Data Analysis of the Passengers' Flows from the Hong Kong Airport

DONG Zhengyuan MAO Yusang LIN Yuhang PENG Zhichao ZHAO Yiming,

Schedule

- Background
- Assumptions
- Estimations
- Forecasting

Background

- Passenger capacity of the airport will grow at an annual rate of 4% in the next 10 years

- KPI (key performance index): At least 95% of departing passengers (with their flights departing from 7:00am to 10:55am) at the immigration counter have to wait for less than 15 minutes.

Background

Airline Counter

Pre-document Counter

Security Counter

Immigration Counter

Arrival Time

Service Time

Waiting Time

Flight Information

Passenger Information

Background

	香港人	訪港旅客	轉機過境旅客總數	非港人旅客總數	非港人旅客轉機過境比例	總旅客
2008	11552	19616	17417	37033	47.03%	48585
2015	14109	23021	19491	42512	45.85%	56621
2023	18883	30809	26296	57105	46.05%	75988
2030	24018	39187	33809	72996	46.76%	97015

全部準確至千位（,000）

Scenarios

	Base	Worst
HK Resident	0.69	0.61
Non-resident	0.31	0.39

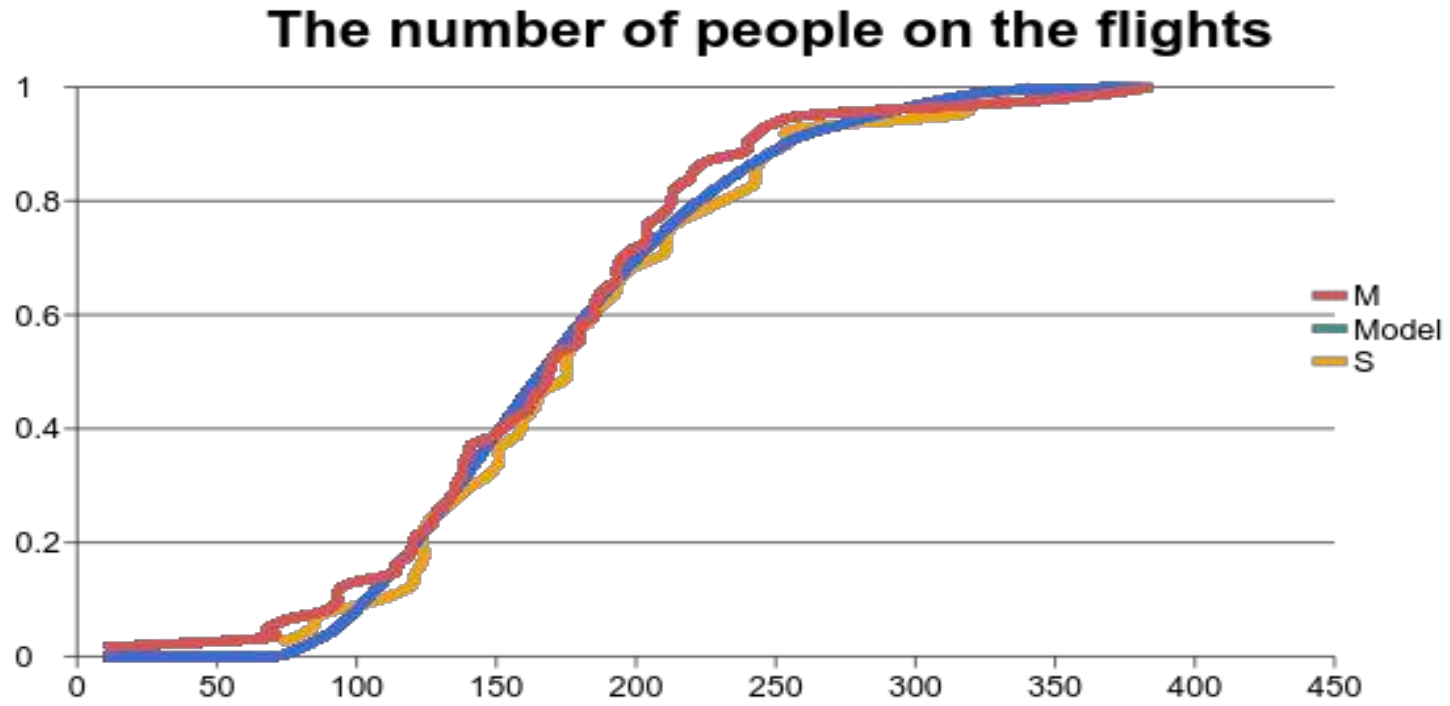
Flight Information

1. Assume 111 flights in 2016 would not change their type and time.
2. Assume the number of flight also increases by 0.04 each year.
3. Assume the flights of airline companies are the same proportion as in 2016.
4. Assume the capacity of flights remains the same.

Flight Information

5. Assume the number of passengers on the flights follows the same distributions as in 2016.

Beta Distribution	
alpha	2.25
beta	5.95
min	66.09
max	458.74



Flight Information

6. Assume the proportion of different groups on different types of flights would keep the same.

# of people in group	1	2	3	4	5	6	7
S	0.32	0.29	0.09	0.20	0.05	0.04	0.00
M	0.30	0.28	0.10	0.20	0.08	0.03	0.01
L	0.33	0.26	0.09	0.24	0.05	0.01	0.01
UL	0.28	0.29	0.12	0.21	0.07	0.02	0.01

Passenger Information

1. Assume the probability of a passenger being resident and the probability of checking in on different types of flights also keep the same as 2016.

	Non-resident	HK Resident	Check in	Don’t Check in
S	0.25	0.75	0.45	0.55
M	0.30	0.70	0.65	0.35
L	0.71	0.29	0.94	0.06
UL	0.69	0.31	0.86	0.14

Arrival Time – Airline Counter

- ΔT = Flight departure time – Airline counter arrival time
- How long the passengers will arrive at the airport in advance.

➢ Whether they need to visit the airline counter

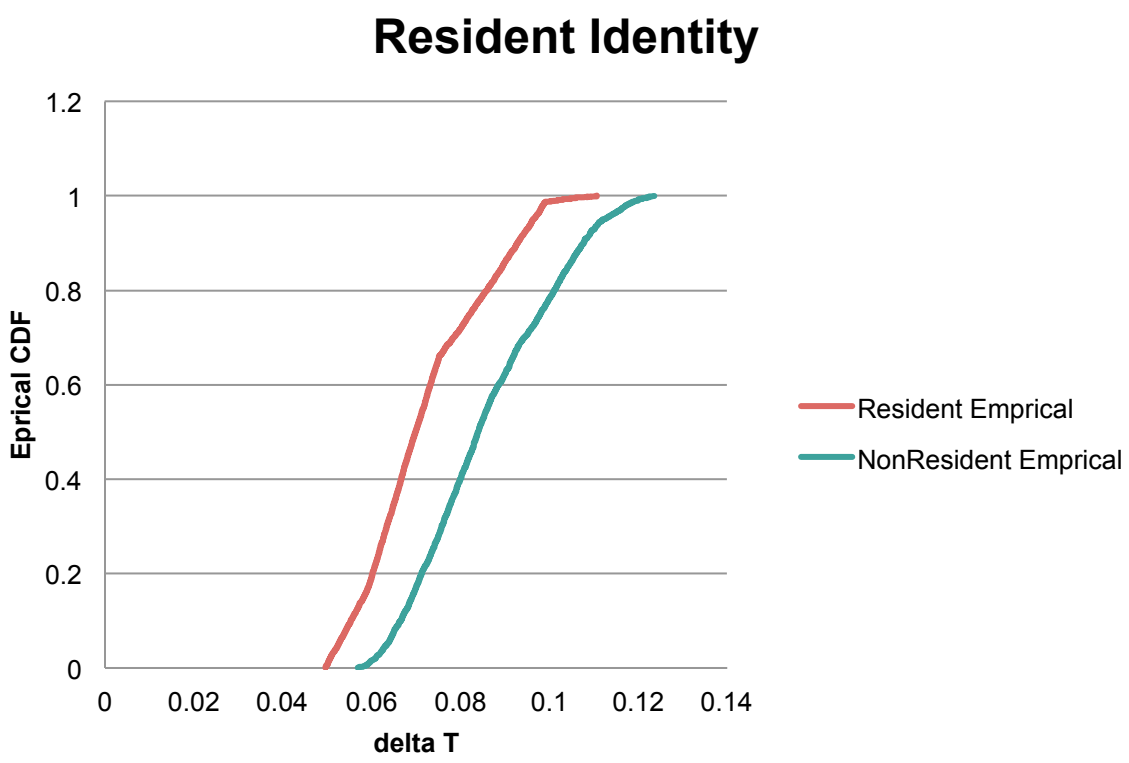
➢ HK resident/non-resident

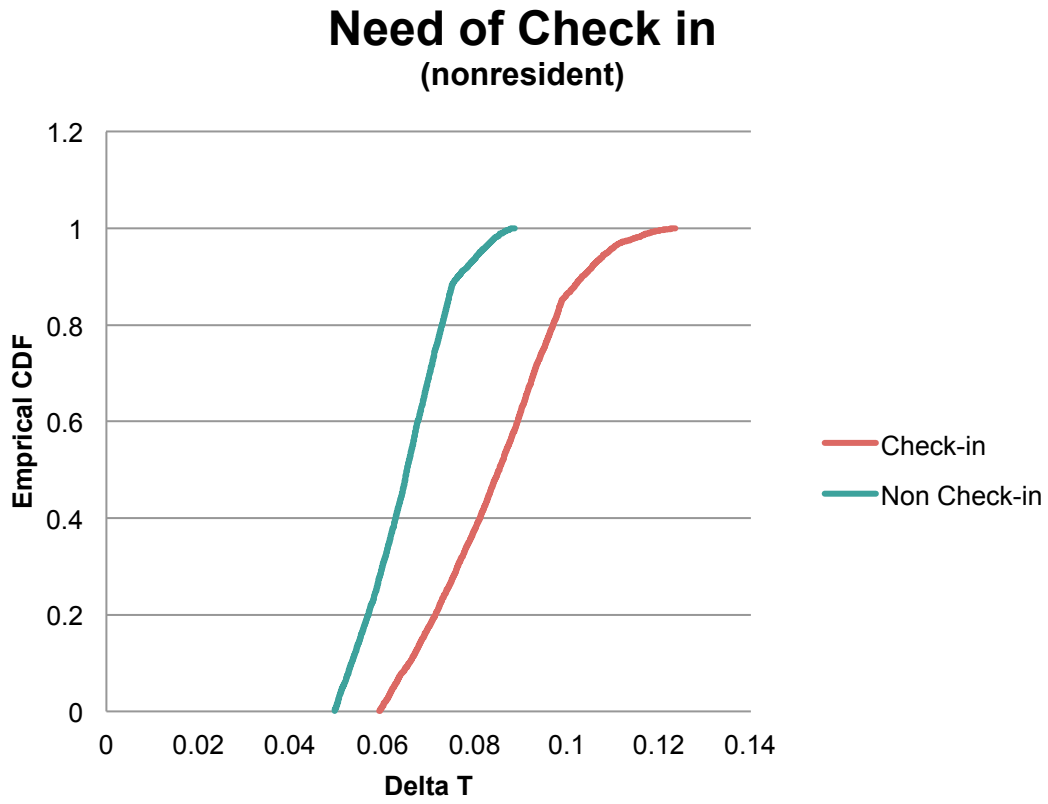
Whether they are familiar with the airport

➢ Take the ticket only/need to deal with luggage

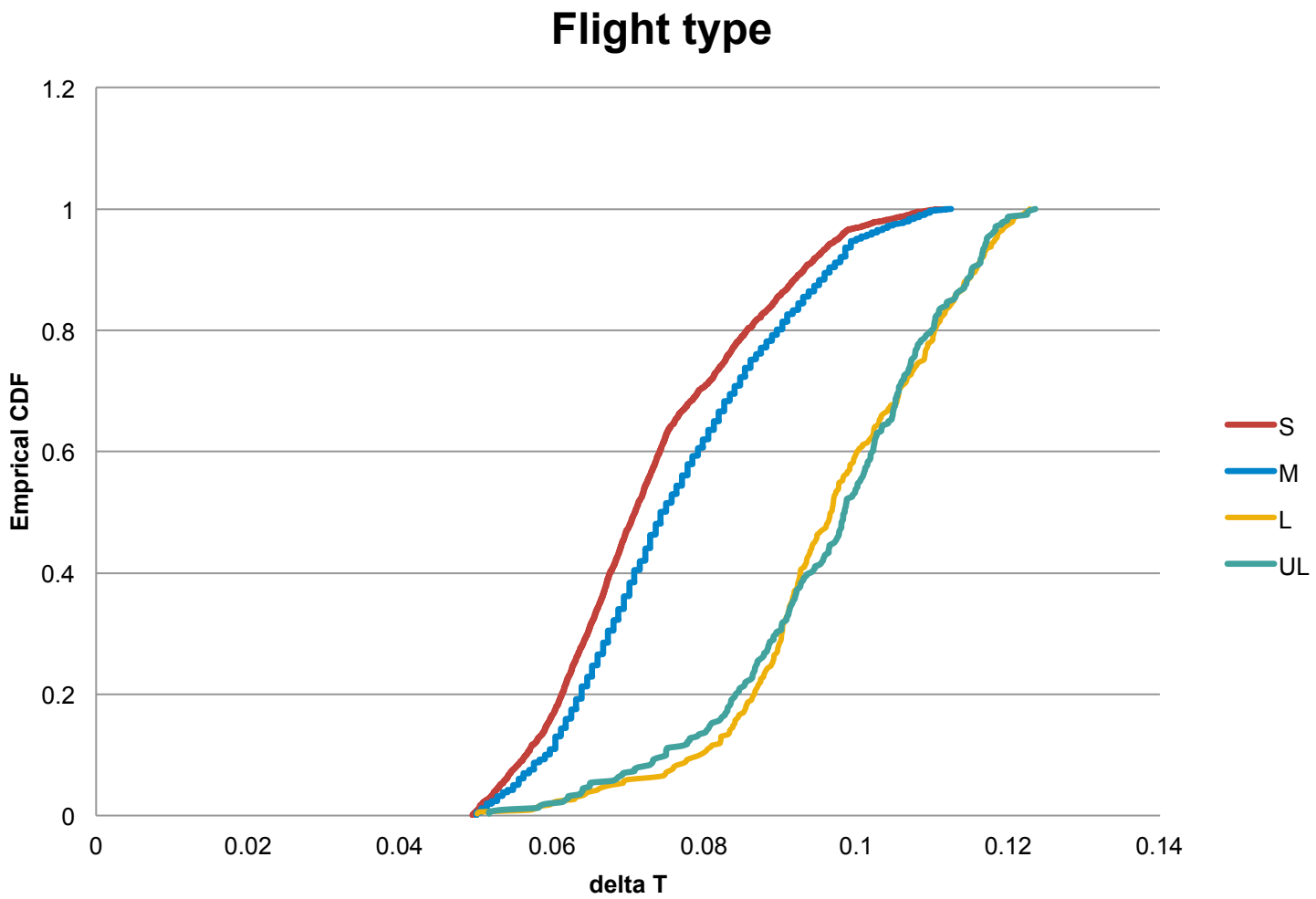
Flight type

Arrival Time – Airline Counter

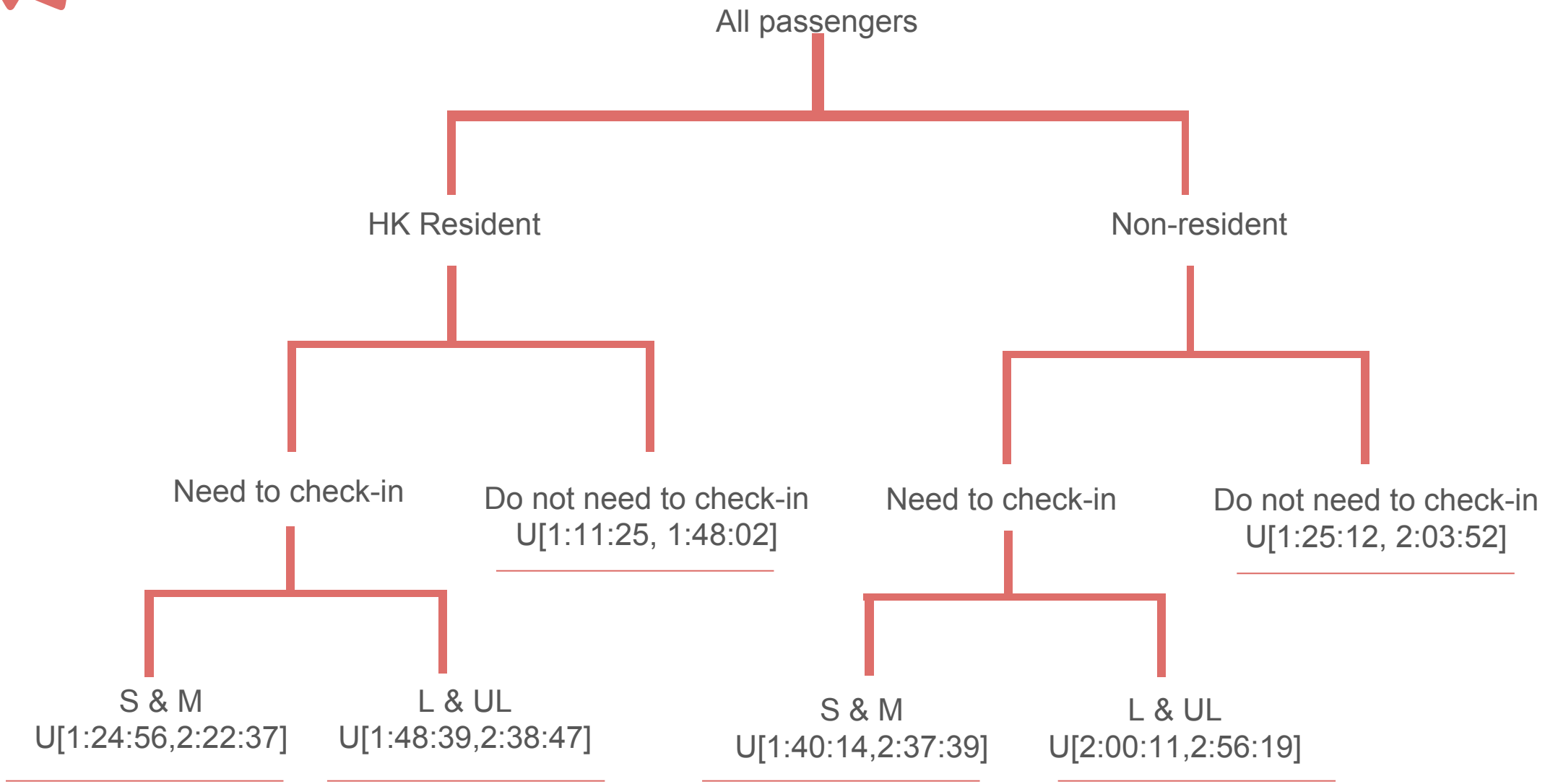




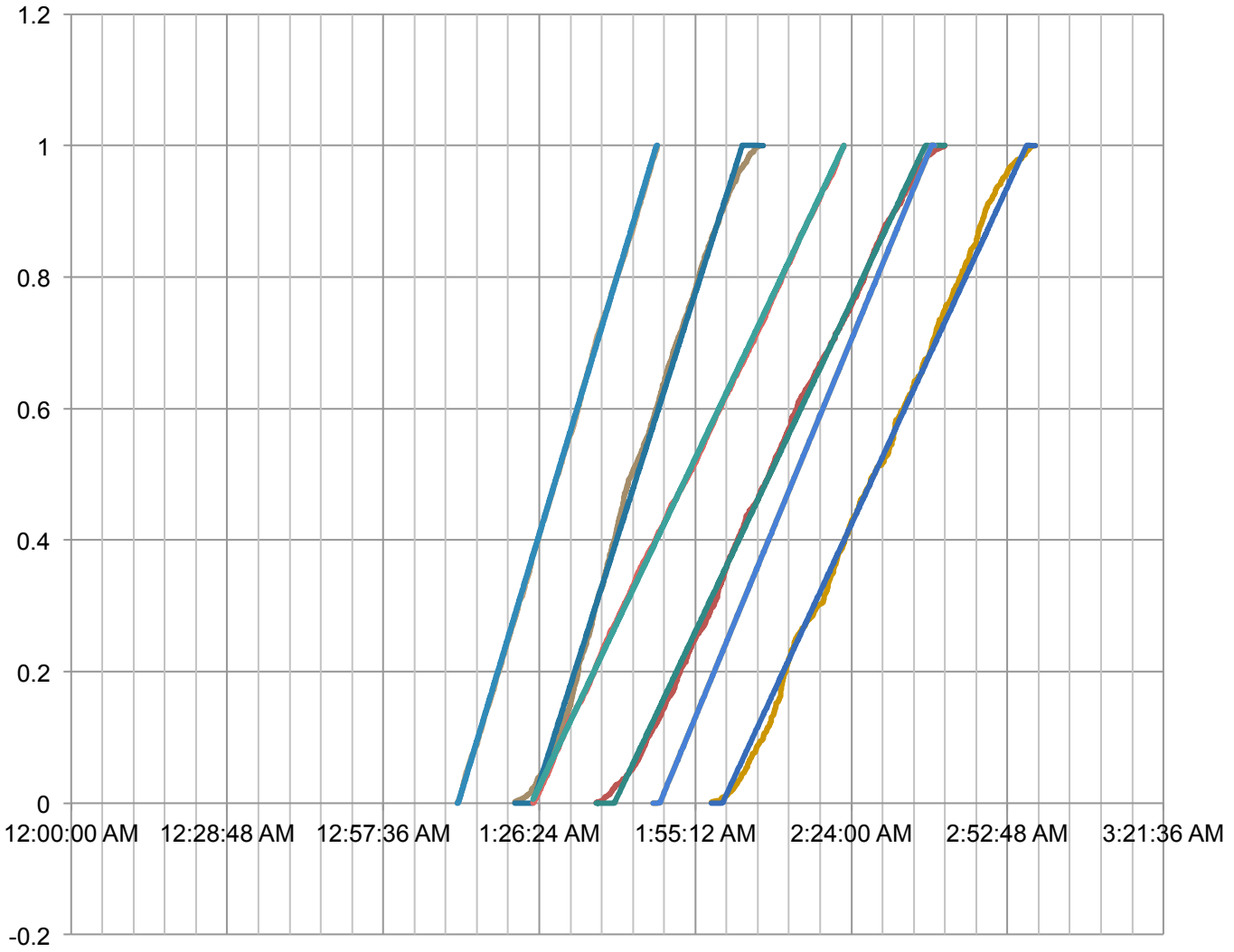
Arrival Time – Airline Counter



Arrival Time – Airline Counter

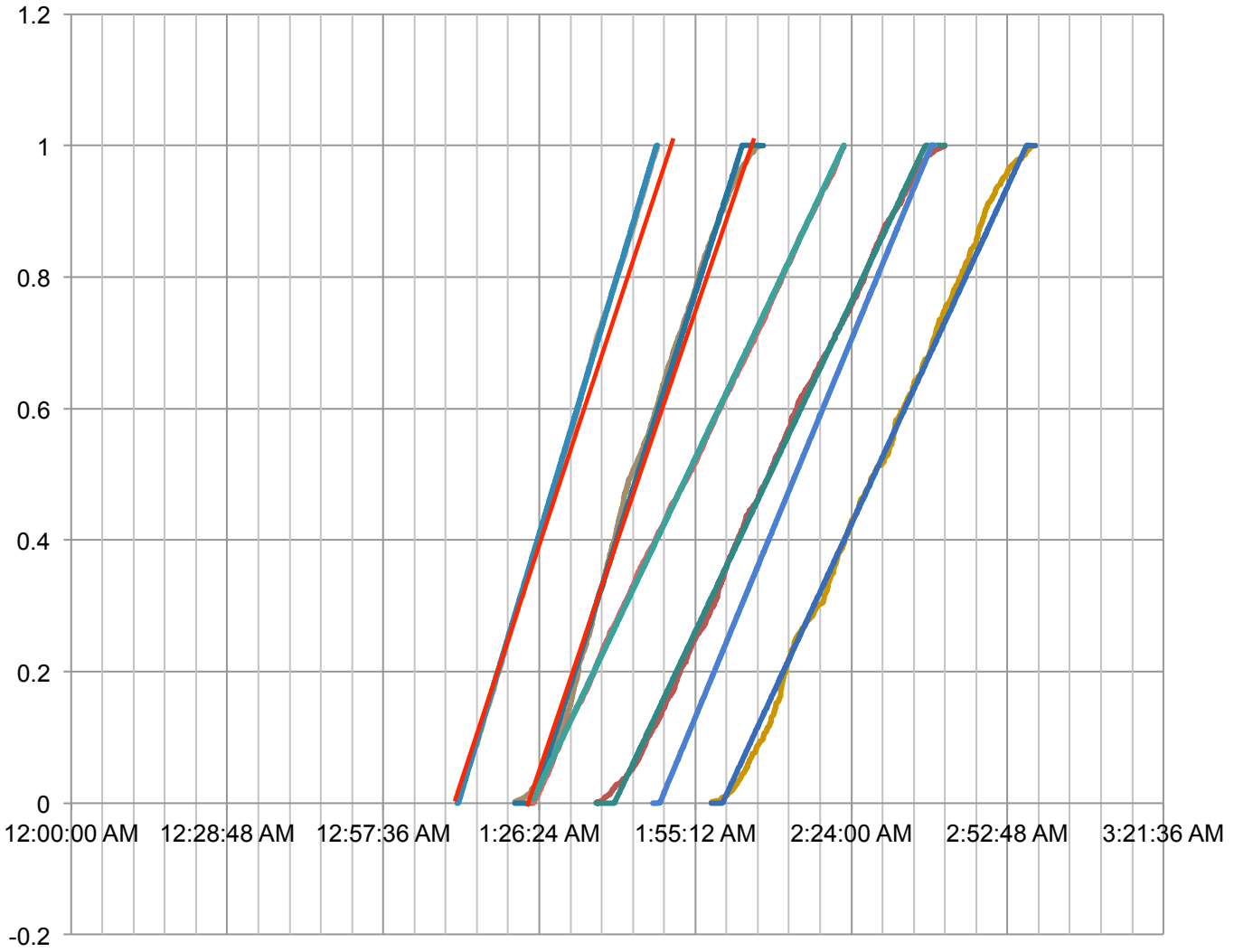


Arrival Time – Airline Counter



- s,m,check in,non resident (Emprical)
- s,m,check in,non resident (Model)
- l,ul,check in,non resident (Emprical)
- l,ul,check in,non resident (Model)
- No need check in, non resident (Emprical)
- No need check in, non resident (Model)
- s,m, check in, resident (Emprical)
- s,m, check in, resident (Model)
- l,ul,check in, resident (Emprical)
- l,ul,check in, resident (Model)
- No need check in, resident (Emprical)
- No need check in, resident (Model)

Arrival Time – Airline Counter



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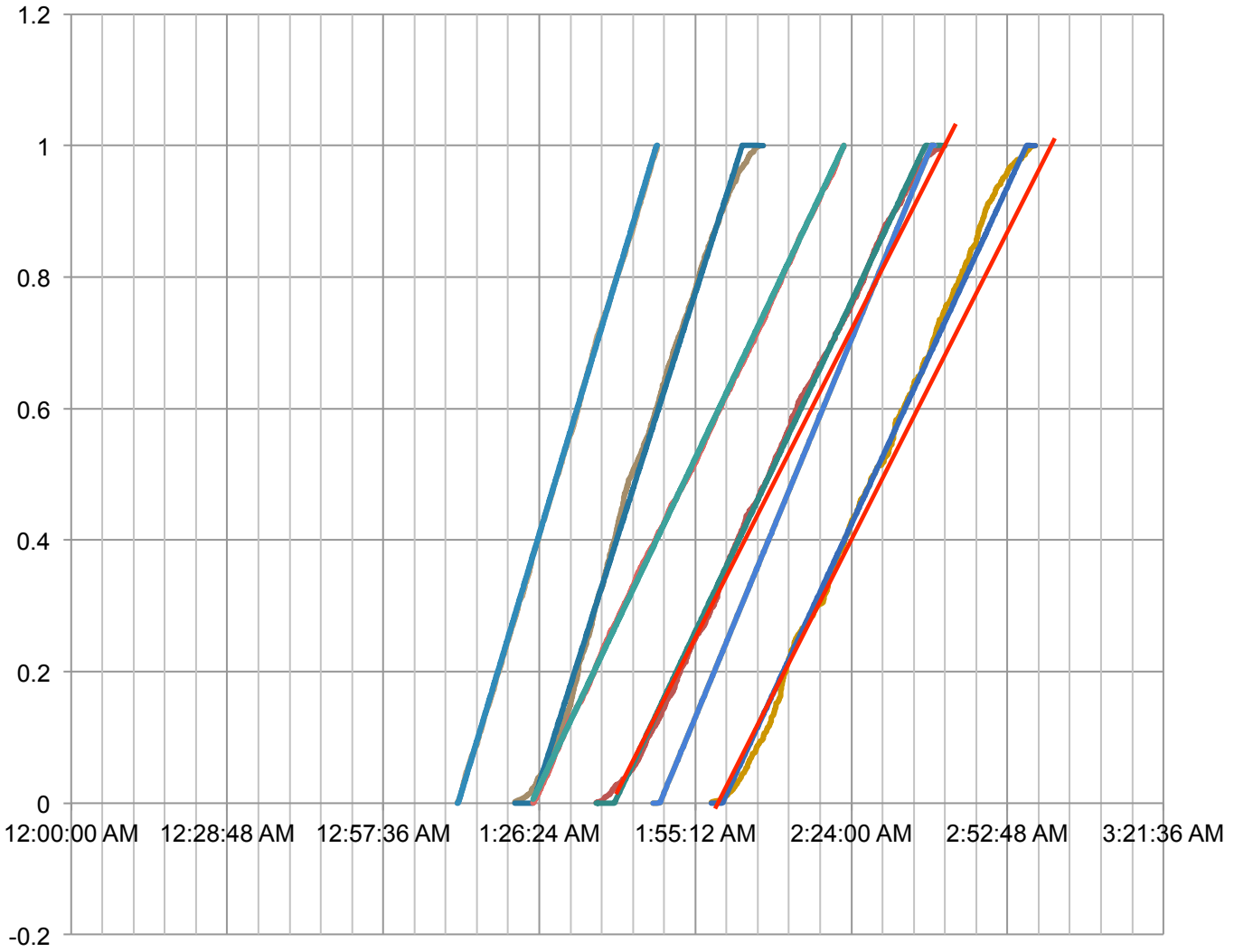
Arrival Time – Airline Counter



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- l,ul,check in, resident (Model)
- No need check in, resident (Emprical)
- No need check in, resident (Model)

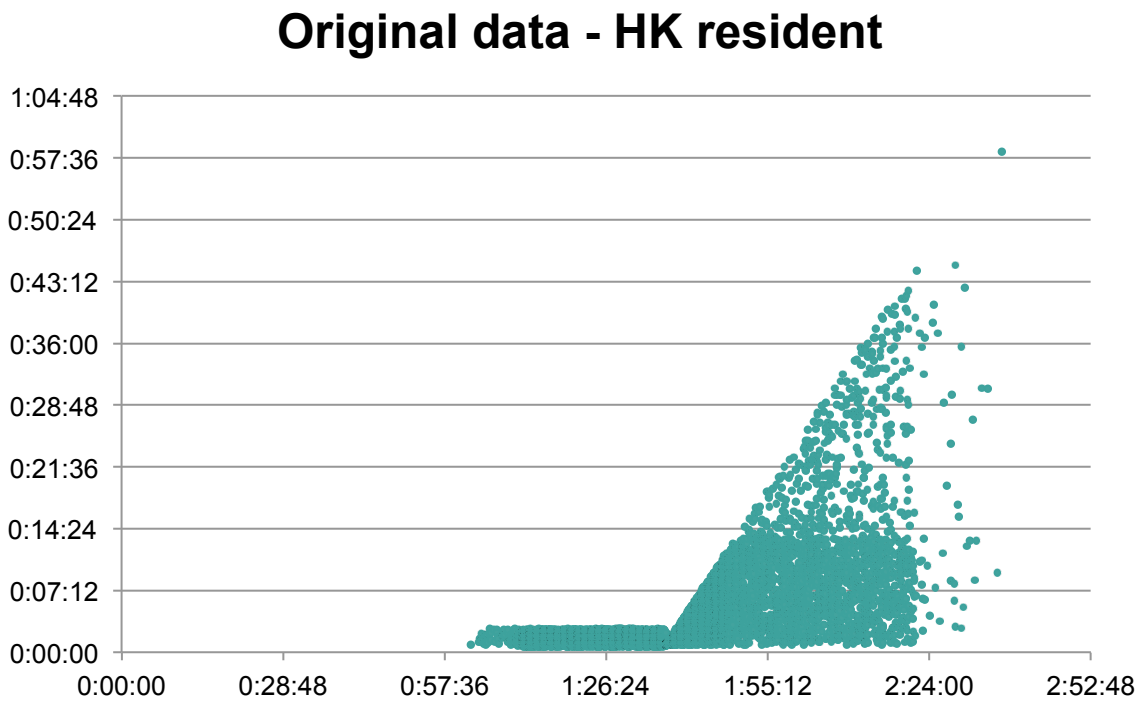
Arrival Time – Pre-document Counter

- ΔT = Pre-document counter arrival time– Airline counter departure time
- Time needed for walking
- Perhaps they will go around or have some meals before entering the restricted area

- HK resident / Non-resident
- Whether they are familiar with the airport

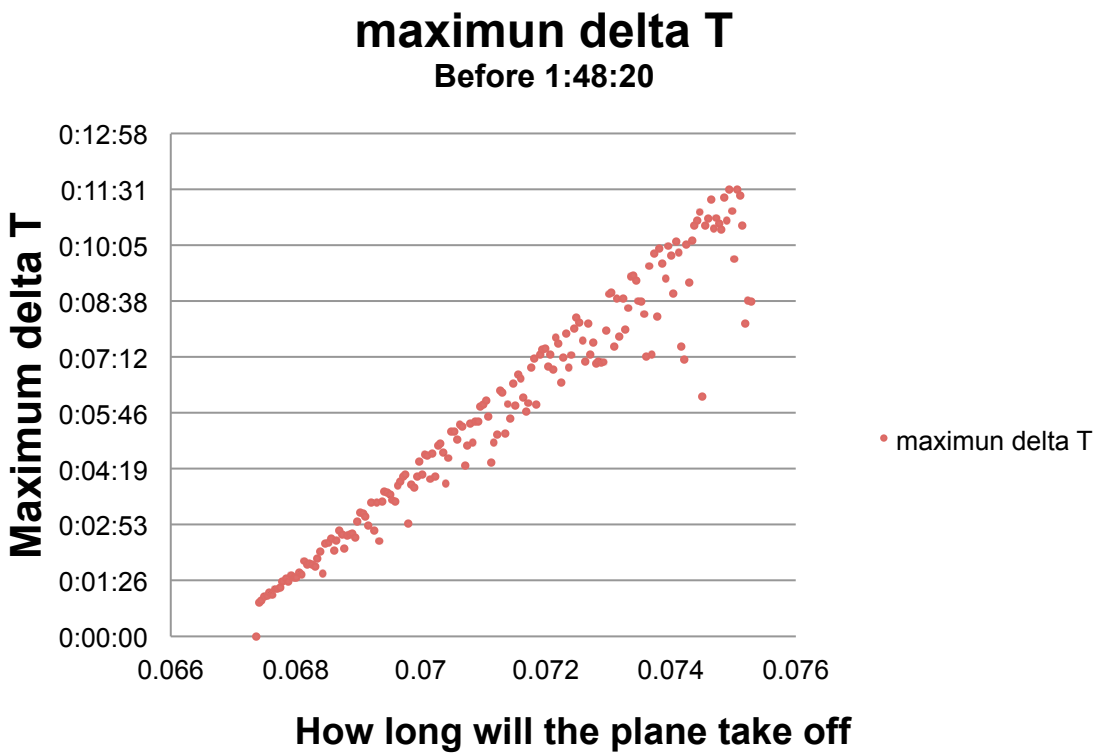
- How long the plane will take off
- Time permitted, perhaps they can walk around

Arrival Time – Pre-document Counter – HK Resident

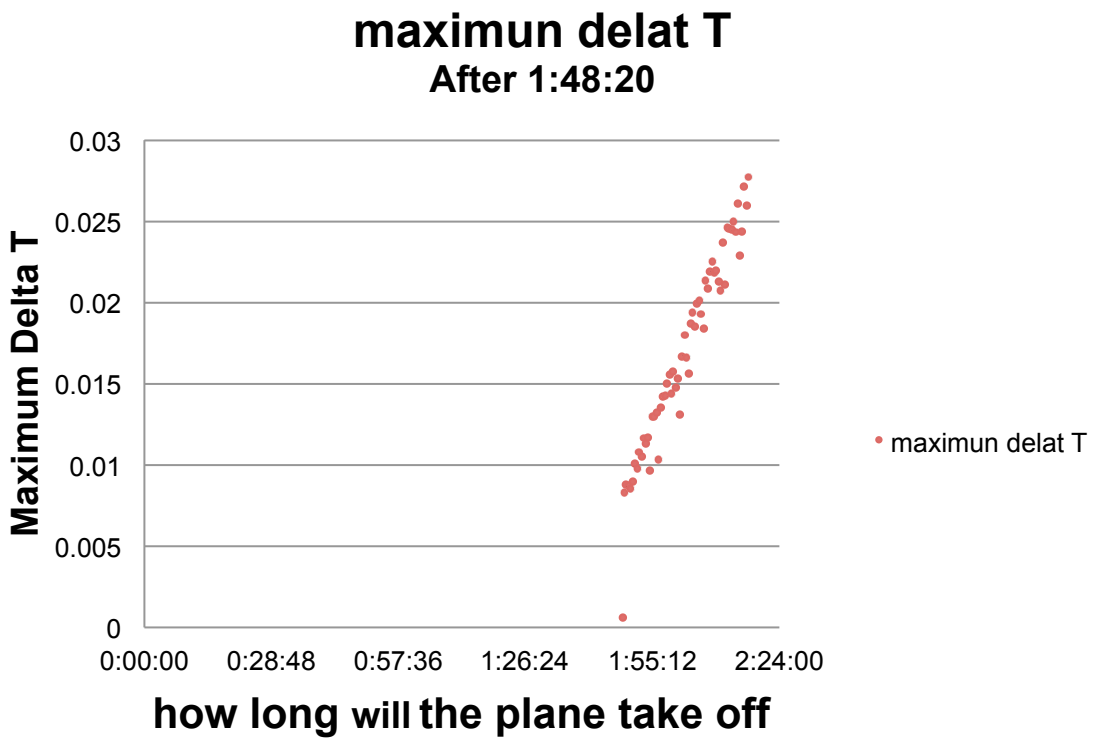


	min	1:37:01					
	max	1:49:20					
	gap	0:00:04					
		0.067367	0.067409878	0.067452648	0.067495	0.067538	0.067581
		1	11	3	16	4	8
0:00:50	1:37:01	0:00:50	0:00:50	0:00:50	0:00:50	0:00:50	0:00:50
0:00:50	1:37:01	0:00:00	0.00058017	0	0	0	0
0:00:50	1:37:01	0:00:00	0.000578251	0	0	0	0
0:00:50	1:37:01	0:00:00	0.000578464	0	0	0	0
0:00:51	1:37:02	0:00:00	0.000594841	0	0	0	0
0:00:50	1:37:02	0:00:00	0.000580846	0	0	0	0
0:00:50	1:37:02	0:00:00	0.000577441	0	0	0	0
0:00:52	1:37:03	0:00:00	0.000602332	0	0	0	0
0:00:52	1:37:03	0:00:00	0.000597831	0	0	0	0
0:00:50	1:37:03	0:00:00	0.000582634	0	0	0	0

Arrival Time – Pre-document Counter – HK Resident

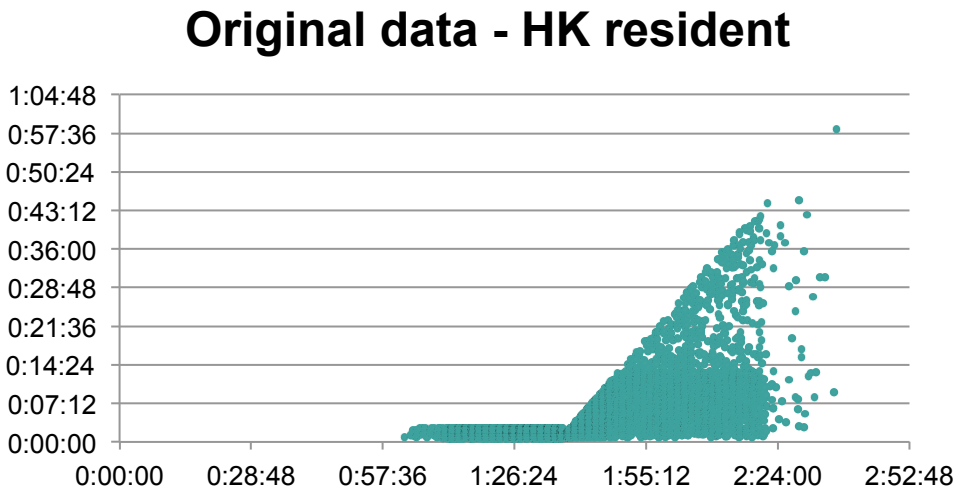


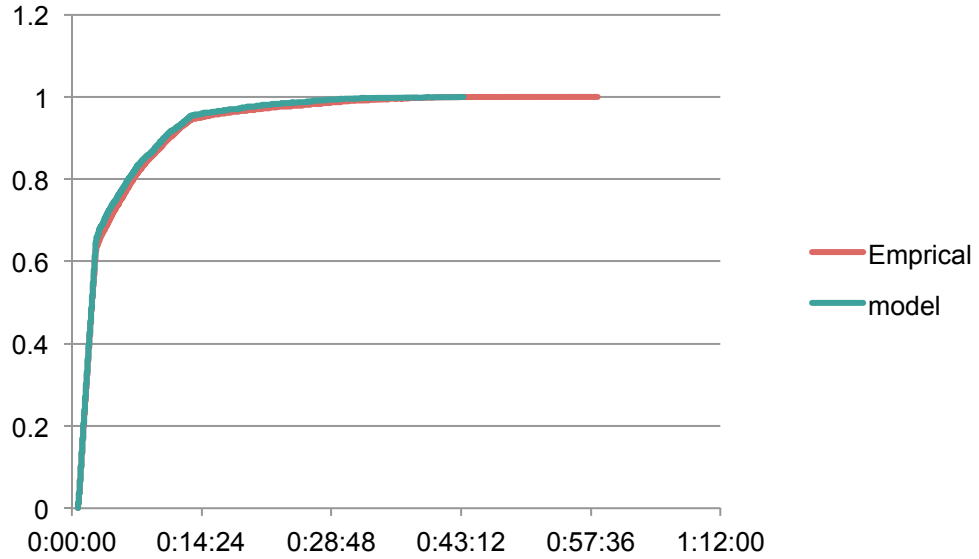
Intercept	-0.05899
X Variable	0.88422



Intercept	-0.06737
X Variable	0.990533

Arrival Time – Pre-document Counter – HK Resident

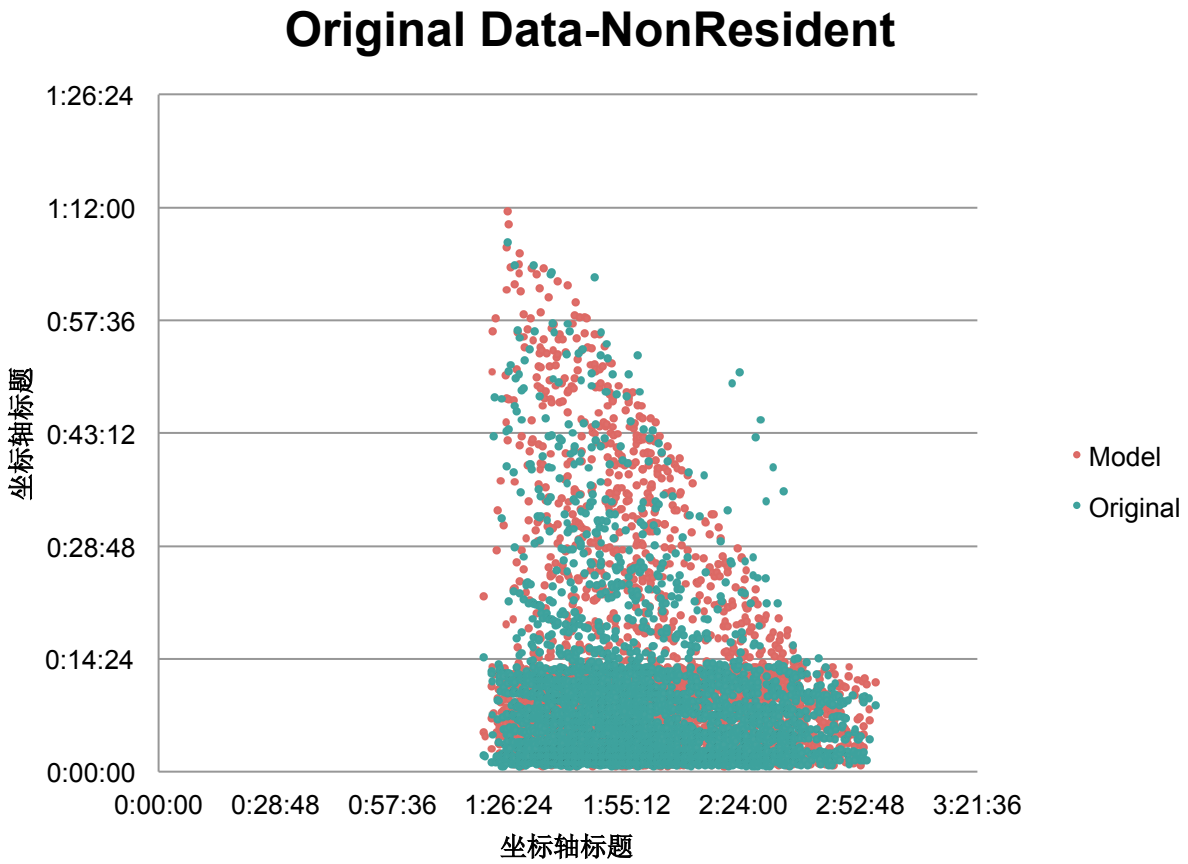




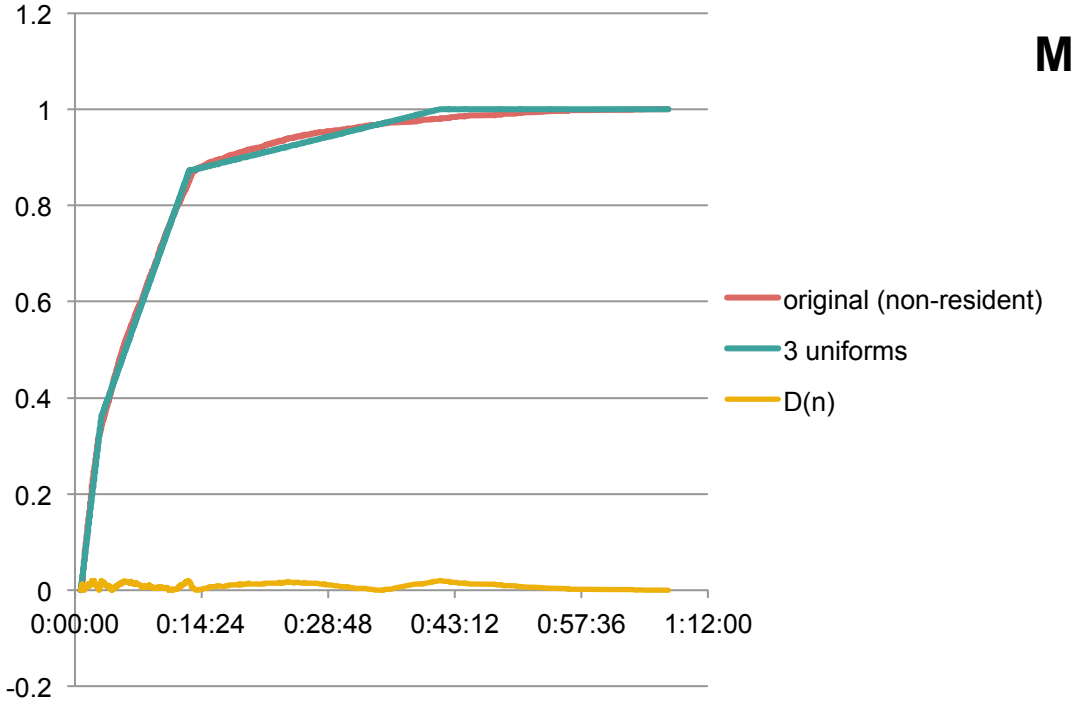
T: How long the plane will take off
X: time difference between pre-document arrival time and airline counter arrival time

T < 1:37:00	U[0:00:40,0:02:40]
1:37:00 ≤ T ≤ 1:48:20	U[0:00:50, 0.8842T-0.0590]
T > 1:48:00	80.50% passengers U[0:00:50,0:13:21] 19.50% passengers U[0:13:21,0.9905T-0.0674]

Arrival Time – Pre-document Counter – Non-resident



Arrival Time – Pre-document Counter – Non-resident



Mixture of three uniforms

U[0:00:40,0:03:00]

U[0:03:00, 0:13:00]

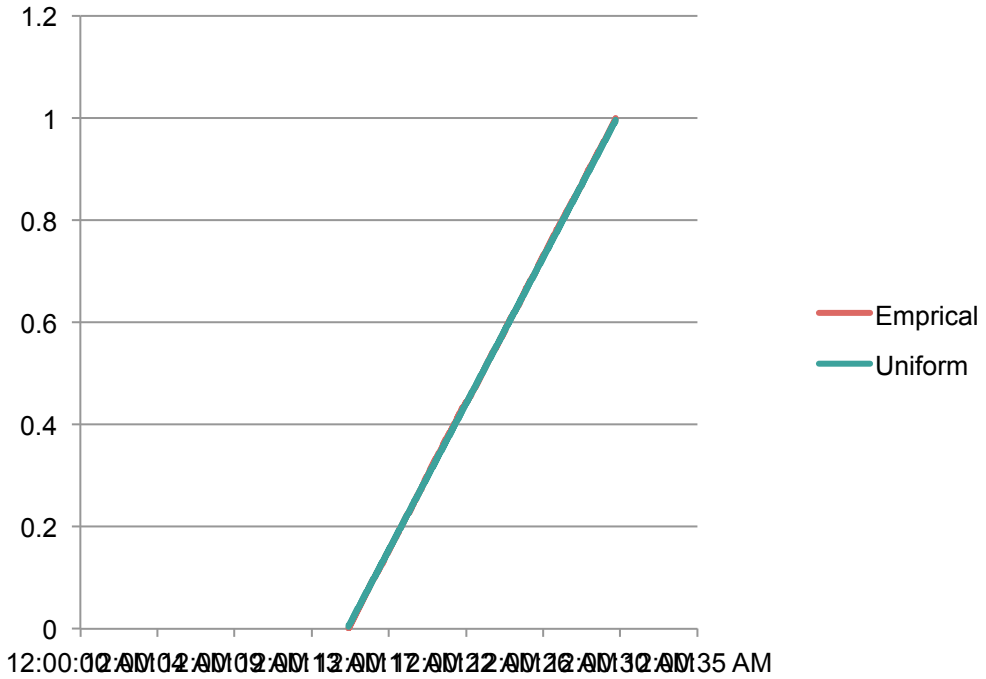
U[0:13:00,0:41:31]

turning point	0:00:40	0
	0:03:00	0.360031633
	0:13:00	0.871781883
	0:41:31	1.000032038
y=kx+b	222.0638085	-0.102807319
	73.75193164	0.206313353
	6.475193822	0.813355783
	critical value	0.020207266

Arrival Time – Security Counter

ΔT = Security counter arrival time – Pre-document counter departure time

- Short distance
- Passengers can do nothing else
- Time needed for **walking ONLY**

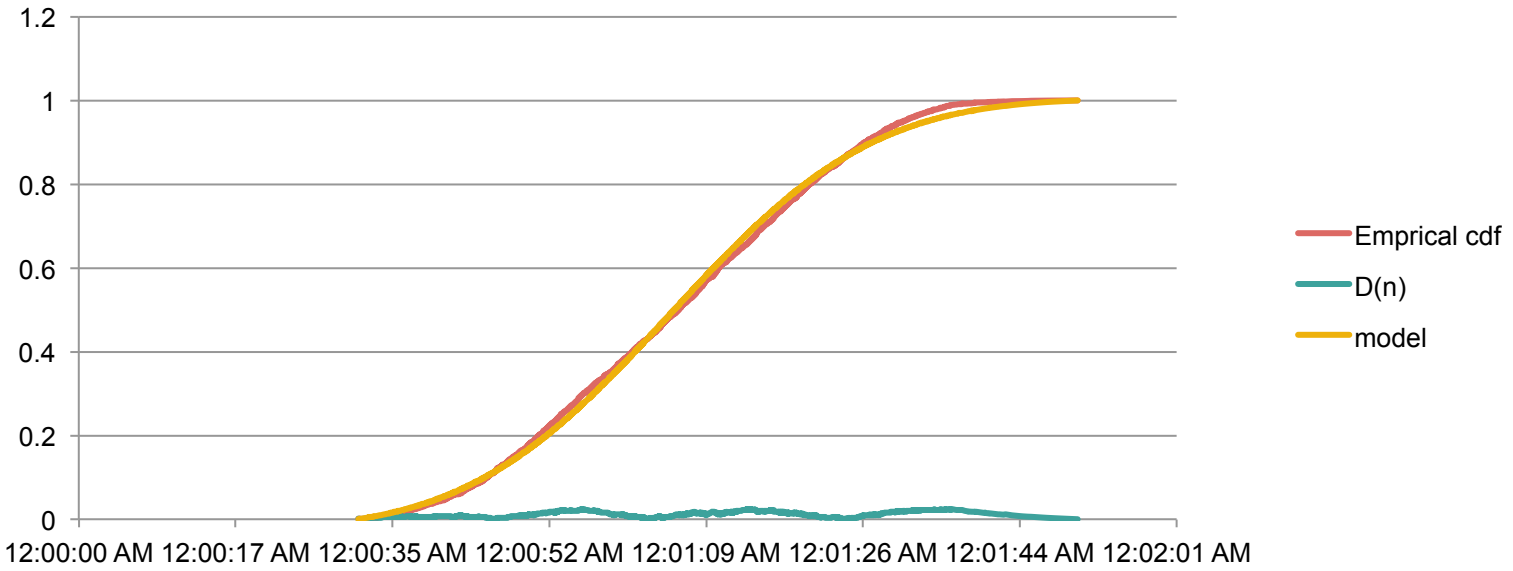


U[0:00:15,0:00:30]

Arrival Time – Immigration Counter

ΔT = Immigration counter arrival time – Security counter departure time

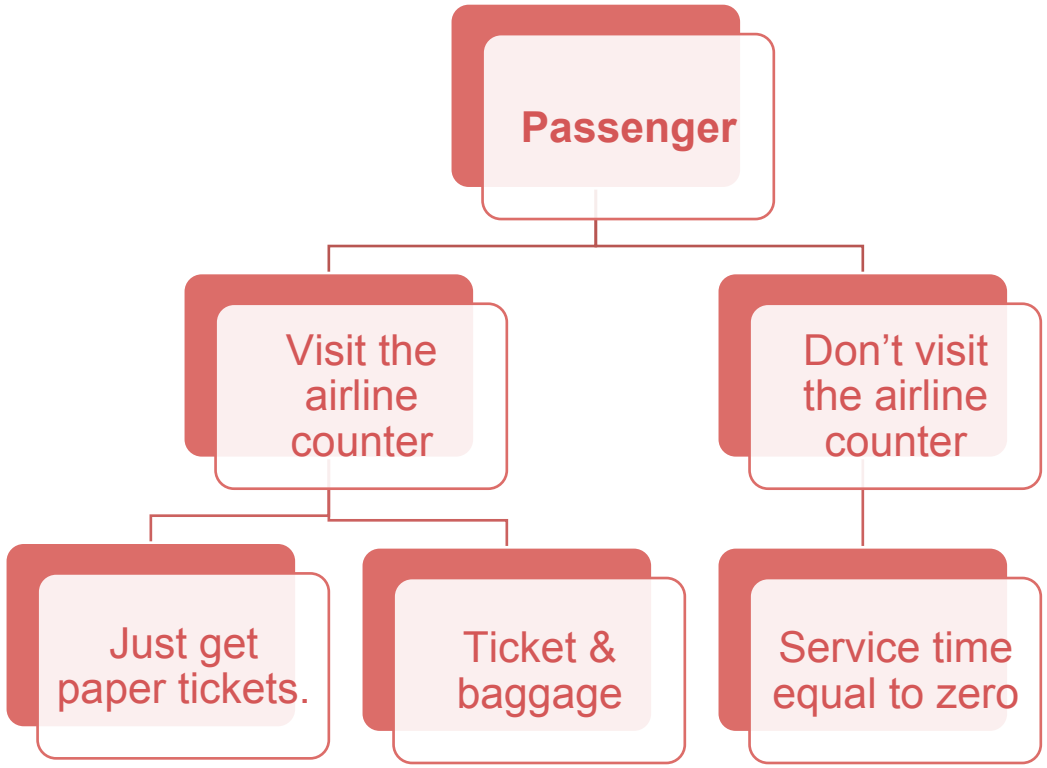
- Non-residents only, walking time
- Groups **DO NOT** go together



Truncated Normal

N(0:01:05,0:00:18^2)

Service Time – Airline Counter



Airline Counter

Service Time – Airline Counter

nformation		Airline Co
Group Travele	Passenger Type	Service Time (in Mi
Group	Non-resident	1.91064
Group	Non-resident	1.91064
Group	Non-resident	1.73883
Group	Non-resident	1.73883
Individual	Non-resident	1.38969
Group	Non-resident	2.14522
Group	Non-resident	2.14522
Group	Non-resident	2.14522
Individual	Non-resident	1.58323

The passengers in the same group have the same service time.

Different sizes of group seem to have different distributions.

Service Time – Airline Counter

=COUNTIF($B$3:$B$3037, “<=”&B3)/COUNT($B$3:$B$3037)

Airline Counter Service Time S&M				
Individual	i/n	Model cdf	abs_i/n	abs_i-1/n
1.13039	0.0003295	0	0.000329	0
1.13042	0.000659	0	0.000659	0.000329
1.13121	0.0009885	0	0.000988	0.000659
1.13151	0.001318	0	0.001318	0.000988
1.13194	0.0016474	0	0.001647	0.001318
1.13208	0.0019769	0	0.001977	0.001647
1.13224	0.0023064	0	0.002306	0.001977
1.13246	0.0026359	0	0.002636	0.002306
1.13253	0.0029654	0	0.002965	0.002636
1.13261	0.0032949	0	0.003295	0.002965
1.13273	0.0036244	0	0.003624	0.003295
1.13287	0.0039539	0	0.003954	0.003624
1.13321	0.0042834	0	0.004283	0.003954
1.13338	0.0046129	0	0.004613	0.004283
1.1337	0.0049423	0	0.004942	0.004613
1.13412	0.0052718	0	0.005272	0.004942

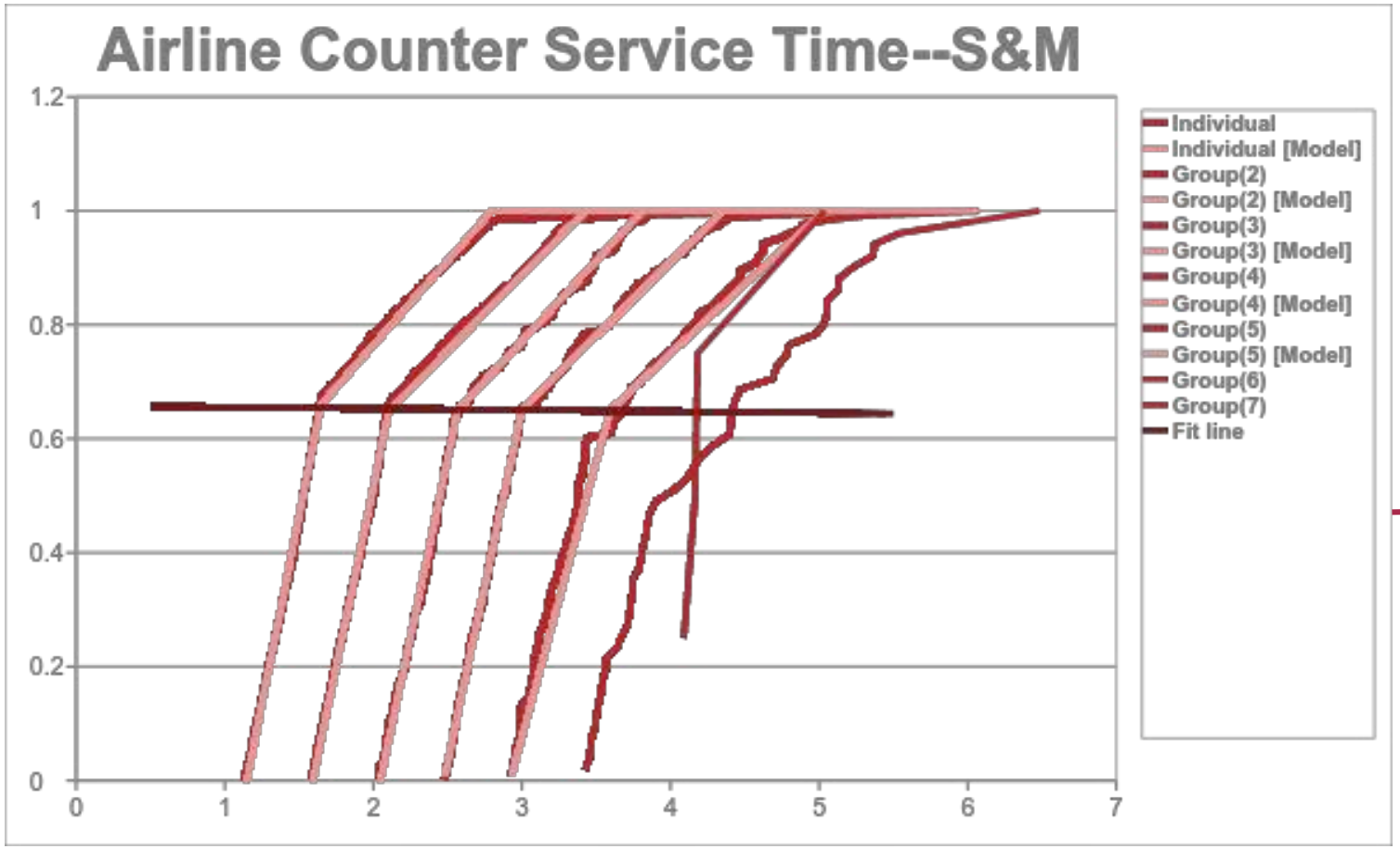
1

Group(2)	i/n	Model cdf	abs_i/n	abs_i-1/n
1.582228	0.000723	0	0.000723	0
1.583922	0.001445	0	0.001445	0.000723
1.584704	0.002168	0	0.002168	0.001445
1.584887	0.00289	0	0.00289	0.002168
1.585083	0.003613	0	0.003613	0.00289
1.585553	0.004335	0	0.004335	0.003613
1.585793	0.005058	0	0.005058	0.004335
1.585803	0.00578	0	0.00578	0.005058
1.586135	0.006503	0	0.006503	0.00578
1.58769	0.007225	0	0.007225	0.006503
1.589087	0.007948	0	0.007948	0.007225
1.589469	0.008671	0	0.008671	0.007948
1.589749	0.009393	0	0.009393	0.008671
1.591413	0.010116	0	0.010116	0.009393
1.591506	0.010838	0	0.010838	0.010116
1.591926	0.011561	0	0.011561	0.010838

Individual	x	y	k	m
a	1.148692	0	1.323632419	-1.52045
turning point	1.646456	0.658855	0.297211623	0.16951
b	2.794273	1		
	max	sumsq	to optimize	
ks-test	0.02108	0.72069	0.021086944	
D_n	0.024652			

Group(2)	x	y	k	m
a	1.593195	0	1.270842724	-2.0247
turning point	2.103528	0.648554	0.265933463	0.089155
b	3.425085	1		
	max	sumsq	to optimize	
ks-test	0.020542	0.339158	0.020544929	
D_n	0.036506			

Service Time – Airline Counter



K-S Test

All pass the test!!

	max	sumsq	to optimize	D_n
Individual	0.02108	0.72069	0.0210869	0.024652
Group(2)	0.020542	0.339158	0.0205449	0.036506
Group(3)	0.030655	0.100096	0.0306559	0.077892
Group(4)	0.022449	0.06088	0.0224496	0.061353
Group(5)	0.09811	0.400933	0.0981144	0.122456

Short and Medium flight type can be modeled by a mixture of two uniform distributions.

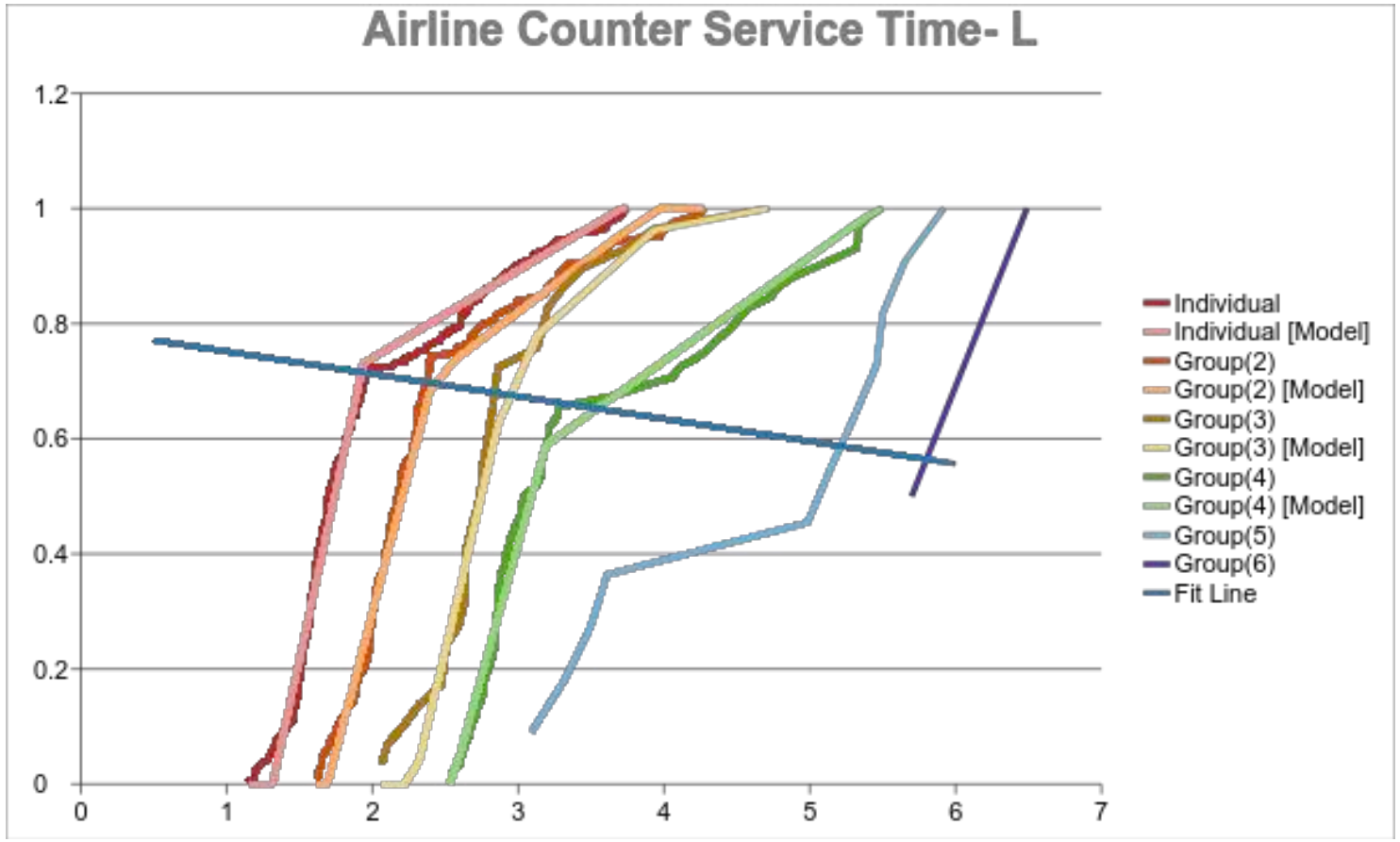
Service Time – Airline Counter

Lines	x	y(min)	y(turning)	y(max)
	1	1.148692	1.6464555	2.794273
	2	1.593195	2.1035283	3.425085
	3	2.048019	2.5670384	3.81
	4	2.473641	2.9984634	4.348375

y-turning	x	y
	1	0.658855
	2	0.648554
	3	0.649069
	4	0.650236

	k	m
min line	0.442967	0.708469
turning line	0.451953	1.198988
max line	0.504722	2.332628
y tunring	-0.00253	0.658015

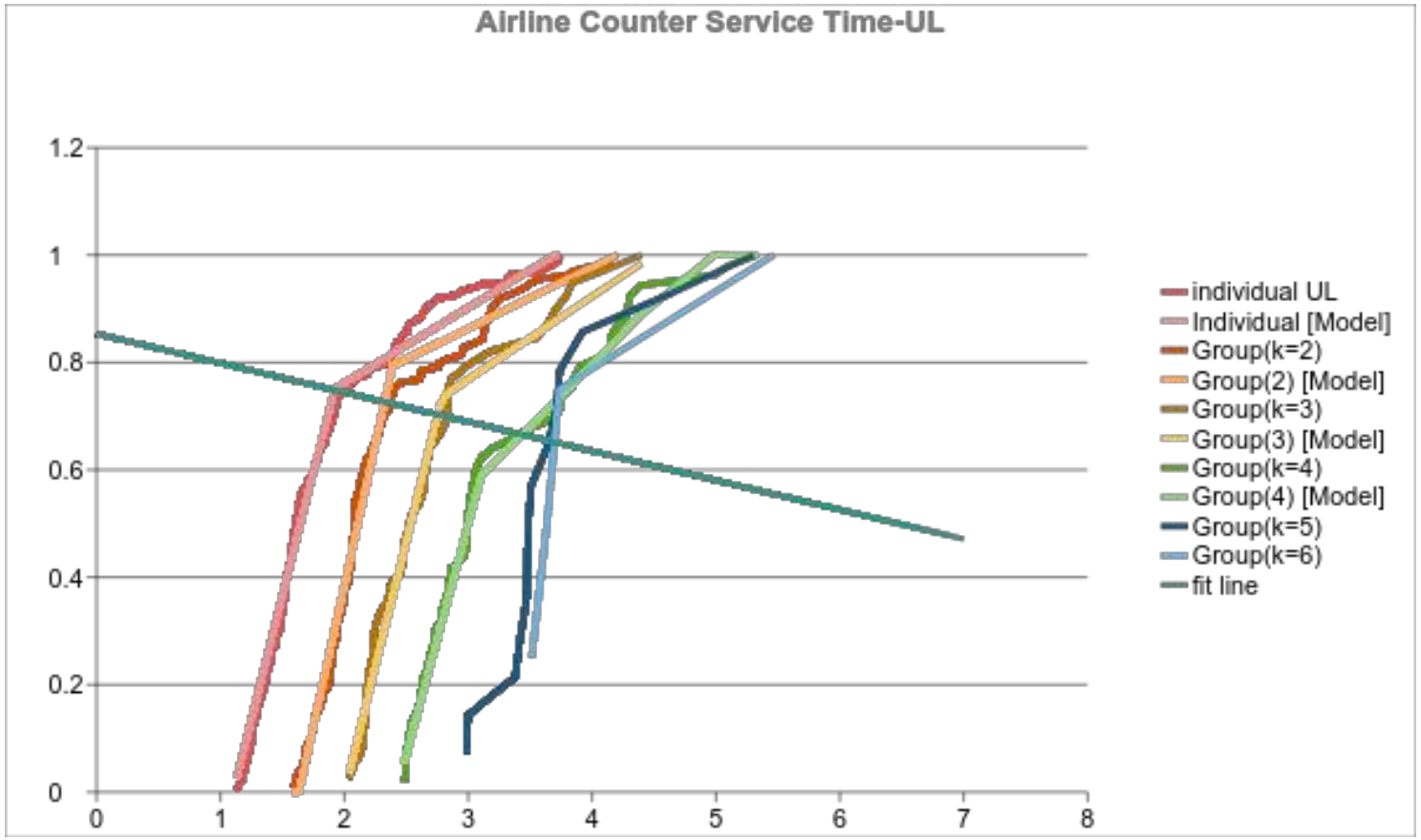
Service Time – Airline Counter



K-S Test

	max	sumsq	to optimize	D_n
Individual	0.058252	0.502083	0.05825745	0.07726
Group(2)	0.056662	0.19687	0.05666392	0.121961
Group(3)	0.103448	0.130756	0.10344958	0.252193
Group(4)	0.060282	0.132066	0.06028327	0.178327

Service Time – Airline Counter



K-S Test

	max	sumsq	to optimize	D_n
Individual	0.051858	0.527202	0.051863	0.082196
Group(2)	0.062711	0.095245	0.062711	0.117322
Group(3)	0.078927	0.095245	0.078928	0.21747
Group(4)	0.056604	0.061156	0.056604	0.18655

Service Time – Airline Counter

Use VBA to calculate the service time of each passenger.

```
Function AirlineSM(i)

p = Rnd()
k = -0.00253
m = 0.658015
a1 = 0.442967
b1 = 0.708469
a2 = 0.451953
b2 = 1.198988
a3 = 0.504722
b3 = 2.332628
k1 = (k * i + m) / ((a2 * i + b2) - (a1 * i + b1))
k2 = (1 - (k * i + m)) / ((a3 * i + b3) - (a2 * i + b2))
m1 = -k1 * (a1 * i + b1)
m2 = 1 - k2 * (a3 * i + b3)

If k * i + m > p Then
x = (p - m1) / k1
Else
x = (p - m2) / k2
End If
AirlineSM = x

End Function
```

J	Airline counter
1	1.395701695
1	1.851661888
2	2.025305764
1	2.025305764
3	2.392169915
2	2.392169915
1	2.392169915
3	0
2	0
1	0

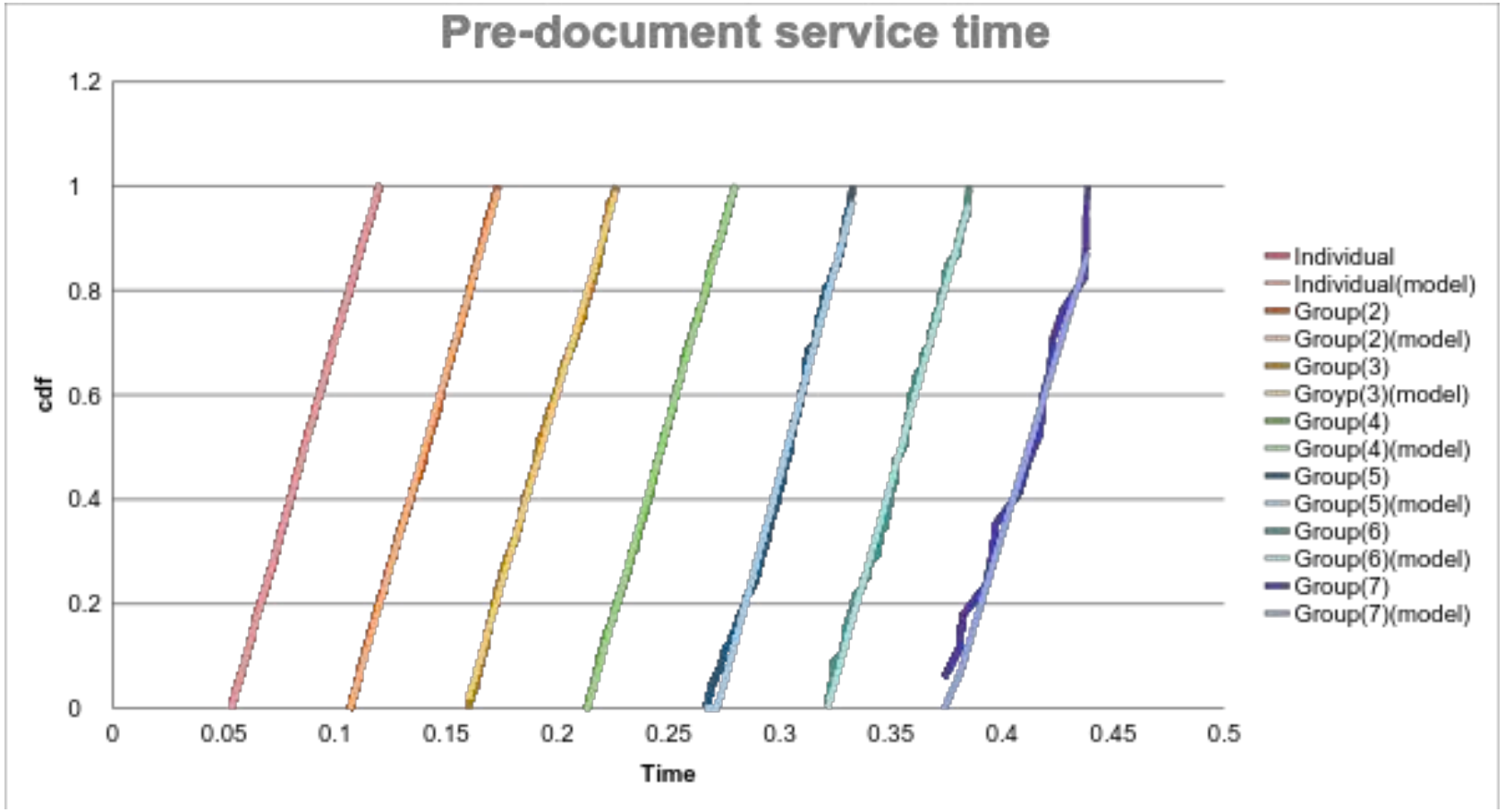
Lines	x	y(min)	y(turning)	y(max)
	1	1.148692	1.6464555	2.794273
	2	1.593195	2.1035283	3.425085
	3	2.048019	2.5670384	3.81
	4	2.473641	2.9984634	4.348375

y-turning	x	y
	1	0.658855
	2	0.648554
	3	0.649069
	4	0.650236

	k	m
min line	0.442967	0.708469
turning line	0.451953	1.198988
max line	0.504722	2.332628
y tunring	-0.00253	0.658015

```
=IF(D2="Y",IF(OR(G2="S",G2="M"),AirlineSM(B2),IF(G2="L",AirlineL(B2),AirlineUL(B2))),0)
=IF(OR(AND(J3>J2,J3>J4),J3=J2),IF(D3="Y",IF(OR(G3="S",G3="M"),AirlineSM(B3),IF(G3="L",AirlineL(B3),AirlineUL(B3))),0)
=IF(OR(AND(J4>J3,J4>J5),J4=J3),IF(D4="Y",IF(OR(G4="S",G4="M"),AirlineSM(B4),IF(G4="L",AirlineL(B4),AirlineUL(B4))),0)
=IF(OR(AND(J5>J4,J5>J6),J5=J4),IF(D5="Y",IF(OR(G5="S",G5="M"),AirlineSM(B5),IF(G5="L",AirlineL(B5),AirlineUL(B5))),0)
=IF(OR(AND(J6>J5,J6>J7),J6=J5),IF(D6="Y",IF(OR(G6="S",G6="M"),AirlineSM(B6),IF(G6="L",AirlineL(B6),AirlineUL(B6))),0)
```

Service Time – Pre-document Counter



	x	y(min)	y(max)
	1	0.053321068	0.119610089
	2	0.106750051	0.173946296
	3	0.158729667	0.227157867
	4	0.213655175	0.279878452
	5	0.272029879	0.334868318
	a	b	
min line	0.05443227	-0.00239966	
max line	a	b	
	0.05364486	0.06615762	

Service Time – Pre-document Counter

	individual	Group(2)	Group(3)	Group(4)	Group(5)	Group(6)	Group(7)
min	0.05332107	0.106750051	0.158729667	0.2136552	0.272029879	0.321691018	0.376401221
max	0.11961009	0.173946296	0.227157867	0.2798785	0.334868318	0.387400873	0.447806343
k	15.0854543	14.88178382	14.61385811	15.100431	15.91382628	15.2184174	14.00459766
m	-0.80437253	-1.58863118	-2.31965284	-3.226285	-4.32903624	-4.895628184	-5.271347659
D0	0.00822891	0.016962079	0.026949622	0.0168765	0.066666667	0.054827124	0.127742139
D_n	0.01709826	0.025214965	0.053433789	0.04242	0.085047616	0.128328531	0.329388
Sumsq	0.13495266	0.35271445	0.203813847	0.1050808	0.314910797	0.090762566	0.101278288
Optimize	0.01709961	0.025218492	0.053435828	0.042421	0.085050765	0.128329439	0.329389013

```
Function Predocument(i)

a1 = 0.054432275
a2 = 0.053644861
b1 = -0.002399656
b2 = 0.06615762
k = 1 / ((a2 * i + b2) - (a1 * i + b1))
b = -(a1 * i + b1) * k
y = Rnd()
x = (y - b) / k
Predocument = x

End Function
```

Service time - Security counter

2	Passenger ID	Group Traveler?	Service Time (in Mins)
3	44	Individual	0.46962
4	34	Individual	0.45032
5	168	Individual	0.46025
6	154	Group	0.28827
7	155	Group	0.41441
8	158	Group	0.25027
9	161	Group	0.44038
10	13	Individual	0.3391
11	112	Individual	0.4009
12	49	Individual	0.34475
13	163	Individual	0.49137
14	116	Individual	0.2713
15	72	Group	0.30914
16	75	Group	0.34429

Same group, but different service time.

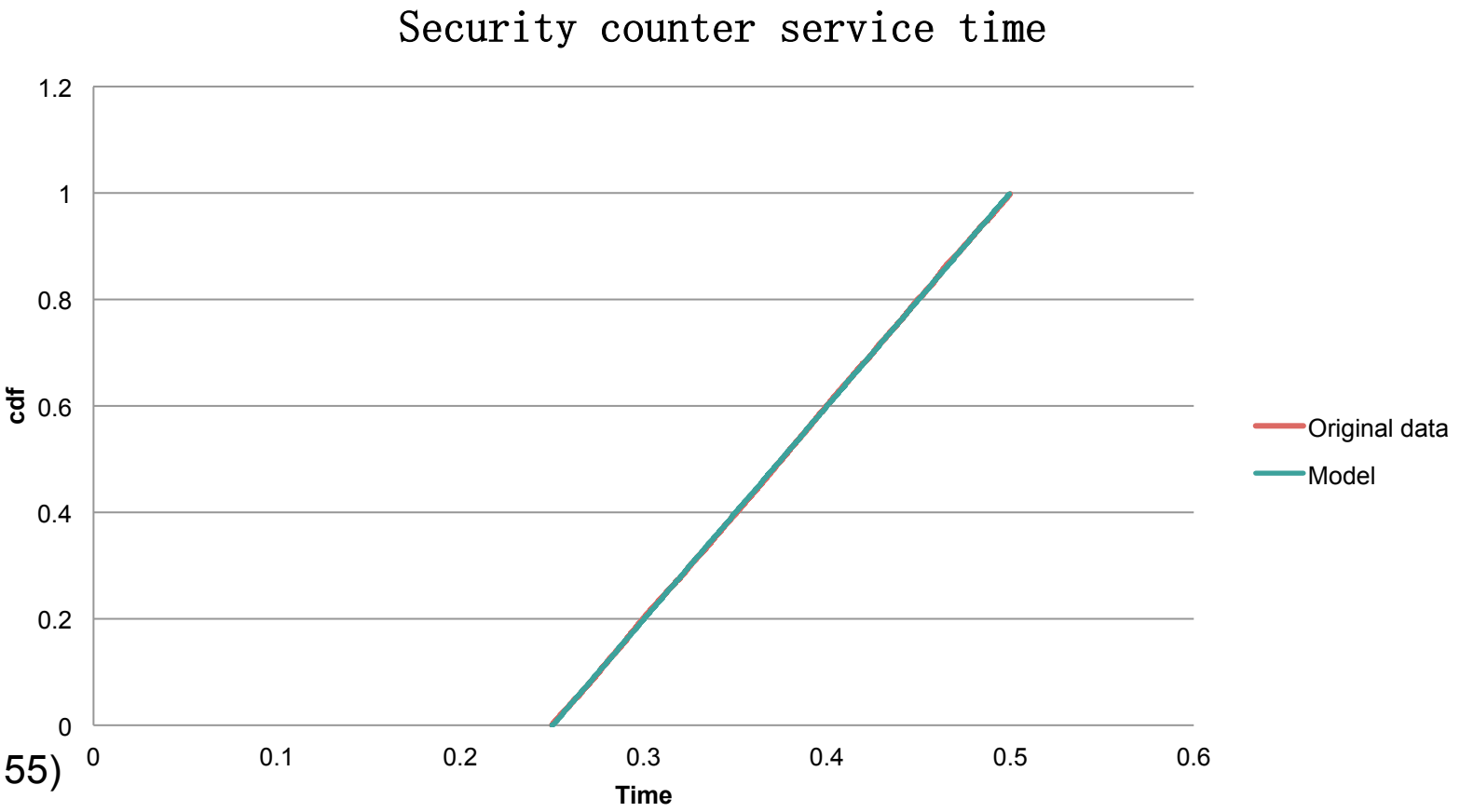
- Total number: 20215
- Min: 0.25000407
- Max: 0.499990668

Passengers pass the security counter (X-ray machine) one by one.

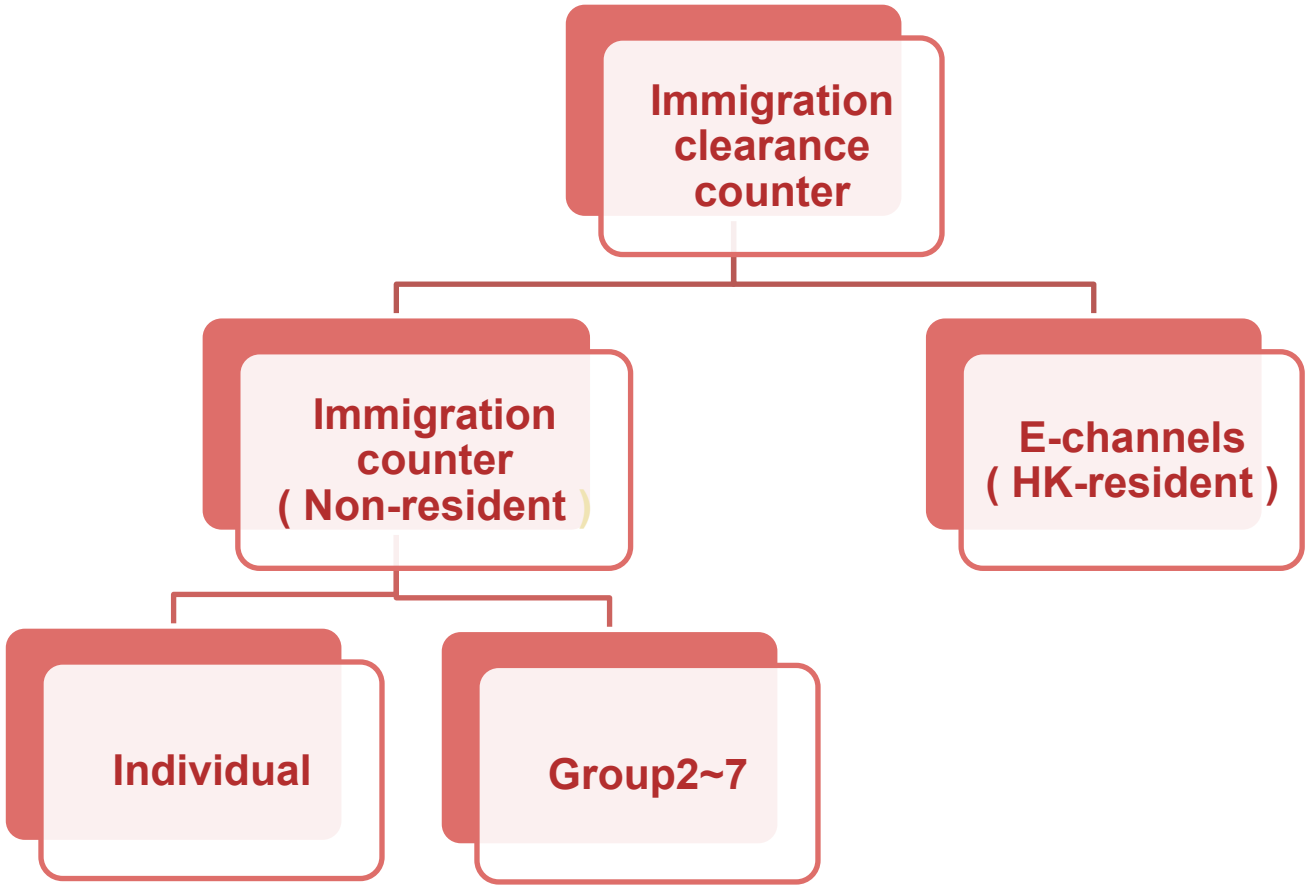
So it is intuitively reasonable to assume that security service time is independent of number of group. And every passenger here is treated fairly.

Service time - Security counter

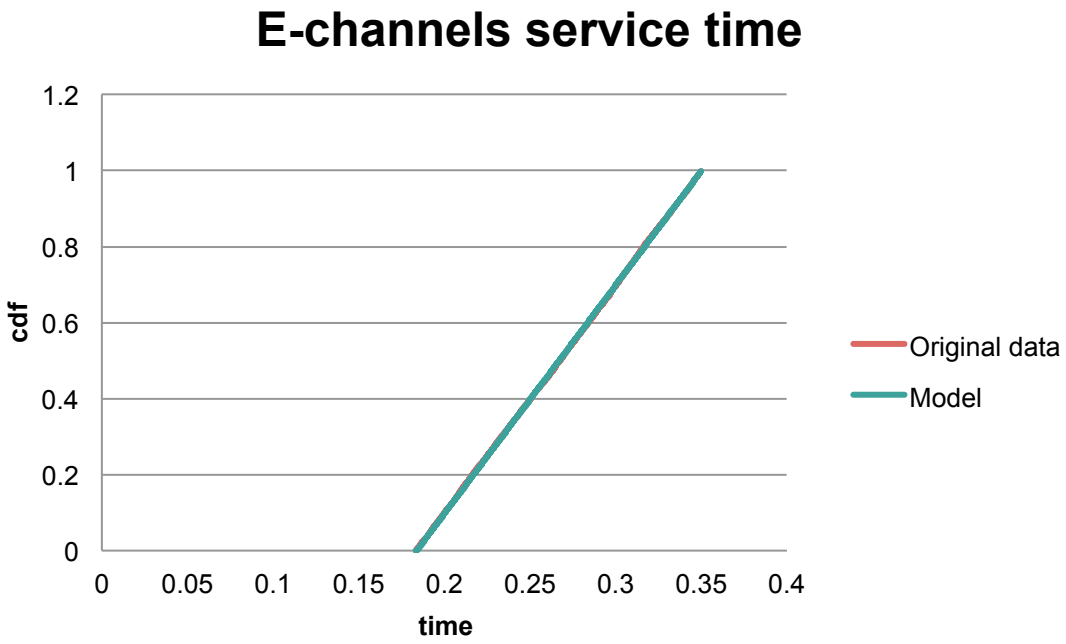
- Time ~ U [0.250468 , 0.499773]
- D0 : 0.003157
- D_n: 0.009552
- F(t)= 4.011155 *t-1.00467
- (Model: time=(rand()+1.00467)/4.011155)



Service time – Immigration counter



Service time – e-Channel Counter



- Assume only HK-residents use e-channels and HK-residents only use e-channels and pass one by one.
- So it is intuitively reasonable to assume that security service time is independent of number of group.

Service time – Immigration counter

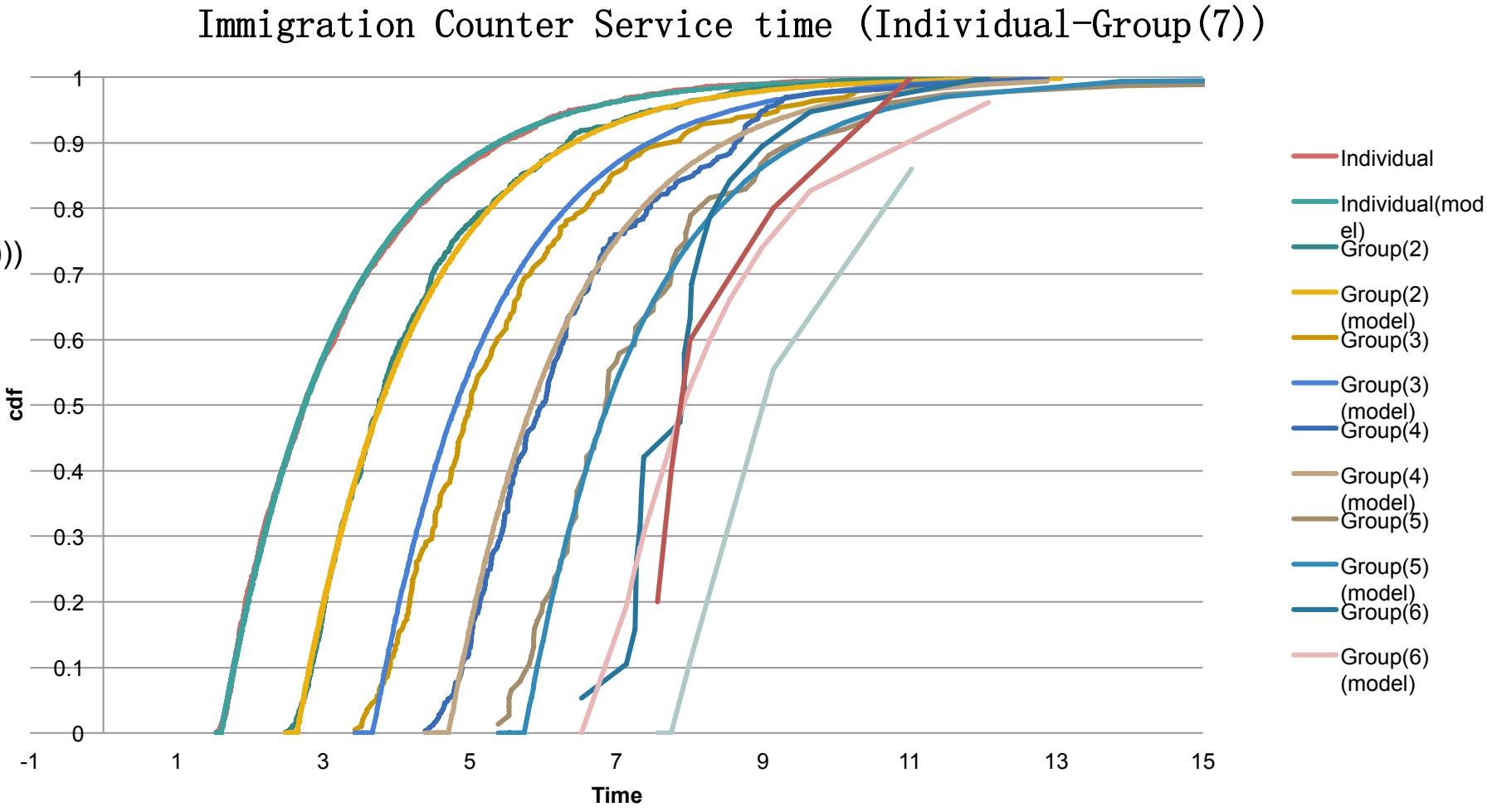
Information		Immigration Clearance Counte	
Group Traveler?	Passenger Type	Counter Type	Service Time (in Mins)
Group	Non-resident	Immigration_Counter	1.792163214
Group	Non-resident	Immigration_Counter	1.792163214
Group	Non-resident	Immigration_Counter	1.43265684
Group	Non-resident	Immigration_Counter	1.43265684
Individual	Non-resident	Immigration_Counter	0.903502285
Group	Non-resident	Immigration_Counter	1.693862741
Group	Non-resident	Immigration_Counter	1.693862741
Group	Non-resident	Immigration_Counter	1.693862741
Individual	Non-resident	Immigration_Counter	1.076388503
Group	Non-resident	Immigration_Counter	1.134586308
Group	Non-resident	Immigration_Counter	1.134586308
Individual	Non-resident	Immigration_Counter	0.968755658
Individual	Non-resident	Immigration_Counter	1.203670088
Group	Non-resident	Immigration_Counter	1.049915669
Group	Non-resident	Immigration_Counter	1.049915669
Individual	Non-resident	Immigration_Counter	1.250377264
Individual	Non-resident	Immigration_Counter	0.943601628
Individual	Non-resident	Immigration_Counter	1.618557995

Same group has the same service time. Thus, grouping and eliminating duplications are necessary.

	A	B	C	D	E	F	G
1	Individual		Group of 2		Group of 3		Group of 4
2	0.723506981		1.020255747		1.335084586		1.640195
3	0.72838919		1.024177918		1.345635772		1.643256
4	0.728827263		1.025466336		1.349600162		1.646206
5	0.730027346		1.03217478		1.352729711		1.658255
6	0.730427434		1.03224422		1.368484126		1.664238
7	0.730681734		1.032779922		1.368822897		1.667594
8	0.73210901		1.034476019		1.369223889		1.667779
9	0.733984181		1.03613211		1.371000575		1.668508
10	0.734351303		1.041011217		1.385935212		1.669308
11	0.735645488		1.041186647		1.386525671		1.672916
12	0.736595168		1.045000818		1.399270173		1.675191
13	0.737223667		1.0488985		1.404937061		1.683902
14	0.738162101		1.049915669		1.414482752		1.686485
15	0.738237171		1.052987948		1.417506742		1.686947
16	0.738641127		1.053960893		1.419021047		1.689167
17	0.738716556		1.053977462		1.421552327		1.694624
18	0.740387908		1.055068758		1.422920692		1.695382
19	0.741268893		1.055720883		1.434025762		1.697855
20	0.742503826		1.057684647		1.43916279		1.699708
21	0.742763976		1.057773717		1.441657467		1.707607
22	0.744675257		1.060968428		1.446494817		1.711264
23	0.745835034		1.064733679		1.454220307		1.716524

Service time – Immigration counter

- Truncated exponential distribution:
  $F(x)=(1-\exp(-\lambda*(x-a))/(1-\exp(-\lambda*(b-a)))$
- Parameter: λ, a, b ;
- (Why not Gamma distribution?
  To reduce number of parameters.)



Truncated exponential distribution

Immigration counter

	k	1		
(Exponential)	Individual	a	1.604238	
		b	18.41783	
		lambda	0.611184	
		max	sumsq	to optimize
	ks-test	0.015462	0.133981	0.0154629
	D_n	0.029337		
	k	2		
(Exponential)	Group(2)	a	2.639773	
		b	18.41783	
		lambda	0.611184	
		max	sumsq	to optimize
	ks-test	0.02556	0.22183	0.02556193
	D_n	0.04522		
	k	3		
(Exp dist)	Group(3)	a	3.675308	
		b	18.41783	
		lambda	0.611184	
		max	sumsq	to optimize
	ks-test	0.097007	1.007054	0.09701732
	D_n	0.097007		

(Exp dist)	Group(5)	a	5.746378	
		b	18.41783	
		lambda	0.611184	
		max	sumsq	to optimize
	ks-test	0.092105	0.130105	0.09210656
	D_n	0.155785		
	k	6		
(Exp dist)	Group(6)	a	6.781913	
		b	18.41783	
		lambda	0.611184	
		max	sumsq	to optimize
	ks-test	0.189153	0.360801	0.18915665
	D_n	0.31157		

Vba code to model.

```
Function immigration(i)
k = 0.320063039
m = 0.42397627
a = k * i + m
b = 6.690427443
lambda = 1.654961148
y = Rnd()
x = -Log(1 - y * (1 - Exp(-lambda * (b - a)))) / lambda + a
immigration = x

End Function
```

- a(min) = 0.320 *k+ 0.42397; k=# of passengers in a group

  (Makes sense, add one period of time per person.)

- b(max)=6.6904;

  (Since b has little influence of model, set it to one certain value to reduce the parameter.)

- λ= 1.654961;

Waiting Time

Calculate rather than model

- Arrival time & Service time

Assumptions:

- Passengers line up in a single queue only, and each of them will be served by the first available counter.
- At airline counter, pre-document counter and immigration counter, a **group** will queue up together and **be served together by one counter**.
- At security counter, a group of people will be served **as individual**, that is to say they can go to different counters.

Waiting Time

Monte Carlo:

- KPI based on waiting time for each type of counter
- Airline counter: for each airline company

Conclusion

	In 2016	Base case	Worst case
Resident	0.69	0.69	0.61
Non-resident	0.31	0.31	0.39
# of immigration counters	20	27	32
# of immigration counters needed to be added		7	12

THANK YOU