LIST OF APPENDICES

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A list of common acronyms used in the airline industry relevant to this paper is provided at the end of this Appendix.

Appendix

Appendix 1

Sigma computation model

	A	B	C	D	E	F
1	Airlines	DPMO	Normalized DPMO	Inversed normalized DPMO = 1- Normalized DPMO	Normsinv (inversed normalized DPMO)	Sigma = Normsinv (c1) + 1.5
2		3.4	=B2/1000000	=1-C2	=NORMSINV(D2)	=E2+1.5
3	Air Canada	0.63	=B3/1000000	=1-C3	=NORMSINV(D3)	=E3+1.5
4	Alaska Airlines	0.74	=B4/1000000	=1-C4	=NORMSINV(D4)	=E4+1.5

Sigma computation model using formulae proposed by Summers (2006, p.687):

Sigma = NORMSINV (1-[DPMO/1,000,000]) + 1.5

Table A1.1. Effects of Sigma levels

Sigma level	DPMO	Yield
7	0.02	99.99999%
6	3.4	99.9997%
5	233	99.9770%
4	6,210	99.3790%
3	66,807	93.3200%
2	308,537	69.2000%
1	690,000	31.0000%

Note: DPMO = Defects per million opportunities

Table A.1.2. Examples of sigma performance capabilities

99.74% Good = Three Sigma (3σ)	**99.999997% Good = Six Sigma (6σ)**
Two short or long flight landings at most major airports each day	One short or long flight landing every five years
731 U.S. air travelers with confirmed reservations are denied boarding per week	2 U.S. air travelers with confirmed reservations are denied boarding per week
5,000 incorrect surgical operations per week	1.7 incorrect surgical operations per week
200,000 wrong drug prescriptions each year	68 wrong drug prescriptions each year

Source: Summers, 2006, p.682

Appendix 2

Table A2.1 Fatal accident rate of international carriers

Airlines	DPMO	Normalized DPMO	Inversed Normalized DPMO = 1-Normalized DPMO	Normsinv (Inversed Normalized DPMO)	Sigma: Normsinv (Normalized DPMO) + 1.5
	3.4	0.0000034	0.9999966	4.49985	6.00
Air Canada	0.63	0.00000063	0.99999937	4.84596	6.35
Alaska Airlines	0.74	0.00000074	0.99999926	4.81392	6.31
Aloha Airlines	0.49	0.00000049	0.99999951	4.89561	6.40
American Airlines/Eagle	0.59	0.00000059	0.99999941	4.85897	6.36
Continental Airlines/Express	0.63	0.00000063	0.99999937	4.84596	6.35
Delta Air Lines/Connection	0.3	0.0000003	0.9999997	4.99122	6.49
Midwest Express Airlines	3.85	0.00000385	0.99999615	4.47336	5.97
Northwest Airlines/Airline	0.43	0.00000043	0.99999957	4.92123	6.42
Trans World Airlines/Express	0.74	0.00000074	0.99999926	4.81392	6.31
United Airlines/Express	0.5	0.0000005	0.9999995	4.89164	6.39
US Airways/Express (USAir)	0.56	0.00000056	0.99999944	4.86929	6.37
ValuJet/Air Tran	5.88	0.00000588	0.99999412	4.38199	5.88
Aerolineas Argentinas	1.2	0.0000012	0.9999988	4.71645	6.22
Aero México	1.85	0.00000185	0.99999815	4.62756	6.13
Aeroperu	16.7	0.0000167	0.9999833	4.14895	5.65
Avianca	3.15	0.00000315	0.99999685	4.51606	6.02
Cubana	24	0.000024	0.999976	4.06516	5.57
LAN Chile	4	0.000004	0.999996	4.46518	5.97
Mexicana Airlines	0.53	0.00000053	0.99999947	4.88016	6.38
Transbrasil	2.35	0.00000235	0.99999765	4.57775	6.08
VASP	3.24	0.00000324	0.99999676	4.51009	6.01
Varig	1.22	0.00000122	0.99999878	4.71308	6.21
Air France	1.19	0.00000119	0.99999881	4.71815	6.22
Alitalia	0.77	0.00000077	0.99999923	4.80597	6.31
Braathens SAFE	0.74	0.00000074	0.99999926	4.81392	6.31
British Airways	0.32	0.00000032	0.99999968	4.97874	6.48
British Midland	0.97	0.00000097	0.99999903	4.75958	6.26
Iberia	0.89	0.00000089	0.99999911	4.77692	6.28
KLM	1.25	0.00000125	0.99999875	4.70813	6.21
Lufthansa	0.41	0.00000041	0.99999959	4.93055	6.43
Olympic Airways	1.67	0.00000167	0.99999833	4.64872	6.15
Swissair	1.25	0.00000125	0.99999875	4.70813	6.21
Tap Air Portugal	1.18	0.00000118	0.99999882	4.71987	6.22
Turkish Airlines (THY)	7.3	0.0000073	0.9999927	4.33464	5.83
Air Afrique	3.33	0.00000333	0.99999667	4.50427	6.00
Air Zimbabwe	12.5	0.0000125	0.9999875	4.21480	5.71
EgyptAir	8	0.000008	0.999992	4.31445	5.81
Ethiopian Airlines	4	0.000004	0.999996	4.46518	5.97

Iran Air	2.5	0.0000025	0.9999975	4.56479	6.06
Kenya Airways	3	0.000003	0.999997	4.52639	6.03
Nigeria Airways	5	0.000005	0.999995	4.41717	5.92
Royal Air Moroc	1.54	0.00000154	0.99999846	4.66541	6.17
Royal Jordanian	8.82	0.00000882	0.99999118	4.29284	5.79
Saudi Arabian Airlines	1.4	0.0000014	0.9999986	4.68497	6.18
South African Airways	0.63	0.00000063	0.99999937	4.84596	6.35
Air India	6.82	0.00000682	0.99999318	4.34958	5.85
Air New Zealand	0.74	0.00000074	0.99999926	4.81392	6.31
All Nippon	0.22	0.00000022	0.99999978	5.05078	6.55
Asiana	1.85	0.00000185	0.99999815	4.62756	6.13
Cathay Pacific	0.97	0.00000097	0.99999903	4.75958	6.26
China Airlines	10.2	0.0000102	0.9999898	4.26047	5.76
Garuda Indonesia	4.08	0.00000408	0.99999592	4.46094	5.96
Indian Airlines	4.8	0.0000048	0.9999952	4.42599	5.93
Japan Airlines	2.05	0.00000205	0.99999795	4.60625	6.11
Korean Air	5.38	0.00000538	0.99999462	4.40131	5.90
Malaysia Airlines	1.11	0.00000111	0.99999889	4.73229	6.23
Pakistan International	5	0.000005	0.999995	4.41717	5.92
Philippine Airlines	4.68	0.00000468	0.99999532	4.43145	5.93
Silk Air/Singapore Airlines	2	0.000002	0.999998	4.61138	6.11
Thai Airways International	2.85	0.00000285	0.99999715	4.53722	6.04
Average:	3.249	0.000003249	0.999996751	4.50950	6.01

Notes: DPMO = Defects per million opportunities. Statistics valid through December 31, 2004.
This table provides statistical information regarding the safety of selected airlines. A fatal event is defined as “an event in which one passenger was fatally injured solely due to the operation of an aircraft.” The number of fatalities in each fatal accident is irrelevant in the statistics presented below. Hijackings are excluded.
DPMO Source: Accident rate by airline (Source: Airdisaster.com, 2008)
Sigma is computed using the model shown in Appendix 1.

Appendix 3

Table A3.1. Fatal and non-fatal accident rates of U.S. domestic carriers

Accident Rates, 1989 through 2008, for U.S. Air Carriers Operating Under 14 CFR 121, Scheduled Service

Year	Illegal Act	Accidents		Departures	Normalized departure Flights/million FLT dept	Non-fatal Accidents DPMO	Fatal Accident DPMO
		All	Fatal				
1983		22	4	5235262	0.191012408	3.43822334	0.764049631
1984		13	1	5666076	0.176488985	2.117867815	0.176488985
1985		17	4	6068893	0.164774696	2.14207105	0.659098785
1986	*	21	2	6928103	0.144339655	2.742453454	0.288679311
1987	*	32	4	7293025	0.137117314	3.839284796	0.548469257
1988	*	27	3	7347575	0.136099325	3.266383807	0.408297976
1989		20	5	7267341	0.13760191	2.064028645	0.688009548
1990		19	4	7795761	0.128274841	1.92412261	0.513099363
1991		21	3	7503873	0.133264516	2.39876128	0.399793547
1992		15	3	7515373	0.133060595	1.596727135	0.399181784
1993		22	1	7721870	0.12950231	2.719548503	0.12950231
1994	*	18	4	7824802	0.127798761	1.789182653	0.511195044
1995		30	1	8105570	0.123371953	3.577786633	0.123371953
1996		31	3	7851298	0.127367475	3.566289294	0.382102424
1997		43	3	9925058	0.100755079	4.030203148	0.302265236
1998		41	1	10535196	0.094919924	3.796796946	0.094919924
1999		40	2	10860692	0.092075164	3.498856242	0.184150329
2000		49	2	11053826	0.090466414	4.251921461	0.180932828
2001	*	41	6	10632880	0.094047897	3.291676385	0.56428738
2002		34	0	10276107	0.097313117	3.308645969	0
2003		51	2	10227924	0.097771552	4.790806033	0.195543103
2004		23	1	10782989	0.092738665	2.040250621	0.092738665
2005		34	3	10910460	0.091655164	2.841310082	0.274965492
2006		27	2	10627481	0.094095675	2.352391879	0.18819135
2007		26	0	10612478	0.094228699	2.449946186	0
2008		20	0	10597000	0.09436633	1.887326602	0
					Average:	2.912417791	0.310359009

Source: Aviation Accident Statistics (National Transportation Safety Board), http://www.ntsb.gov/aviationquery/index.aspx

Notes: Flight hours, miles, and departures are compiled by the Federal Aviation Administration.

Since March 20, 1997, aircrafts with 10 or more seats used in scheduled passenger service have been operated under 14 CFR 121.
Years followed by * are those in which an illegal act was responsible for an occurrence in this category. These acts, such as suicide and sabotage, are included in the totals for accidents and fatalities but are excluded for the purpose of accident rate computation.

Non-fatal accident rate 1983 - 2008

Carrier	Non-fatal Accident DPMO	Normalized DPMO	Inversed Normalized DPMO = 1- Normalized DPMO	Normsinv (Inversed Normalized DPMO)	Sigma
US Domestics Flight	2.912417791	2.91242E-06	0.999997088	4.532649741	6.03
Intl (proportion 10.48%)	30.50	0.0000305	0.9999695	4.008908674	5.51

Appendix 4

Table A4.1 U.S. domestic and international carrier casualty rate

Year	US Domestic[#]	Casualty*	Normalized domestic casualty/million travel PAX	$DPMO_{dom}$	INTL[#]	Casualty[*]	Normalized international casualty/million travel PAX	$DPMO_{INTL}$
2000	599563678	89	0.00166788	0.14844	134287145	1082	0.00745	8.05736
2001	559618055	531	0.001786933	0.94886	122907077	768	0.00814	6.24862
2002	551960680	0	0.001811723	0.00000	118718997	1101	0.00842	9.27400
2003	583293766	22	0.001714402	0.03772	117569855	679	0.00851	5.77529
2004	629769620	13	0.001587882	0.02064	133940071	431	0.00747	3.21786
2005	657261487	22	0.001521464	0.03347	143588422	1063	0.00696	7.40310
2006	658362620	50	0.00151892	0.07595	149720383	889	0.00668	5.93774
2007	679185448	0	0.001472352	0.00000	156014432	750	0.00641	4.80725
2008	649916840	0	0.001538658	0.00000	156189808	577	0.00640	3.69422
Average:	618770244	80.7778	0.001616109	0.13055	136992910	815.5556	0.00730	5.95327

Notes: The table presents an aggregated summary of data in the tables from Appendix 2 and Appendix 3.
* Source: Aviation Accident Statistics (National Transportation Safety Board, no date), http://www.ntsb.gov/aviationquery/index.aspx
# Annual air passenger travel (U. S. Bureau of Transportation Statistics, No date), http://www.transtats.bts.gov/Data_Elements.aspx?Data=1

Excel formulae for calculations in Table A4.1:

	A	B	C	D	E	F	G	H	I
1	Year	DOMESTIC#	Casualty*	Normalize dom casualty/millio	$DPMO_{dom}$	INTL#	Casualty*	Normalize intl casualty/million PAX	$DPMO_{INTL}$
2	2000	599563678	89	=1000000/B2	=D2*C2	134287145	1082	=1000000/F2	=H2*G2
3	2001	559618055	531	=1000000/B3	=D3*C3	122907077	768	=1000000/F3	=H3*G3

Carrier	Death DPMO	Normalized DPMO	Inversed Normalized DPMO = 1- Normalized DPMO	Normsinv (Inversed Normalized DPMO)	Sigma = Normsinv (D3) + 1.5
International casualty rate	5.95	5.9533E-06	0.999994047	4.379292252	5.88
US domestic casualty rate	0.13	1.3055E-07	0.999999869	5.149564954	6.64

Appendix 5

Table A5.1. International Flights - Delays and Cancellations, February 1, 2009 - March 31, 2009

Carrier	Total Flights operated*	Total Delay*	Total Cancelled*	Normalized operated FLT/million Flights	Delay DPMO	Delay σ Level	Cancel DPMO	Cancel σ Level
China Airlines (CI)	4255	1147	399	235.0176263	269565.22	2.11	93772.03	2.82
Thai Airways (TG)	4824	592	0	207.2968491	122719.73	2.66	0.00	9.43
All Nippon (NH)	6173	572	0	161.9957881	92661.59	2.82	0.00	9.43
Singapore Air (SQ)	4451	509	1	224.6686138	114356.32	2.70	224.67	5.01
British Airways (BA)	8950	1926	312	111.7318436	215195.53	2.29	34860.34	3.31
Lufthansa (LH)	11251	1790	159	88.88098836	159096.97	2.50	14132.08	3.69
Turkish Airlines (TK)	7754	3326	130	128.9656951	428939.90	1.68	16765.54	3.63
Air France (AF)	14292	2253	363	69.96921355	157640.64	2.50	25398.82	3.45
Air Canada (AC)	7213	1962	106	138.6385692	272008.87	2.11	14695.69	3.68
Aerolineas Argentina (AR)	2277	849	11	439.1743522	372859.03	1.82	4830.92	4.09
Mexicana Airline (MX)	5431	1137	7	184.1281532	209353.71	2.31	1288.90	4.51
Kenya Airways (KQ)	161	27	20	6211.180124	167701.86	2.46	124223.60	2.65
South African Airways (SA)	1979	148	38	505.30571	74785.25	2.94	19201.62	3.57
Royal Jordanian (RJ)	581	113	3	1721.170396	194492.25	2.36	5163.51	4.06
Emirates (EK)	4014	1015	7	249.1280518	252864.97	2.17	1743.90	4.42
Average:	5573.7333	1157.7333	103.7333	179.4130	206949.46	2.36	23753.44	4.52

Source: *On-time performance rating (Flight Stats, No date), http://www.flightstats.com/go/FlightRating/flightRatingByRoute.do

Appendix 6

Table A6.1. U.S. Domestic Flights - Delays and Cancellations, September 1, 2008 - March 31, 2009

Carrier	Total Flights operated*	Total Delay*	Total Cancelled*	Normalized operated FLT/million Flight	Delay DPMO	Delay σ Level	Cancel DPMO	Cancel σ Level
American Airlines (AA)	280818	52829	5113	3.56103	188125.41	2.38	18207.52	3.59
Delta Airlines (DL)	217487	44947	2483	4.59798	206665.23	2.32	11416.77	3.78
Northwest Airlines (NW)	144316	25878	897	6.92924	179314.84	2.42	6215.53	4.00
United Airlines (UA)	195076	35771	3064	5.12621	183369.56	2.40	15706.70	3.65
Hawaiian (HA)	34154	3435	266	29.27915	100573.87	2.78	7788.25	3.92
Alaska (AS)	68246	14404	1200	14.65287	211059.99	2.30	17583.45	3.61
Southwest (WN)	576461	83133	8214	1.73472	144212.70	2.56	14249.01	3.69
US Airways (US)	212697	37859	2762	4.70152	177994.99	2.42	12985.61	3.73
Continental Airlines (CO)	129721	27648	2124	7.70885	213134.34	2.30	16373.60	3.64
Jetblue (B6)	92325	19173	1181	10.83130	207668.56	2.31	12791.77	3.73
Average:	195130.1	34507.7	2730.4	5.12479	176844.58	2.42	13992.72	3.73

SOURCE: *OAEP U.S. Aviation Enforcement and Proceedings of Department of Transportation (2009, May), http://airconsumer.ost.dot.gov/reports/atcr09.htm

Appendix 7

Table A7.1. Denied boarding by U.S. Carriers, January - December 2008

US Carriers	Voluntary DB	Involuntary DB	Total DB PAX	Enplaned PAX	Normalized Enplaned PAX factor	DPMO
Jetblue Airways	58	22	80	21,900,554	0.04566	3.65288
Hawaiian Airlines	317	54	371	7,856,711	0.12728	47.22078
Airtran Airways	41,877	834	42711	24,619,120	0.04062	1734.87111
Alaska Airlines	8,128	983	9111	15,546,453	0.06432	586.05008
American Airlines	56,649	5,568	62217	82,247,704	0.01216	756.45881
Northwest Airlines	48,473	3,027	51500	42,519,162	0.02352	1211.21860
Frontier Airlines	4,436	983	5419	10,497,522	0.09526	516.21707
Southwest Airlines	73,403	10,362	83765	102,045,003	0.00980	820.86332
United Airlines	92,624	6,812	99436	57,568,962	0.01737	1727.25018
Skywest Airlines	34,155	2,090	36245	15,572,248	0.06422	2327.53807
Us Airways	85,001	7,205	92206	53,145,064	0.01882	1734.98709
Mesa Airlines	25,048	1,355	26403	9,947,777	0.10052	2654.16082
Continental Airlines	37,825	5,671	43496	40,283,669	0.02482	1079.74276
Delta Air Lines	62,243	10,403	72646	65,735,090	0.01521	1105.13274
Pinnacle Airlines	6,572	540	7112	3,160,628	0.31639	2250.18572
American Eagle Airlines	7103	2184	9287	8,940,543	0.11185	1038.75123
Comair	13,461	1,909	15370	5,599,468	0.17859	2744.90362
Atlantic Southeast Airlines	22,982	3,610	26592	9,290,037	0.10764	2862.42132
Average:	34,464	3,534	37,998	32,026,429	0.03122	1186.46282

Source: OAEP U.S. Aviation Enforcement and Proceedings of Department of Transportation (2009, February)
http://airconsumer.ost.dot.gov/reports/atcr09.htm

Carrier	DB DPMO	Normalized DPMO	Inversed Normalized DPMO = 1- Normalized DPMO	Normsinv (Inversed Normalized DPMO)	Sigma
US Domestics Flight DB	1186.46	0.001186463	0.998813537	3.039091764	4.54
Intl (proportion 1.859%)	2205	0.002205	0.997795	2.847240732	4.35

Appendix 8

Table A8.1 Mishandled baggage statistics for all international carriers, 2008

Lost bags	Mishandled bags	Total number of travelers worldwide	Factor for normalized total # to 1 Million PAX	Lost bags / 1 Million PAX	Mishandled bags / 1 Million PAX
736,000	32,800,000	2,300,000,000	0.000434783	320	14260.87

Source: SITA reports worldwide drop in mishandled baggage as industry saves $800 million (SITA, 2009) http://www.sita.aero/content/sita-reports-worldwide-drop-mishandled-baggage-industry-saves-800-million

Table A8.2 Mishandled Baggage statistics for U.S. domestic carriers, January - December 2008

US Carriers	Total Baggage reports[#]	Enplaned PAX[#]	Normalized Enplaned PAX/million PAX	Reports /1Milion PAX
Airtran Airways	73,088	25,465,698	0.0393	2870.0568
Hawaiian Airlines	23,573	7,947,315	0.1258	2966.1590
Jetblue Airways	74,020	21,361,147	0.0468	3465.1697
Northwest Airlines	138,919	39,581,942	0.0253	3509.6560
Continental Airlines	142,961	36,027,443	0.0278	3968.1140
Alaska Airlines	69,467	15,546,453	0.0643	4468.3504
Frontier Airlines	46,461	10,359,873	0.0965	4484.7075
Southwest Airlines	476,902	104,758,285	0.0095	4552.4037
Us Airways	240,285	50,388,949	0.0198	4768.6051
United Airlines	283,357	54,114,611	0.0185	5236.2383
American Airlines	424,796	74,446,833	0.0134	5706.0318
Delta Air Lines	370,120	61,910,660	0.0162	5978.2919
Expressjet Airlines	89,509	14,018,563	0.0713	6385.0339
Pinnacle Airlines	77,324	10,237,024	0.0977	7553.3671
Skywest Airlines	160,210	21,041,977	0.0475	7613.8283
Mesa Airlines	91,538	11,608,433	0.0861	7885.4743
Comair	68,186	8,190,831	0.1221	8324.6743
Atlantic Southeast Airlines	121,171	12,344,839	0.0810	9815.5189
American Eagle Airlines	160,730	16,244,392	0.0616	9894.4916
Totals:	3,132,617	595,595,268	0.0017	5259.6405

Source: [#]OAEP U.S. Aviation Enforcement and Proceedings of Department of Transportation (2009, February), http://airconsumer.ost.dot.gov/reports/atcr09.htm

Carrier	MB DPMO	Normalized DPMO	Inversed Normalized DPMO = 1- Normalized	Normsinv (Inversed Normalized	Sigma

			DPMO	DPMO)	
US Domestics mishandled rate	5259.64	0.00526	0.99474	2.55828	4.06
US Domestic loss rate	116.00	0.000116	0.999884	3.68135	5.18
Intl baggage mishandle rate	14260.87	0.01426	0.98574	2.19003	3.69
Intl baggage loss rate	320	0.00032	0.99968	3.41407	4.91

Appendix 9

9.1 *Annual international and U.S. domestic carriers' casualty rate*

The casualty numbers for U.S. domestic and international flights from the years 2000-2008 across all airlines can be obtained from the third and seventh columns of Table A4.1. The average U.S. casualty rate per year is 80.78, and the average INTL casualty rate is 815.56.

9.2 *Annual international flight delay and cancellation rate – affected passengers in a Boeing 744 aircraft*

The total international flights operated, the total delays, and the total flights cancelled from February 1, 2009, to March 31, 2009, across all airlines can be obtained from the first, second, third and fourth columns of Table A5.1. The average total flights operated per airline is 5573.73, total delay per airline is 1157.73, and total flights cancelled is 103.73.

9.3 *Annual U.S. domestic flight delay and cancellation rate – affected passengers in a Boeing 733 aircraft*

The total U.S. domestic flights operated, the total delays, and the total flights cancelled from September 1, 2008, to March 31, 2009, across all airlines can be obtained from the first, second, third and fourth columns of Table A6.1. The average total flights operated per airline is 195,130.1, total delays per airline is 34,507.7, and total flights cancelled is 2730.4.

9.4 *Annual International carriers mishandled and lost baggage rate 2008*

Lost bags	Mishandled bags
736,000	32,800,000

Source: SITA reports worldwide drop in mishandled baggage as industry saves $800 million https://www.4hoteliers.com/news/story/5710

9.5 *Annual U.S. domestic carriers mishandled and lost baggage rate – January to December 2008*

The total mishandled baggage reports, enplaned passengers, and normalized enplaned passengers/million passengers for U.S. domestic flights across all U.S. domestic airlines from January to December 2008 can be obtained from the first, second, third and fourth columns of Table A8.2. The total mishandled baggage reports across all airlines in this period is 3,132,617, the total number of enplaned passengers is 595,595,268, and normalized enplaned passengers/million passengers is 0.0017.

9.6 *U.S. Domestic flight denied boarding rate, January to December 2008*

Voluntary denied boarding, involuntary denied boarding, and total denied boarding across all U.S. domestic airlines from January to December 2008 can be obtained from the first, second, third and fourth columns of Table A7.1. The average across all airlines in this period for voluntary denied boarding, involuntary denied boarding, and total denied boarding is 34,464, 3534, and 37,998 respectively.

9.7 *Annual international flight denied boarding rate – 2008*

Annual International flight denied boarding rate = Annual U.S. Domestic flight denied boarding rate x ratio obtained to compute the DPMO in Table 4: 37,998 x 1.859 = **70,638**

Appendix 10

10.1 *Annual casualty rate at 6 sigma level*

International: 0.13 / 0.00730 (new DMPO / normalized enplaned PAX/million PAX from Appendix 4) = 18

US Domestic: 0.13 / 0.001616109 (new DPMO / normalized enplaned PAX / million PAX from Appendix 4) = 81

10.2 *Annual international carriers' delay and cancellation rates at 6 sigma level*

The data in the below table are similar to the data in Table A5.1. It lists the international flights delayed and cancelled during the two-month period of February 1, 2009, to March 31, 2009. The following calculations are made on the aggregated numbers across all airlines.

International Flight - Delay and Cancellation: February 1, 2009 - March 31, 2009

Carrier	Total flights operated*	Total Delay*	Total Cancelled*	Normalized FLT operated/ million FTL	FLT Delay DPMO	FLT Delay σ Level	FLT Cancel DPMO	FLT Cancel σ Level
2months data:	5573.73333	1157.73333	103.73333	179.4129608	206949.46	2.36	23753.44	4.52
Annual rate at 6 sigma: 3.4/29.90216013 =	33442.4	0.11370416	0.1137042	29.90216013	3.40	6.00	3.40	6.00
Affected PAX aboard Boeing 744:	451	51.2805762	51.280576					

10.3 *Annual U.S. domestic carriers' delay and cancellation rates at 6 sigma level*

The data in the below table is similar to the data in Table A6.1. It lists the U.S. domestic flights delayed and cancelled during the six-month period of September 1, 2008, to March 31, 2009. The following calculations are made on the aggregated numbers across all airlines.

US Domestic Flight - Delay and Cancellation: September 1, 2008 - March 31, 2009

Carrier	Total flights operated*	Total Delay*	Total Cancelled*	Normalized operated FLT/million FLT	Delay DPMO	Delay σ Level	Cancel DPMO	Cancel σ Level
Jetblue (B6)	92325	19173	1181	10.83130246	207668.56	2.31	12791.77	3.73
6-month data:	195130.1	34507.7	2730.4	5.124785976	176844.58	2.42	13992.72	3.73
Annual DPMO at 6 sigma:	390260.2	1.32688468	1.32688468	2.562392988	3.40	6.00	3.40	6.00
Affected PAX aboard Boeing 733:	60	79.6130808	79.6130808					

10.4 *Annual international carriers' lost baggage rate at 6 sigma level*

Lost bags	Mishandled bags	Total number of travelers worldwide	Normalized total PAX/million PAX	Lost bags/million PAX	Mishandled bags/million PAX
7820	7820	2,300,000,000	0.000434783	3.4	3.4

Source: SITA reports worldwide drop in mishandled baggage as industry saves $800 million https://www.4hoteliers.com/news/story/5710

10.5 *Annual U.S. domestic carriers' lost baggage rate at 6 sigma level*

The total mishandled baggage reports, enplaned passengers, normalized enplaned passengers/million passengers, and the DPMO for U.S. domestic flights from January to December 2008, across all U.S. domestic airlines can be obtained from the first, second, third fourth, and fifth columns of Table A8.2. The table below presents the "Annual mishandled bag rate at 6 sigma" and the "Annual lost bag rate at 6 sigma"

US Carriers	Total baggage reports	Enplaned PAX	Normalized Enplaned PAX/million	DPMO
Average:	164,875	31,347,119	0.0319008579	5259.6405
Annual mishandled bag rate at 6 sigma	107		0.0319008579	3.4
Annual lost bag rate at 6 sigma	107		0.0319008579	3.4

10.6 *Annual international flight and U.S. domestic flight denied boarding rates at 6 sigma level*

3.4/0.03122 (normalized enplaned PAX factor from Appendix 7) = 109

Appendix 11

Table A11.1. Causes of Fatal Accidents by Decade (percentage)

Cause	1950s	1960s	1970s	1980s	1990s	2000s	All
Pilot Error	40	32	24	25	27	25	29
Pilot Error (weather-related)	11	18	14	17	21	17	16
Pilot Error (mechanical-related)	7	5	4	2	4	3	4
Total Pilot Error	58	57	42	44	53	45	50
Other Human Error	0	8	9	6	8	9	7
Weather	16	10	13	15	9	8	12
Mechanical Failure	21	20	23	21	21	28	22
Sabotage	5	5	11	13	10	9	9
Other Cause	0	2	2	1	0	1	1

Source: Kebabjian (2009), http://planecrashinfo.com/cause.htm

The data in Table A11.1 are compiled from the PlaneCrashInfo.com accident database and represent 1,300 fatal accidents involving commercial aircraft for which a specific cause is known. The data are world-wide and cover the period from 1950 thru 2008. Aircraft with 10 or fewer people aboard, military aircraft, private aircraft, and helicopters are not included.

“Pilot error (weather-related)” represents accidents in which pilot error was the cause but which were brought about by weather-related phenomena. “Pilot error (mechanical-related)” represents accidents in which pilot error was the cause but which were brought about by some type of mechanical failure. “Other human error” includes mistakes made by air traffic controllers, improper loading of aircraft, fuel contamination, and improper maintenance procedures. Sabotage includes explosive devices, shoot-downs, and hijackings. “Total pilot error” is the total of all three types of pilot error. Where there were multiple causes, the most prominent cause was used.

Appendix 12

Passenger service operations process steps

As quality of operations is the focus of this paper, we first sketch out a value stream map of the current airline operational process, which depicts the steps a passenger goes through before obtaining the final services from an airline company (see Figure A12.1). The value stream map creates a visual process flow so that users can identify non-value-added steps during the process. These non-value-added steps can be eliminated to reduce errors and avoid rework time. In this Appendix, we present simplified process maps for each step a passenger must go through when traveling on an international or domestic flight.

Figure A12.1. Major steps of obtaining air transportation services

A list of common acronyms used in Figures 3, 4, 5, 6, 7, 8, 9, 10 is listed below:

APT: Airport, ARR: Arrival, BRS: Baggage Reconciliation System, CHK-IN: Check in, DEP: Departure, DES: Destination, FLT: Flight, INTL: International, MCT: Minimum connecting time, OPS: Operations, PAX: Passenger, PIR: Property Irregularity report (loss baggage report) SPCL REQ: Special Request, SVC: Service, RFID: Radio Frequency Identification Device, RSVN: Reservation, SDR: Special drawing right, STN: Station, TKT: Ticket, TKTG: Ticketing, ULD: Unit load devices (baggage containers)

Step 1. Ticket Reservation Process

Figure A12.2 illustrates how air travelers reserve air tickets directly via the airline's website or

ticketing office. No travel agents or third-party travel operators, like online travel agencies, are involved. Currently, a valid passport and travel visa are not required when booking a flight. Reservation and ticket agents do not provide visa requirement information but refer air passengers to the destination's embassy office for detailed information. At the end of the process, agents read out the reservation information and check-in requirements to passengers before finishing the transaction.

Even though the passenger may provide correct travel information, errors can occur due to data entry errors by airline personnel or reservation system programming errors. Mistakes may include incorrect travel dates, special meal requests, special seat requests, special handling for disabled passengers and animals, and unaccompanied minor travel services. If air travelers pay no attention to the printed ticket or confirmation printout for electronic tickets, they might not find the mistakes until it is time for departure.

Queues at the busy reservation call center and the busy ticketing office, or queues created during reservation system downtime might also cause loss of prospective air travel customers and frustrate current passengers due to the long waiting times.

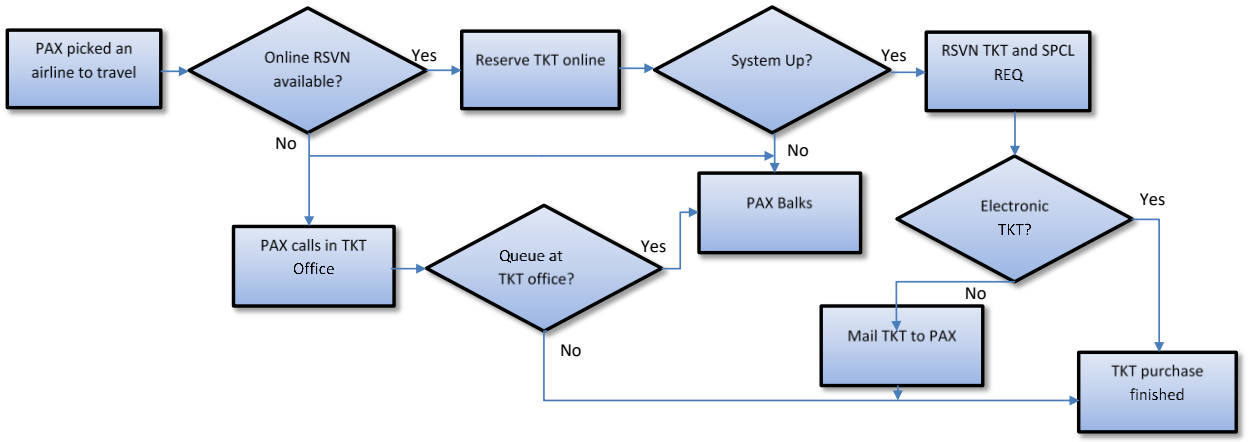

Figure A12.2. Ticket Reservation Process Map

Step 2. Check-In Process

Figure A12.3 shows the general steps for air passenger check-in. Most airlines, both international and U.S. domestic, have deployed an online check-in system for air passengers to check in between 48 hours and 2 hours before the scheduled departure time. Passengers can also check in using the auto check-in kiosks at the airport. If passengers have checked in using the Internet check-in system and printed their boarding pass, they can drop their checked luggage at the designated counter after their identification is validated. Otherwise, they will queue up at the check-in counter for manual check-in with their ticket and identification.

Incidents that delay the check-in process include passengers not having valid travel documents (e.g., ticket, visa, personal identification or passport), finding out the travel date was incorrect, having to repack their luggage due to weight requirements, the seats they requested are taken, inexperienced check-in agents, systems down, or language barriers.

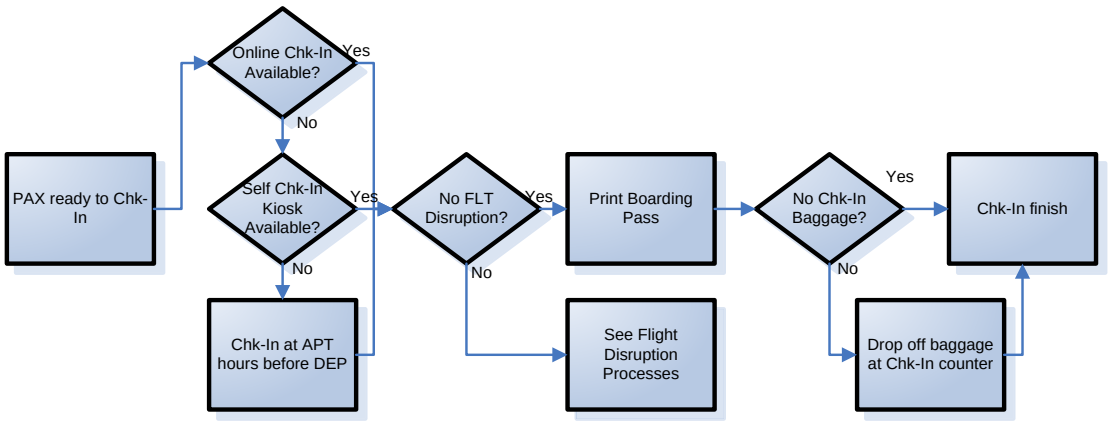

Figure A12.3. Check-In Process Map

Step 3. Check-In Baggage Handling Process

Figure A12.4 shows what baggage goes through before being loaded onto the aircraft. This process begins once a passenger hands over their baggage to the check-in agent. After receiving baggage from the passenger, check-in agents print a barcoded baggage tag that comprises three detachable portions: one part is attached to each of the checked-in bags, the second part is attached to the passenger's ticket, and the third adheres to the unit load devices (ULD), baggage cargo containers. The bar code tag number is a numeric code generated by a combination of flight data of the checked-in passenger and serial boarding number of the passenger.

All baggage is then loaded into the baggage conveyor belt, where it goes through x-ray and security systems controlled by the airport's security company. Baggage for all flights, especially in domestic airports, arrives at a designated suitcase sorting area. Baggage handling agents then sort baggage in order of airline, flight number, destination, and class of the passenger. Finally, they load baggage to the designated ULD manually and the ULDs are loaded into the aircraft. During this process, the barcoded tags may be detached or damaged so handlers are unable to sort the bag. Human error is also a possibility when sorting the baggage manually.

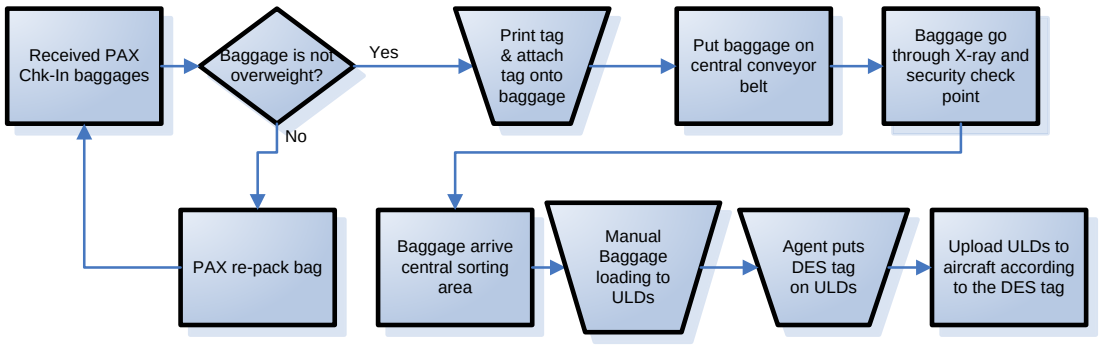

Figure A12.4. Check-In Baggage Handling Process Map

Step 4. Flight Disruption Processes Process Map

Figure A12.5 shows the regular procedure a customer service team performs when flight delay, flight cancellation, or flight over-booking occurs. If airlines foresee a potential flight delay, they notify the passengers by their traveling class order and frequent flyer program status. When flight delay is unforeseeable and expected to be short (within 6 hours), customer service agents announce the delay to passengers in the waiting area. Some good practice airlines will provide refreshments for international flight travelers during the waiting time, or they may transfer air passengers who miss their connecting flight to other airlines (especially for international travelers). For flight delays over 6 hours, airlines should provide ground assistance and transfer passengers to another available flight. Mishandling occurs when airlines are unable to communicate with an affected passenger on time.

Similar to a flight delay, when airlines foresee a potential flight cancellation, they notify the passengers in order of their traveling class and frequent flyer program status. Airlines need to rebook the next available flight for passengers and provide ground assistance. Mishandling occurs when airlines are unable to communicate with an affected passenger on time.

In the case of an overbooked flight, customer service agents first distinguish whether upgrading or downgrading a passenger is an option. If not, they can expect to deny boarding to some passengers on the flight and call for volunteers to surrender their reservations in exchange for certain benefits. If an insufficient number of volunteers come forward to allow the remaining passengers to board the flight, agents will then deny boarding to passengers against their will. Agents avoid denying boarding to disabled passengers and their companions, unaccompanied minor travelers, and passengers who require special handling. Those passengers denied boarding are compensated and confirmed on the next available flight.

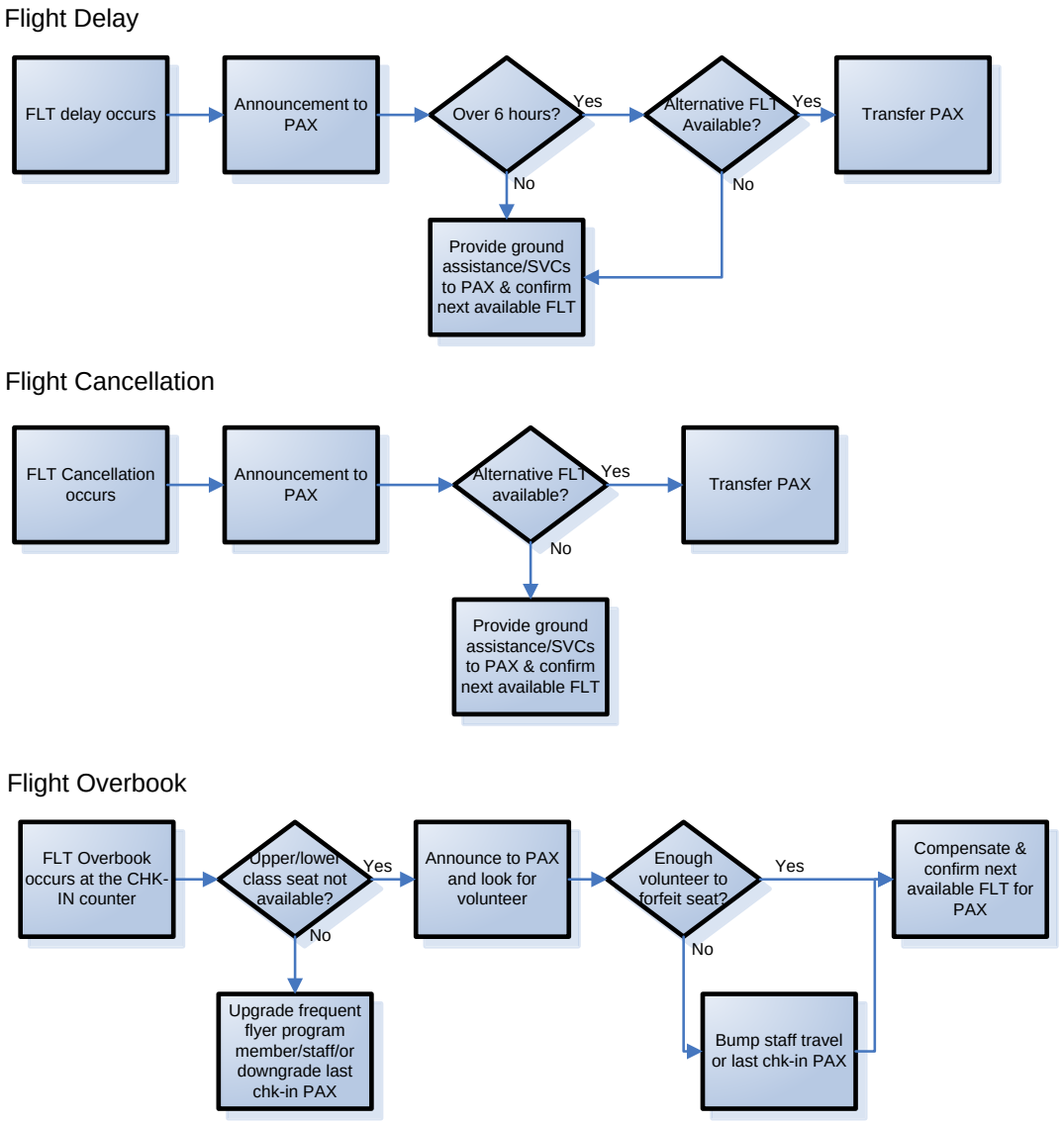

Figure A12.5. Flight Disruption Process Map

Step 5. Boarding and Departure Process

Figure A12.6 shows an ordinary boarding process for both international and domestic flights. Boarding gates normally open 1 hour to 15 minutes before the scheduled departure time. If passengers show up at the gate after it closes, they are not allowed to board the plane. Airlines

are very strict with this policy to avoid delays and other complications.

For an international flight, first-class and business class passengers can board at any time within the time frame. Passengers with limited mobility and their companions have priority to embark first. All other passengers will board according to their seat location.

Inside the aircraft, flight attendants start to serve first and business class passengers with drinks while others help the economy class passengers find their seats and secure their carry-on baggage. After the boarding gate is closed, the ground staff tries to tally the load sheet and the check-in record. If ground staff finds a checked-in passenger has not boarded, the ground staff instructs the baggage handling agents to offload the no-show passenger's baggage. This process takes 15-25 minutes and thus causes flight delays. Finally, flight crews demonstrate the safety drill and show safety videos to passengers before take-off.

Potential problems that may occur during this step are that flights may be delayed or passengers find flight attendants inattentive.

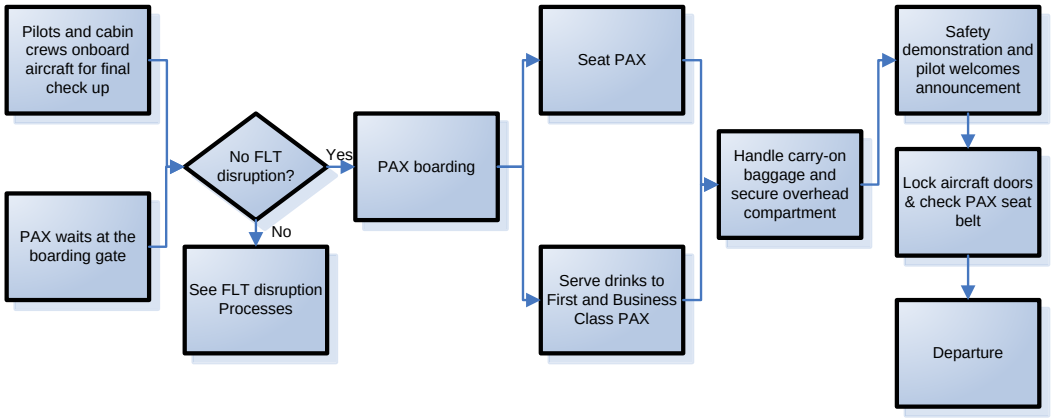

Figure A12.6. Boarding and Departure Process Map

Step 6. In-Flight Service Process

Figure A12.7 shows the major operational steps during the flight itself. After the airplane reaches a stable status, the cabin crew serves drinks and snacks. If a meal is served on the flight, special-requested meals will be served before regular meals. At the same time, in-flight entertainment is on, if applicable. While approaching the destination, pilots announce the estimated arrival time, flight status, and destination information. As the plane is descending for landing, all passengers must be seated with their seat belt fastened. For international flights, the cabin crew distributes customs declaration and immigration forms to passengers at this time.

During the in-flight service, passengers may find broken headsets, cabin crew may spill food or drinks, there may be a shortage of meals, or the wrong special meal request may be served.

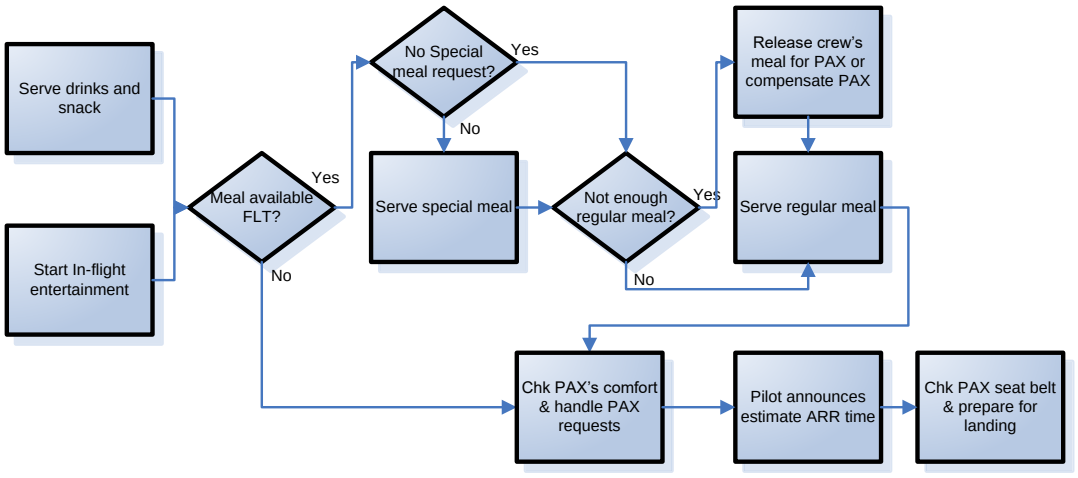

Figure A12.7. In-Flight Service Process Map

Step 7. Flight Arrival Process

When an aircraft has safely landed at the destination, airline operators perform the processes shown in Figure A12.8. When the flight arrives on time, domestic travelers leave the plane and

proceed to the baggage claim areas, whereas international travelers go through immigration and customs or proceed to another flight gate for a connecting flight. If a flight is delayed, cabin crews from good-practice airlines let passengers with connecting flights leave the aircraft first to catch their connecting flight. Upon coming out of the flight gate, ground agents should have all connecting passengers' information and notify them which gate to go to or what to do if they miss their flight. However, letting transfer passengers get off first may create chaos.

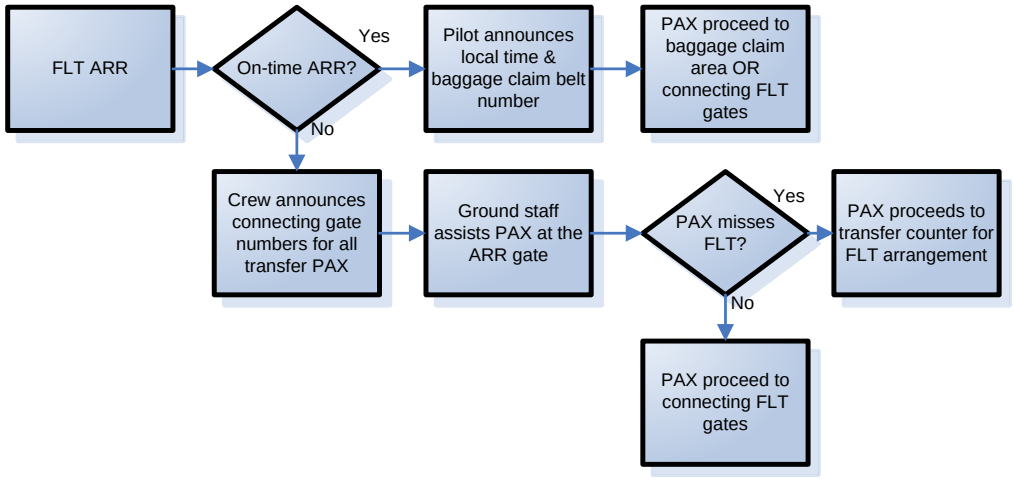

Figure A12.8. Flight Arrival Process Map

Step 8. Baggage Claim Process

Figure A12.9 shows all the major scenarios during the baggage claim process. This is the opposite of the baggage loading process. After offloading the ULDs from the aircraft, all bags are sent to the central sorting area.

If the baggage is damaged and contents have spilled, handlers put all the contents in a pallet before loading it on the conveyor belt. Baggage will be loaded on the designated conveyor belt and later taken through x-ray and security check before arrival at the carousel.

The interline baggage transfer for transfer passengers creates special challenges for current airline practices. Handlers sort bags by airline and flight number and then send them to the designated flight gate. Handlers will not be notified whether the connecting flight gate has changed until they reach the gate.

If passengers find their baggage is damaged or missing, they must approach the airline that provides the last flown segment of the journey and fill out a Property Irregularity Report (PIR) form. Airlines that arrange the portion last flown are solely responsible for locating the lost baggage and compensating for any damage. If found, the bags will usually be delivered to the passenger at the airline's cost. If not found, the airline will compensate the passenger. For a temporary delay in baggage claim, the airline will provide monetary assistance for the affected passenger who arrives at a destination that is not their hometown.

Any unclaimed baggage left on the carousel will be located and eventually sent to the intended destination.

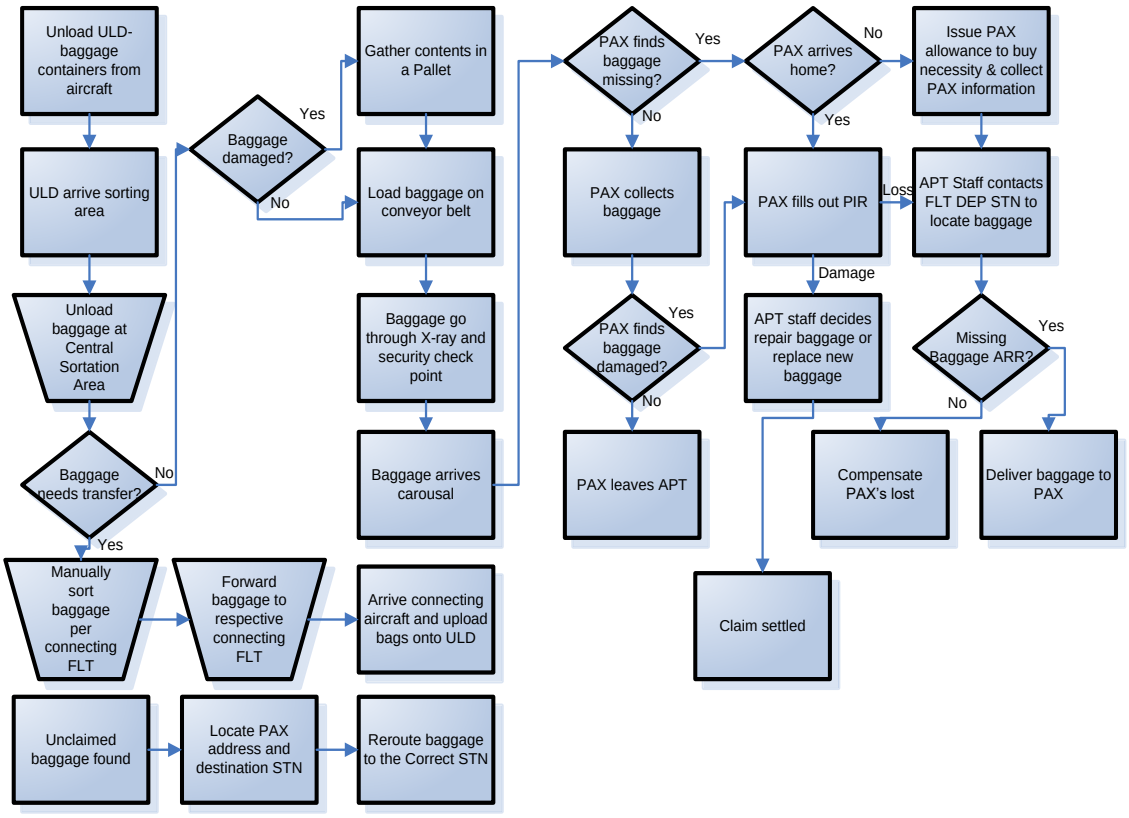

Figure A12.9. Baggage Claim Process Map

The process outlined above in Appendix 12 offers an overview of how airline companies deliver their services to their passengers starting from ticket purchase to baggage pickup at the final destination.

COMMON ACRONYMS

ACSI	American Consumer Satisfaction Index
APICS	The Association for Operations Management
APT	Airport
ARR	Arrival
AVE	Average
BRS	Baggage Reconciliation System
CHK-IN	Check-in
DEP	Departure
DES	Destination
DMAIC	Define, measure, analysis, implement and control
DPMO	Defects per million opportunities
FLT	Flight
IATA	International Air Transportation Association
ICAO	United Nation's International Civil Aviation Organization
INTL	International
IOSA	IATA Operational Safety Audit
ISO	International Organization for Standardization
KPI	Key Performance Indicator
MCT	Minimum Connecting Time
OPS	Operations
PAX	Passenger
PIR	Property Irregularity Report (Loss Baggage Report)
SPCL REQ	Special Request
SVC	Service
RFID	Radio Frequency Identification Device
RSVN	Reservation
SDR	Special Drawing Right
SS	Six Sigma
STN	Station
TKTG	Ticketing
TQM	Total Quality Management
ULD	Unit Load Devices (Baggage Containers)