58097016	1.0000000

```
## United Air Lines Inc.-Southwest Airlines Co.      -4.27792598 0.0000000
## US Airways Inc.-Southwest Airlines Co.            -12.34061429 0.0000000
## Virgin America-Southwest Airlines Co.             -2.62785262 0.0000000
## US Airways Inc.-United Air Lines Inc.             -7.14920484 0.0000000
## Virgin America-United Air Lines Inc.              2.73014580 0.9967843
## Virgin America-US Airways Inc.                    11.15167299 0.0000000
```

```
tukey_2023
```

```
## Tukey multiple comparisons of means
## 95% family-wise confidence level
##
## Fit: aov(formula = dep_delay ~ name.x, data = data_2023)
##
## $name.x
##
## diff lwr
## American Airlines Inc.-Alaska Airlines Inc. 2.2223585 -0.06798732
## Delta Air Lines Inc.-Alaska Airlines Inc. 3.2051962 0.97945767
## Endeavor Air Inc.-Alaska Airlines Inc. -4.3872091 -6.63261681
## Envoy Air-Alaska Airlines Inc. -1.3139012 -11.33037630
## Frontier Airlines Inc.-Alaska Airlines Inc. 23.9698510 18.28875185
## Hawaiian Airlines Inc.-Alaska Airlines Inc. 11.2395214 1.32944643
## JetBlue Airways-Alaska Airlines Inc. 11.8399683 9.62194289
## SkyWest Airlines Inc.-Alaska Airlines Inc. 8.0021449 4.86049720
## Southwest Airlines Co.-Alaska Airlines Inc. 4.2229936 1.53781241
## United Air Lines Inc.-Alaska Airlines Inc. 5.5983805 3.40068595
## Delta Air Lines Inc.-American Airlines Inc. 0.9828377 -0.20754849
## Endeavor Air Inc.-American Airlines Inc. -6.6095676 -7.83633693
## Envoy Air-American Airlines Inc. -3.5362597 -13.37459697
## Frontier Airlines Inc.-American Airlines Inc. 21.7474925 16.38670949
## Hawaiian Airlines Inc.-American Airlines Inc. 9.0171629 -0.71282645
## JetBlue Airways-American Airlines Inc. 9.6176098 8.44170852
## SkyWest Airlines Inc.-American Airlines Inc. 5.7797864 3.26322976
## Southwest Airlines Co.-American Airlines Inc. 2.0006351 0.08404825
## United Air Lines Inc.-American Airlines Inc. 3.3760220 2.23893424
## Endeavor Air Inc.-Delta Air Lines Inc. -7.5924053 -8.69385495
## Envoy Air-Delta Air Lines Inc. -4.5190974 -14.34259522
## Frontier Airlines Inc.-Delta Air Lines Inc. 20.7646548 15.43115471
## Hawaiian Airlines Inc.-Delta Air Lines Inc. 8.0343252 -1.68065919
## JetBlue Airways-Delta Air Lines Inc. 8.6347720 7.59027597
## SkyWest Airlines Inc.-Delta Air Lines Inc. 4.7969486 2.33904597
## Southwest Airlines Co.-Delta Air Lines Inc. 1.0177974 -0.82109726
## United Air Lines Inc.-Delta Air Lines Inc. 2.3931843 1.39258602
## Envoy Air-Endeavor Air Inc. 3.0733079 -6.75466506
## Frontier Airlines Inc.-Endeavor Air Inc. 28.3570601 23.01532194
## Hawaiian Airlines Inc.-Endeavor Air Inc. 15.6267305 5.90722100
## JetBlue Airways-Endeavor Air Inc. 16.2271774 15.14139853
## SkyWest Airlines Inc.-Endeavor Air Inc. 12.3893540 9.91362596
## Southwest Airlines Co.-Endeavor Air Inc. 8.6102027 6.74754945
## United Air Lines Inc.-Endeavor Air Inc. 9.9855896 8.94197065
## Frontier Airlines Inc.-Envoy Air 25.2837522 14.15621498
## Hawaiian Airlines Inc.-Envoy Air 12.5534226 -1.22180091
## JetBlue Airways-Envoy Air 13.1538695 3.33211639
## SkyWest Airlines Inc.-Envoy Air 9.3160461 -0.75456202
```


## Southwest Airlines Co.-Envoy Air	5.5368948	-4.40078073
## United Air Lines Inc.-Envoy Air	6.9122817	-2.90490008
## Hawaiian Airlines Inc.-Frontier Airlines Inc.	-12.7303296	-23.76218785
## JetBlue Airways-Frontier Airlines Inc.	-12.1298827	-17.46016860
## SkyWest Airlines Inc.-Frontier Airlines Inc.	-15.9677061	-21.74371348
## Southwest Airlines Co.-Frontier Airlines Inc.	-19.7468574	-25.28784186
## United Air Lines Inc.-Frontier Airlines Inc.	-18.3714705	-23.69332845
## JetBlue Airways-Hawaiian Airlines Inc.	0.6004469	-9.11277331
## SkyWest Airlines Inc.-Hawaiian Airlines Inc.	-3.2373766	-13.20216252
## Southwest Airlines Co.-Hawaiian Airlines Inc.	-7.0165278	-16.84695035
## United Air Lines Inc.-Hawaiian Airlines Inc.	-5.6411409	-15.34973867
## SkyWest Airlines Inc.-JetBlue Airways	-3.8378234	-6.28874362
## Southwest Airlines Co.-JetBlue Airways	-7.6169747	-9.44652595
## United Air Lines Inc.-JetBlue Airways	-6.2415877	-7.22490932
## Southwest Airlines Co.-SkyWest Airlines Inc.	-3.7791513	-6.65970179
## United Air Lines Inc.-SkyWest Airlines Inc.	-2.4037643	-4.83630104
## United Air Lines Inc.-Southwest Airlines Co.	1.3753869	-0.42946288
##	upr	p adj
## American Airlines Inc.-Alaska Airlines Inc.	4.51270427	0.0664850
## Delta Air Lines Inc.-Alaska Airlines Inc.	5.43093478	0.0001876
## Endeavor Air Inc.-Alaska Airlines Inc.	-2.14180140	0.0000000
## Envoy Air-Alaska Airlines Inc.	8.70257391	0.9999984
## Frontier Airlines Inc.-Alaska Airlines Inc.	29.65095014	0.0000000
## Hawaiian Airlines Inc.-Alaska Airlines Inc.	21.14959638	0.0118114
## JetBlue Airways-Alaska Airlines Inc.	14.05799363	0.0000000
## SkyWest Airlines Inc.-Alaska Airlines Inc.	11.14379251	0.0000000
## Southwest Airlines Co.-Alaska Airlines Inc.	6.90817478	0.0000223
## United Air Lines Inc.-Alaska Airlines Inc.	7.79607508	0.0000000
## Delta Air Lines Inc.-American Airlines Inc.	2.17322398	0.2195355
## Endeavor Air Inc.-American Airlines Inc.	-5.38279824	0.0000000
## Envoy Air-American Airlines Inc.	6.30207762	0.9868263
## Frontier Airlines Inc.-American Airlines Inc.	27.10827555	0.0000000
## Hawaiian Airlines Inc.-American Airlines Inc.	18.74715231	0.0986341
## JetBlue Airways-American Airlines Inc.	10.79351105	0.0000000
## SkyWest Airlines Inc.-American Airlines Inc.	8.29634301	0.0000000
## Southwest Airlines Co.-American Airlines Inc.	3.91722199	0.0320639
## United Air Lines Inc.-American Airlines Inc.	4.51310984	0.0000000
## Endeavor Air Inc.-Delta Air Lines Inc.	-6.49095570	0.0000000
## Envoy Air-Delta Air Lines Inc.	5.30440038	0.9264850
## Frontier Airlines Inc.-Delta Air Lines Inc.	26.09815484	0.0000000
## Hawaiian Airlines Inc.-Delta Air Lines Inc.	17.74930957	0.2174305
## JetBlue Airways-Delta Air Lines Inc.	9.67926811	0.0000000
## SkyWest Airlines Inc.-Delta Air Lines Inc.	7.25485130	0.0000000
## Southwest Airlines Co.-Delta Air Lines Inc.	2.85669201	0.7914353
## United Air Lines Inc.-Delta Air Lines Inc.	3.39378257	0.0000000
## Envoy Air-Endeavor Air Inc.	12.90128088	0.9955970
## Frontier Airlines Inc.-Endeavor Air Inc.	33.69879827	0.0000000
## Hawaiian Airlines Inc.-Endeavor Air Inc.	25.34624003	0.0000123
## JetBlue Airways-Endeavor Air Inc.	17.31295621	0.0000000
## SkyWest Airlines Inc.-Endeavor Air Inc.	14.86508197	0.0000000
## Southwest Airlines Co.-Endeavor Air Inc.	10.47285595	0.0000000
## United Air Lines Inc.-Endeavor Air Inc.	11.02920859	0.0000000
## Frontier Airlines Inc.-Envoy Air	36.41128940	0.0000000
## Hawaiian Airlines Inc.-Envoy Air	26.32864612	0.1126338

## JetBlue Airways-Envoy Air	22.97562253	0.0008301
## SkyWest Airlines Inc.-Envoy Air	19.38665412	0.1000754
## Southwest Airlines Co.-Envoy Air	15.47457032	0.7845028
## United Air Lines Inc.-Envoy Air	16.72946350	0.4573805
## Hawaiian Airlines Inc.-Frontier Airlines Inc.	-1.69847132	0.0093508
## JetBlue Airways-Frontier Airlines Inc.	-6.79959687	0.0000000
## SkyWest Airlines Inc.-Frontier Airlines Inc.	-10.19169879	0.0000000
## Southwest Airlines Co.-Frontier Airlines Inc.	-14.20587293	0.0000000
## United Air Lines Inc.-Frontier Airlines Inc.	-13.04961251	0.0000000
## JetBlue Airways-Hawaiian Airlines Inc.	10.31366702	1.0000000
## SkyWest Airlines Inc.-Hawaiian Airlines Inc.	6.72740942	0.9940092
## Southwest Airlines Co.-Hawaiian Airlines Inc.	2.81389473	0.4355923
## United Air Lines Inc.-Hawaiian Airlines Inc.	4.06745688	0.7370219
## SkyWest Airlines Inc.-JetBlue Airways	-1.38690319	0.0000250
## Southwest Airlines Co.-JetBlue Airways	-5.78742338	0.0000000
## United Air Lines Inc.-JetBlue Airways	-5.25826617	0.0000000
## Southwest Airlines Co.-SkyWest Airlines Inc.	-0.89860073	0.0012172
## United Air Lines Inc.-SkyWest Airlines Inc.	0.02877235	0.0560990
## United Air Lines Inc.-Southwest Airlines Co.	3.18023671	0.3328667

One-way ANOVA tests showed the significant differences in average departure delays across airlines in both years. Tukey HSD tests further revealed specific airline pairs with meaningful differences, highlighting operational disparities. And as a result, we reject the null hypothesis and conclude that airline performance varies meaningfully, with some airlines having significantly lower delays than others in both years. Average delays increased in 2023 across the top-performing airlines, suggesting worsening punctuality industry-wide. This may be due to factors like increased air traffic, staffing shortages, or post-pandemic recovery challenges. These findings can inform consumers when choosing airlines and encourage airlines to reassess scheduling and efficiency strategies.

Conclusions

1. Have flight delays improved over time overall?

- What about with individual airlines?

[Write a quick paragraph recapping conclusions made from your analysis]

2. Do busy destinations tend to have more or less delays?

[Write a quick paragraph recapping conclusions made from your analysis] i will do this tmrw i;m so sleepy

3. Is the weather correlated with flight delays?

- How has this changed over time?

[Write a quick paragraph recapping conclusions made from your analysis]

4. Is the time of the year correlated between flight delays (holidays or rainy season)?

[Write a quick paragraph recapping conclusions made from your analysis]

5. Which airlines have the least delays?

- How has this changed over time?

[Write a quick paragraph recapping conclusions made from your analysis]

Authors' Contributions

Author	Contributions
Richard Zhou	
Adam Rui	Question 4
Jonathan Darius	
Ojasvi Godha	
Ryan Huang	Question 2
Isaac Kang	