FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Airline Flight Data Examination to Improve flight Performance Modeling

Project 35

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Research Objectives

Analyze aircraft departure operating data for two wide-body and two narrow body commercial aircraft to:

1. Develop a functional relationship between stage/trip length and weight that can replace the existing guidance provided for weight estimation

2. Determine the percentage of departures that use reduced thrust as well as the level of reduced thrust that is used.

Research Approach

Two large operational databases were analyzed to meet the research objectives:

- A Flight Planning Database containing actual weight, with departure and destination airports which was used to develop a relationship between distance and aircraft actual weight.
- An Aircraft Communications Addressing and Reporting System (ACARS) database that contained the same pertinent information plus, if used, the actual percentage of reduced thrust applied for the departure.
- IBM SPSS 19 used for all regression analyses.

Research Results

The four aircraft selected were:

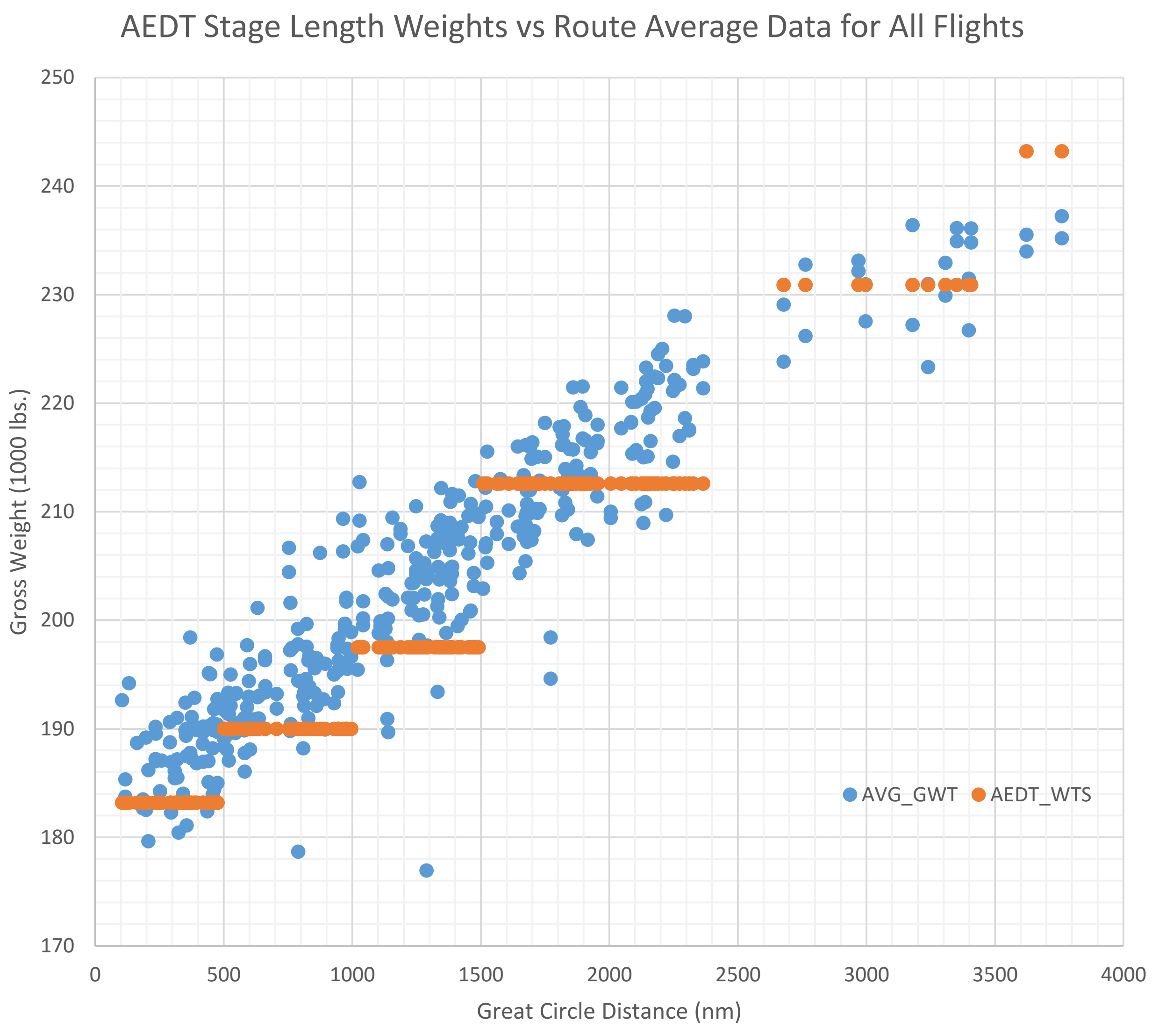
B757-200/PW2037

B737-800/CFM56-7B26

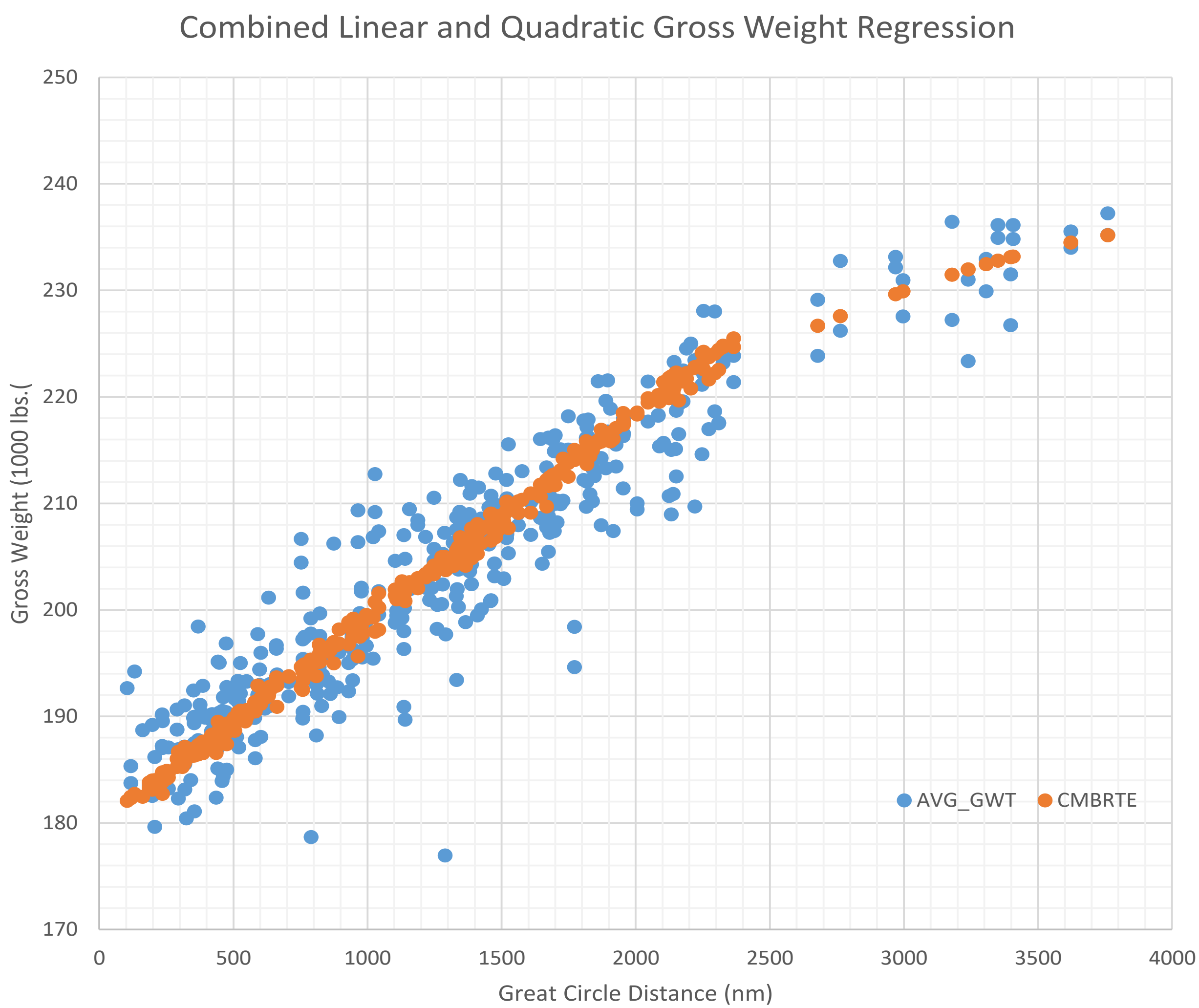
B767-400ER/CF6-80C2B8F

B767-300ER/CF6-80C2B6F

B757- 200 AEDT Weight Estimation



B757-200 Combined Regression:



B757-200 Regression:

Flight Planning Database:

- 45,343 Flights
- 376 Routes from 97 Airports

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.909[a]	.826	.825	5900.6880141
2	.910[b]	.828	.827	5873.6849681

a. Predictors: (Constant), GCD

b. Predictors: (Constant), GCD, RWYL

c. Dependent Variable: AVG-GWT

$GWT + 175571.496 + 19.188(GCD) + .374$*(RUNWAY LEN)*

for GCD's < 2365 nm

$GWT = 175381.001 + 27.18(GCD) - .003(GCD)^2$

for GCD's ≥ 2365 nm

B737- 800 Weight Estimation

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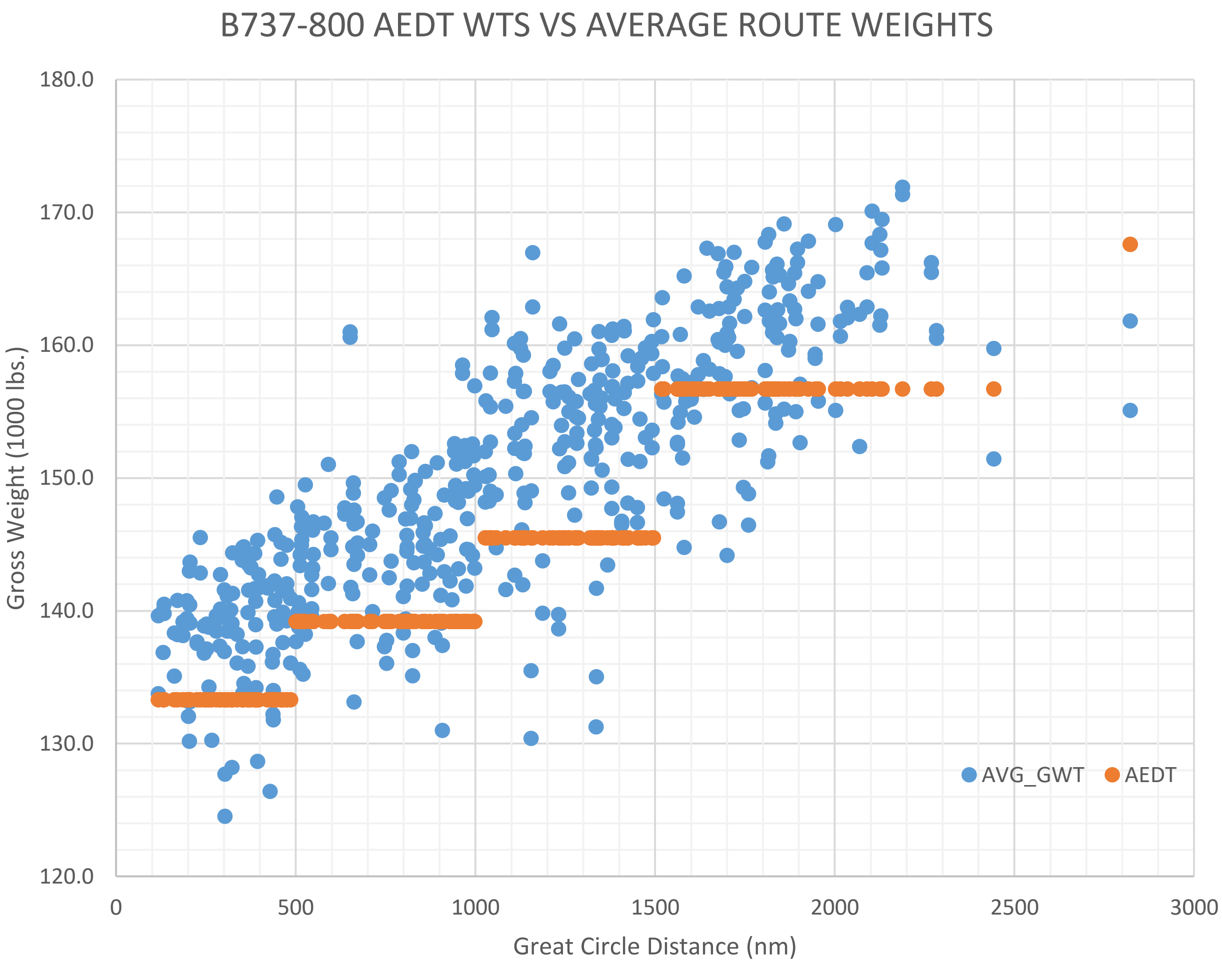
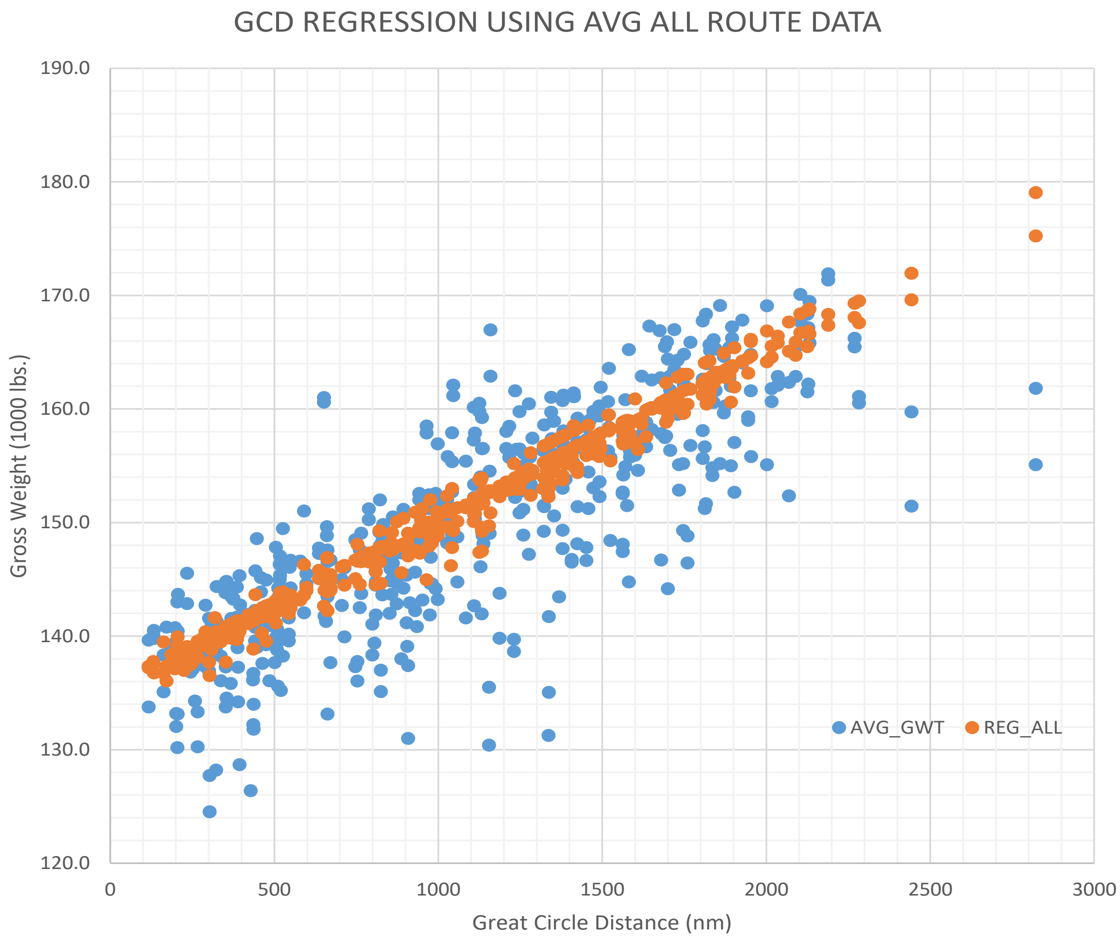


B737-800 Weight Estimate



B737-800 Regression:

Flight Planning Database:

- 33,933 Flights
- 467 Routes Departing 94 Airports

$$GWT = 128007.473 + .625(RUNWAY\ LEN) - .094(ELEV) + 14.880(GCD)$$

Model Summary[c]

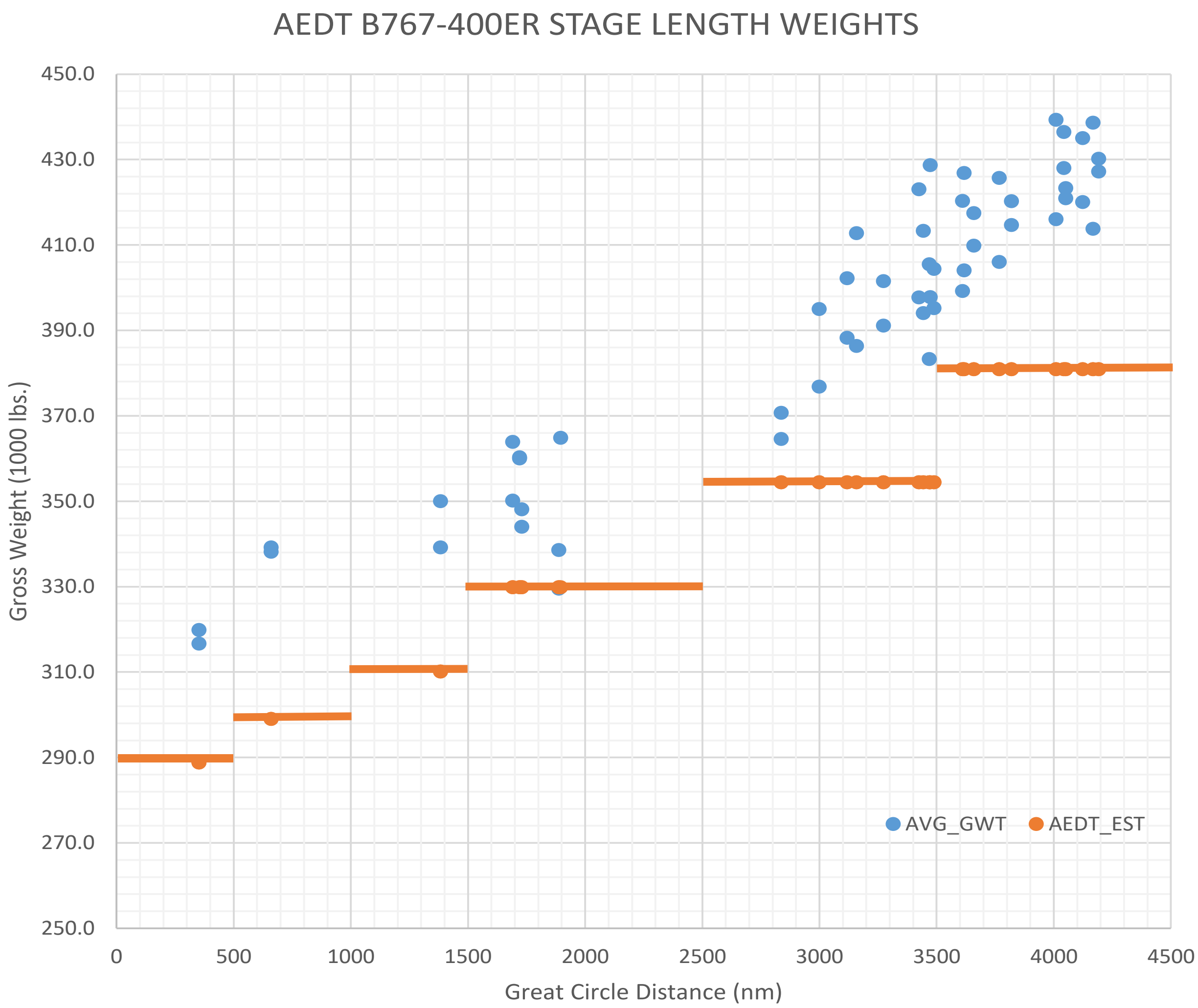
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.895[a]	.801	.801	4361.5687221
2	.901[b]	.812	.811	4251.5240030

a. Predictors: (Constant), AVG_PLDST

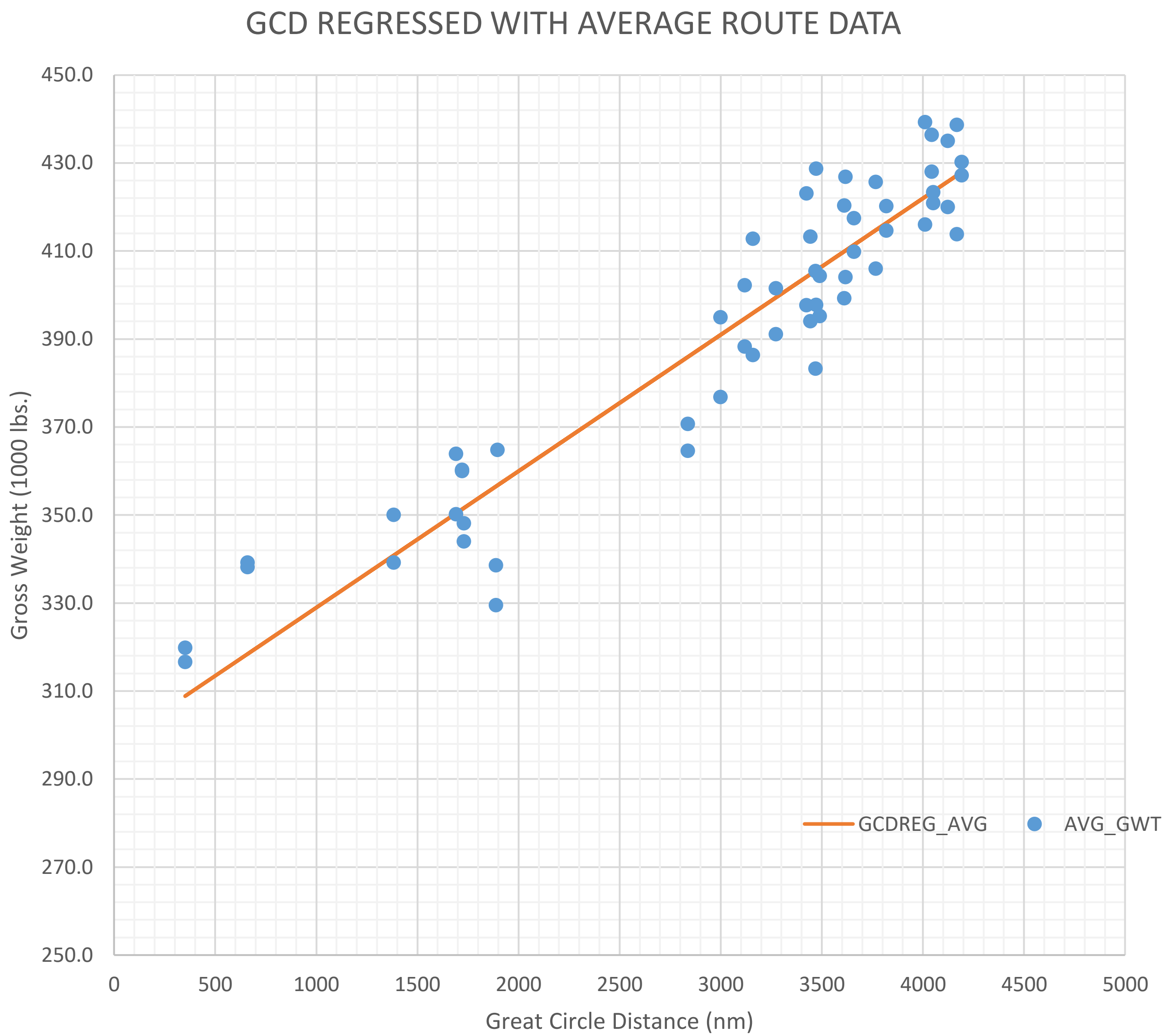
b. Predictors: (Constant), AVG_PLDST, RWYL

c. Dependent Variable: AVG_GWT

B767- 400ER AEDT Weight Estimation



B767- 400ER Weight Estimation



B767- 400ER Regression:

Specifics of the Flight Planning Database:

- 12,138 Flights
- 94 Routes from 28 Departure Airports

$$GWT = 297.966 + .031(GCD)$$

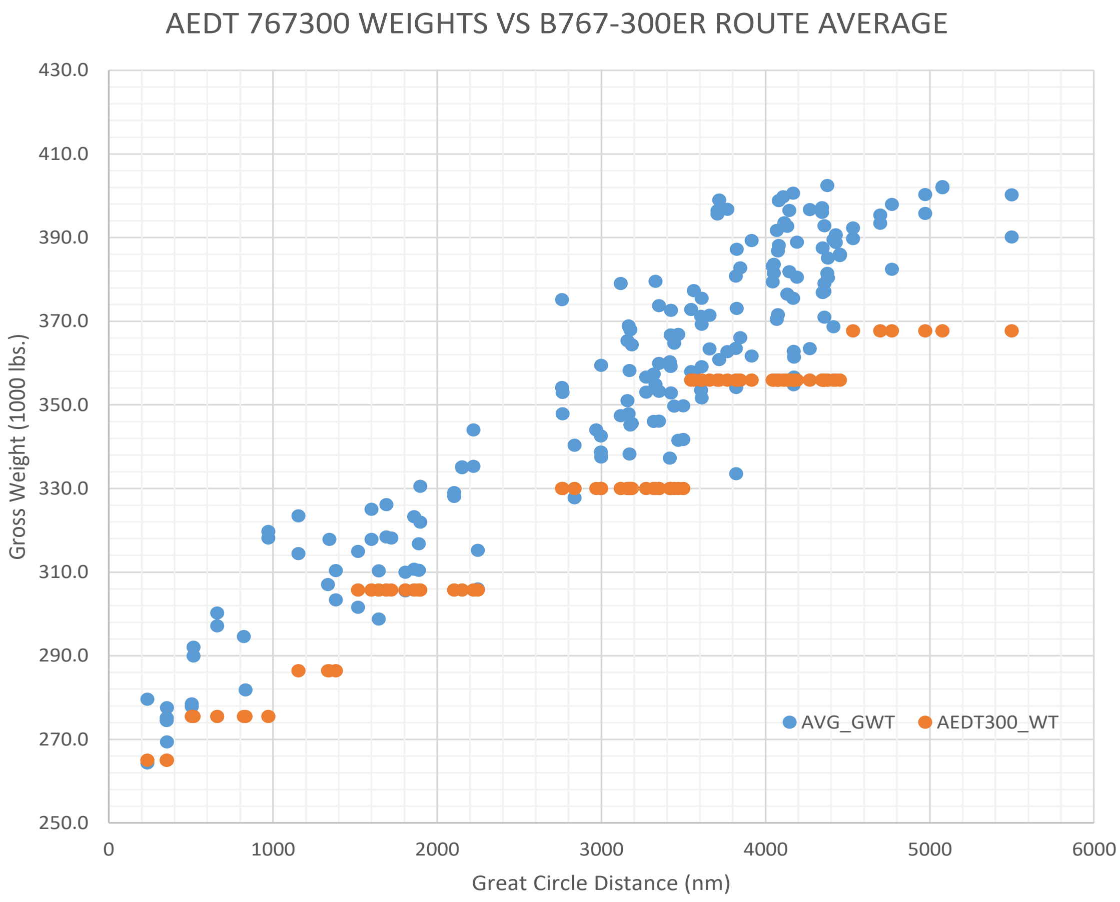
Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.930[a]	.865	.863	13.66898455

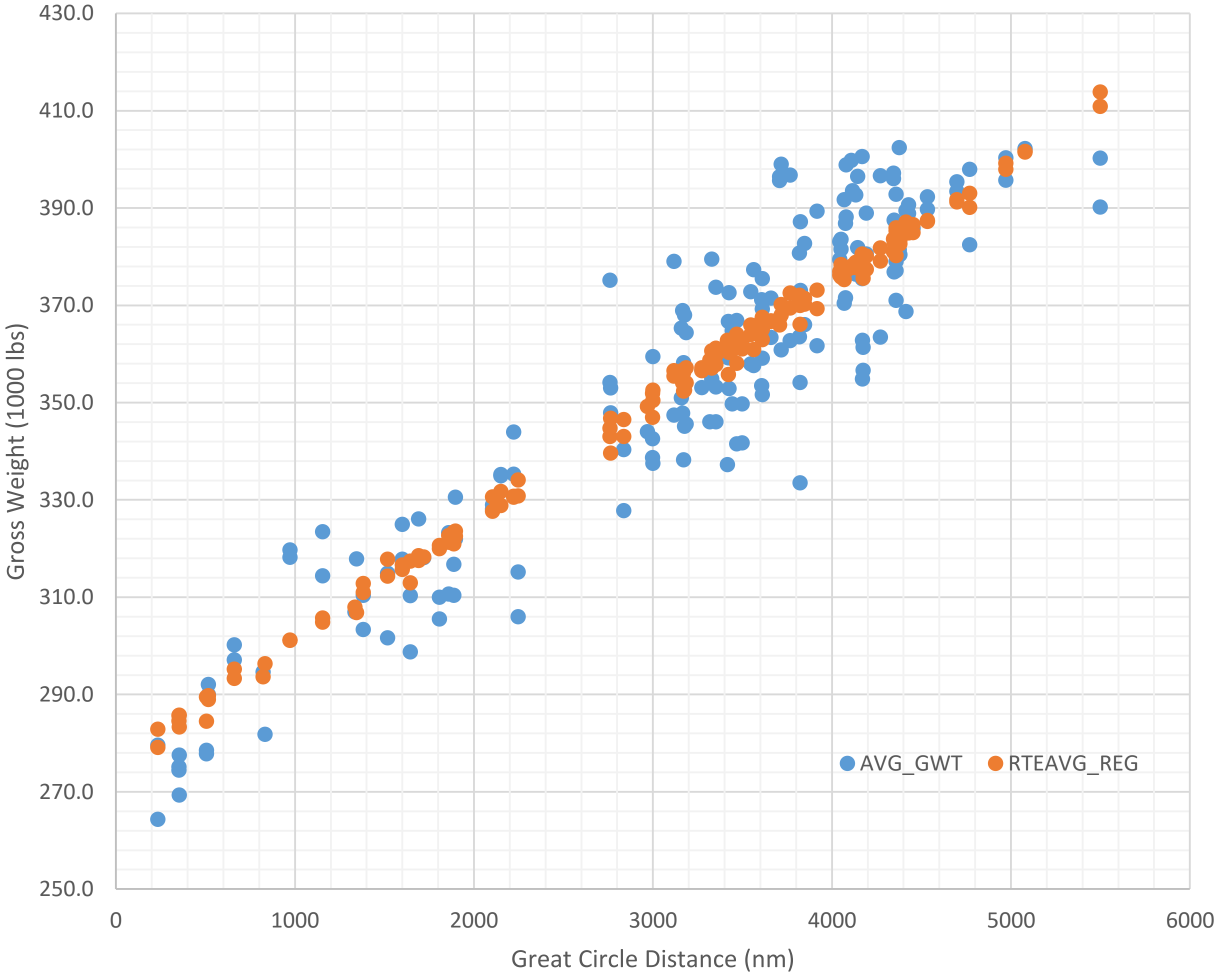
a. Predictors: (Constant), GCD

b. Dependent Variable: AVG_GWT

B767- 300ER Weight Estimation



B767-300ER REGRESSION USING AVERAGE ROUTE FLIGHTS



B767-300ER Regression:

Flight Planning Database:
- 15,956 Flights
- 185 Routes Departing 53 Airports

$$GWT = 260913.478 + .716(ELEV) + 1.247(RUNWAY\ LEN) + 24.520(GCD)$$

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.907[a]	.822	.819	13417.6824909

a. Predictors: (Constant), GCD, RWYL, ELEV

b. Dependent Variable: AVG_GWT

Weight Regression Tabular Data (Example):

APRPTS	AVG_GWT	REG_ALL	REG_DF	%REG_DF	AEDT	AEDT_DF	%AEDT_DF
RDUSLC	155.8	157.8	2032	1.6%	156.7	931	0.9%
RNOSLC	135.8	139.9	4108	3.2%	133.3	-2521	-1.7%
ROCATL	160.6	142.6	-17957	-11.1%	139.2	-21400	-13.2%
RSWATL	139.0	142.2	3156	2.5%	133.3	-5700	-3.9%
RSWDTW	152.0	149.5	-2478	-1.6%	139.2	-12800	-8.3%
RTBATL	149.0	147.8	-1203	-0.7%	145.5	-3500	-2.3%
SALATL	152.2	152.9	722	1.1%	145.5	-6700	-3.8%
SALLAX	160.7	164.6	3898	2.8%	156.7	-3960	-2.1%
SANDTW	160.9	159.2	-1742	-1.0%	156.7	-4219	-2.6%
SANJFK	161.5	165.5	3994	2.6%	156.7	-4807	-2.9%
SANMSP	153.6	153.7	92	0.2%	145.5	-8094	-5.2%
SANSEA	142.9	147.5	4529	3.4%	139.2	-3738	-2.4%
SANSLC	141.6	142.0	370	0.5%	139.2	-2406	-1.5%
SATATL	142.5	144.6	2056	1.6%	139.2	-3300	-2.2%
SATJFK	147.7	153.8	6066	4.4%	145.5	-2201	-1.2%
SATSLC	148.3	147.3	-992	-0.4%	139.2	-9086	-5.9%
SDFATL	138.5	139.5	1075	1.0%	133.3	-5167	-3.5%
SDQATL	158.0	152.8	-5182	-3.2%	145.5	-12519	-7.8%
SDQJFK	155.4	154.9	-463	0.2%	145.5	-9869	-5.8%
SEAANC	151.2	154.1	2983	2.4%	145.5	-5656	-3.4%
SEAATL	166.2	163.6	-2603	-1.5%	156.7	-9520	-5.7%
SEACVG	156.3	160.8	4456	3.1%	156.7	351	0.4%
SEADTW	160.4	160.3	-111	0.0%	156.7	-3740	-2.2%
SEAJFK	167.7	166.7	-983	-0.5%	156.7	-10996	-6.5%
SEALAS	136.0	146.6	10571	8.4%	139.2	3161	2.9%
SEALAX	148.4	147.7	-619	-0.2%	139.2	-9159	-5.9%
SEAMSP	155.7	153.5	-2240	-1.3%	145.5	-10239	-6.5%
SEAPVR	155.6	162.3	6642	4.7%	156.7	1064	1.1%
SEASAN	148.7	149.0	267	0.4%	139.2	-9523	-6.2%
SEASLC	144.6	144.3	-306	0.0%	139.2	-5409	-3.5%
SFOATL	155.2	163.1	7896	5.5%	156.7	1510	1.4%
SFOCVG	156.8	161.7	4948	3.5%	156.7	-100	0.2%
SFODTW	162.6	162.3	-334	-0.1%	156.7	-5932	-3.6%
SFOMSP	156.9	156.0	-909	-0.5%	145.5	-11384	-7.2%
SFOSLC	135.2	143.2	7942	6.4%	139.2	3980	3.4%
SJCATL	160.6	162.2	1658	1.1%	156.7	-3883	-2.3%
SJCSLC	138.8	142.4	3650	2.8%	139.2	414	0.5%
SJDATL	153.0	156.0	2994	2.1%	145.5	-7549	-4.8%
SJOATL	156.4	154.9	-1490	-0.7%	145.5	-10930	-6.7%
SJUATL	159.7	154.5	-5211	-3.2%	145.5	-14217	-8.9%
SJUJFK	153.8	155.2	1345	1.3%	145.5	-8315	-5.0%
SKBATL	148.4	155.4	7004	4.9%	156.7	8271	5.8%
SLCABQ	126.4	141.5	15080	12.1%	133.3	6900	5.6%
SLCANC	161.6	162.6	955	1.1%	156.7	-4925	-2.6%
SLCATL	158.1	155.7	-2402	-1.4%	145.5	-12578	-7.9%
SLCBIL	138.2	140.1	1884	1.7%	133.3	-4942	-3.3%
SLCBOI	139.0	138.9	-139	0.1%	133.3	-5700	-3.9%
SLCBOS	161.3	162.3	1062	0.7%	156.7	-4565	-2.8%
SLCBWI	157.8	159.2	1439	1.0%	156.7	-1078	-0.6%
SLCBZN	141.6	139.6	-1981	-1.2%	133.3	-8271	-5.6%
SLCCVG	155.0	153.9	-1144	-0.7%	145.5	-9504	-6.1%

APRPTS	AVG_GWT	REG_ALL	REG_DF	%REG_DF	AEDT	AEDT_DF	%AEDT_DF
SLCDCA	154.6	159.1	4468	3.0%	156.7	2114	1.5%
SLCDFW	146.5	147.9	1424	1.2%	139.2	-7269	-4.8%
SLCDTW	154.5	154.3	-260	-0.1%	145.5	-9022	-5.7%
SLCGEG	144.9	142.2	-2754	-1.8%	133.3	-11633	-7.9%
SLCJFK	159.5	160.8	1309	1.0%	156.7	-2830	-1.6%
SLCLAS	138.5	139.9	1371	1.2%	133.3	-5187	-3.5%
SLCLAX	144.2	142.7	-1492	-0.9%	139.2	-5022	-3.3%
SLCMCI	141.1	147.0	5938	4.4%	139.2	-1863	-1.1%
SLCMCO	160.2	160.1	-168	-0.1%	156.7	-3548	-2.2%
SLCMSP	146.4	147.9	1511	1.4%	139.2	-7212	-4.6%
SLCOAK	139.5	142.7	3245	2.6%	139.2	-270	0.1%
SLCONT	140.9	142.3	1405	1.3%	133.3	-7623	-5.1%
SLCPDX	146.1	143.3	-2818	-1.8%	139.2	-6869	-4.6%
SLCPHX	139.6	141.7	2111	1.7%	133.3	-6262	-4.3%
SLCRDU	156.3	158.7	2396	1.6%	156.7	400	0.3%
SLCRNO	139.9	140.6	704	0.6%	133.3	-6568	-4.6%
SLCSAN	142.7	143.2	500	0.6%	139.2	-3506	-2.2%
SLCSAT	149.4	149.2	-286	0.0%	139.2	-10244	-6.7%
SLCSEA	145.5	144.0	-1476	-0.7%	139.2	-6286	-4.1%
SLCSFO	140.0	142.8	2800	2.4%	139.2	-849	-0.2%
SLCSJC	140.6	142.7	2046	1.8%	139.2	-1425	-0.7%
SLCSMF	141.5	142.0	445	0.3%	133.3	-8241	-5.8%
SLPATL	157.3	150.1	-7178	-4.5%	145.5	-11773	-7.4%
SLPLAX	162.9	150.9	-12029	-7.1%	145.5	-17382	-10.4%
SMFATL	161.8	160.4	-1383	-0.8%	156.7	-5118	-3.1%
SMFMSP	156.3	153.0	-3324	-2.1%	145.5	-10833	-6.9%
SMFSLC	141.8	140.3	-1586	-1.1%	133.3	-8544	-6.0%
SRQATL	141.7	139.7	-1992	-1.3%	133.3	-8377	-5.8%
STIJFK	152.6	152.4	-215	0.4%	145.5	-7117	-4.1%
STLATL	141.9	141.1	-798	-0.4%	133.3	-8600	-5.9%
STLMSP	134.2	140.6	6415	5.2%	133.3	-911	-0.2%
TPAATL	144.8	140.1	-4653	-3.2%	133.3	-11487	-7.9%
TPACVG	145.1	144.9	-235	0.1%	139.2	-5915	-3.9%
TPADTW	144.9	147.6	2714	2.2%	139.2	-5675	-3.6%
TPAJFK	142.8	147.9	5038	3.9%	139.2	-3633	-2.2%
TPALAX	163.3	162.8	-549	-0.2%	156.7	-6630	-3.9%
TPPATL	151.4	169.6	18166	12.3%	156.7	5257	3.7%
TPPJFK	155.1	175.2	20148	13.2%	167.6	12500	8.3%
UVFATL	162.2	159.7	-2505	-1.3%	156.7	-5463	-3.2%
UVFJFK	149.3	159.6	10314	7.7%	156.7	7400	5.8%
YVRDTW	160.6	160.6	-7	0.2%	156.7	-3871	-2.3%
YVRJFK	162.2	166.9	4661	3.0%	156.7	-5498	-3.3%
YVRMSP	150.8	153.8	2914	2.1%	145.5	-5350	-3.4%
ZIHLAX	135.0	153.0	17985	14.0%	145.5	10459	8.4%
ZLOLAX	130.4	149.7	19302	15.4%	145.5	15100	12.1%

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Reduced Thrust Usage and Level

B757-200/PW2037 ACARS Database:

- 85,738 Flights
- 412 Routes Departing 101 Airports
- 96% of All Departures Used Reduced Thrust/Power
- Average Reduced Thrust/Power was 15.3%

B767-400ER/CF6-80C2B8F ACARS Database:

- 10,511 Flights
- 57 Routes Departing 21 Airports
- 93.5% of All Departures Used Reduced Thrust/Power
- Average Reduced Thrust/Power was 10.4%

Reduced Thrust Usage and Level

B737-800/CFM56-7B26 ACARS Database:

- 58,921 Flights
- 504 Routes Departing 105 Airports
- 94.5% of All Departures Used Reduced Thrust/Power
- Average Reduced Thrust/Power was 15.5%

B767-300ER/CF6-80C2-B6F ACARS Database:

- 11,360 Flights
- 179 Routes Departing 61 Airports
- 92.8% of All Departures Used Reduced Thrust/Power
- Average Reduced Thrust/Power was 12.3%

Reduced Thrust Tabular Data (Example):

ROUTE	AVG_WT	AVG_%DRATE	ROUTE	AVG_WT	AVG_%DRATE
AMSATL	388.8	6.9	CDGEWR	359.0	15.7
AMSBOM	396.5	5.9	CDGJFK	365.3	13.3
AMSDTW	372.8	10.8	CDGORD	370.8	12.6
AMSEWR	369.7	12.0	CDGSEA	378.5	11.7
AMSJFK	369.1	12.8	CDGSLC	389.3	9.5
AMSPDX	387.5	5.5	CPHJFK	360.6	14.9
ANCATL	344.0	8.7	CVGCDG	354.1	15.6
ATLAMS	373.3	11.0	DTWAMS	354.7	15.2
ATLBRU	366.5	11.2	DTWATL	292.2	19.7
ATLCDG	363.7	13.3	DTWCDG	351.2	18.1
ATLDTW	290.1	20.3	DTWGRU	390.9	7.5
ATLDUB	359.6	14.2	DTWLHR	353.5	15.8
ATLDUS	360.9	13.3	DTWSFO	310.0	20.7
ATLEZE	396.0	7.4	DUBATL	366.7	6.1
ATLFCO	382.5	9.3	DUBJFK	352.9	9.7
ATLFLL	277.8	21.1	DUSATL	387.1	3.5
ATLGIG	394.5	5.8	EWRAMS	345.7	15.1
ATLGRU	384.4	9.6	EWRCDG	338.7	16.6
ATLJAX	279.6	18.2	EZEATL	396.8	5.3
ATLJFK	300.3	21.1	FCOATL	402.7	7.4
ATLLAS	314.9	19.1	FCOJFK	399.0	7.8
ATLLAX	326.3	17.7	FLLATL	278.5	20.1
ATLLHR	362.8	12.6	FRAJFK	373.5	13.3
ATLLIM	354.2	16.6	FUKHNL	333.5	16.0
ATLLOS	401.9	4.5	GIGATL	394.5	7.4
ATLMAD	363.0	14.1	GRUATL	377.2	6.5
ATLMAN	358.1	14.1	GRUDTW	385.7	4.5
ATLMCO	275.1	19.4	HKGNRT	325.8	20.5
ATLMUC	376.9	9.9	HNDLAX	379.2	3.5
ATLMXP	376.5	9.7	HNDSEA	355.4	8.3
ATLPDX	317.1	18.7	HNLFUK	354.0	18.1
ATLSAN	310.3	19.3	HNLLAX	335.4	20.5
ATLSCL	388.1	8.2	HNLNGO	349.9	18.3
ATLSEA	330.5	17.0	HNLNRT	357.3	17.1
ATLSFO	321.2	18.1	ICNSEA	388.8	10.4
ATLSLC	309.5	19.8	ISTJFK	393.3	4.5
ATLSTR	370.5	10.8	JAXATL	264.3	17.5
ATLTPA	277.5	19.0	JFKAMS	349.1	18.5
ATLVCE	363.5	12.7	JFKATL	297.3	19.8
ATLZRH	371.6	11.2	JFKBCN	354.8	16.9
BCNJFK	379.9	6.3	JFKBRU	346.0	17.9
BOMAMS	396.4	5.1	JFKCDG	351.0	17.7
BOSATL	294.6	18.2	JFKCPH	346.1	19.1
BOSCDG	338.7	12.1	JFKDUB	348.5	17.8
BOSLHR	328.2	13.9	JFKFCO	360.8	15.9
BRUATL	381.2	5.5	JFKFRA	354.5	16.9
BRUJFK	363.2	9.6	JFKIST	377.1	13.2
CDGATL	380.6	11.6	JFKLAX	335.6	19.2
CDGBOS	343.1	18.1	JFKLHR	338.0	18.7
CDGCVG	370.4	13.2	JFKMAD	349.2	16.5
CDGDTW	364.5	14.0	JFKNCE	340.3	20.2

Conclusions:

1. The regressions developed from operational flight planning databases represented a definite improvement in aircraft specific takeoff weight determination. The real issue not the magnitude of the difference, but the impact on the resulting noise and emission levels. Implementation of the regressed equations into the AEDT is not complex and the required information from the user is easily attained from a number of sources.

2. The analysis of the significantly large ACARS databases presented the first known definitive data regarding the air carrier use of reduced thrust/power for departure. The high percentage of use confirms not only that the use of full rated takeoff power is very small but that existing noise and emissions inventories attributed to aircraft departures requires reexamination.