

103rd Purdue Road School
Purdue University

**Queuing Theory - based Modeling & Analysis of
an Airport's Customs Facility**

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Agenda

- Intro to Queuing Theory
- Statement of Problem
- Purpose of Work
- MS Excel-based Computer Simulation
- Sensitivity Analysis
- Future Work
- Q & A

Intro to Queuing Theory

- ▶ Significant amount of time spent in waiting lines by people, products, transportation equipment, etc.
- ▶ Providing quick service is an important aspect of quality customer service.
- ▶ The basis of waiting line analysis is the trade-off between the cost of improving service and the costs associated with making customers wait.



<http://www.si.wsj.net>



<http://www.floridahospital.com>

Approximate Stand By
Wait Time

10

Minutes

Disney's
FASTPASS





order

APPETIZERS **SEASONAL FAVES** **SHAKES** **DESSERTS**

DRINKS **FOOD** **GAMES** **THE FEED** **REWARDS** **PAY**

Ziosk

MITYNice – Restaurant & Bar (Chicago, IL)





<https://www.cbp.gov/border-security/ports-entry/cargo-security/c-tpat-customs-trade-partnership-against-terrorism>

What is C-TPAT?



- Voluntary government-business initiative to build cooperative relationships that strengthen and improve overall international supply chain and U.S. border security

- CBP is asking businesses to ensure the integrity of their security practices and communicate and verify the security guidelines of their business partners within the supply chain.



Benefits for Members

- Reduced number of Inspections
- Reduced Border delay Times
- Priority processing for CBP Inspections
- Assignment of C-TPAT Supply chain security specialist (SCSS)
- Eligibility to attend C-TPAT Supply chain security Training Seminars
- Reduced cargo theft and pilferage
- Reduced Insurance cost

CUSTOMS - TRADE
PARTNERSHIP AGAINST TERRORISM



*In recognition of your commitment to partnership,
and in appreciation for joining with us to secure
the international supply chain and protect our country's security,*

U.S. Customs and Border Protection

is pleased to certify your membership in the

C-TPAT
*Customs - Trade
Partnership Against Terrorism*

and to present this certificate to

Kepix Corp.

Importer

During the month of June, 2005

at Washington, D.C.

Alte Brown
Commissioner

Browser window showing the Delta website. The address bar displays <http://www.delta.com/>. The page features the Delta logo and navigation links: ENGLISH, NEED HELP?, COMMENT/COMPLAINT?, SHOP, TRAVELING WITH US, SKYMILES, and a search bar. The main navigation menu includes MY TRIPS (MANAGE AN EXISTING TRIP), BOOK A TRIP (FLIGHT, HOTEL, CAR & VACATION PACKAGES), FLIGHT STATUS (ARRIVALS & DEPARTURES), and CHECK IN (BOARDING PASS & BAGGAGE). The CHECK IN section is active, displaying a form with the following fields:

- Confirmation Number (dropdown menu)
- CONFIRMATION NUMBER (input field)
- FROM AIRPORT (input field with location pin icon)
- SEARCH (button)

Below the form is a link for [Check-In Requirements](#). The background image shows a desert landscape with mountains and a river. The Windows taskbar at the bottom shows the date and time as 4:59 PM on 3/6/2017.





- No processing lines**
- No paperwork**
- Access to expedited entry benefits in other countries**
- Available at major U.S. airports**
- Reduced Wait Times**

Apply Now!

Intro to Queuing Theory (Cont'd)

- ▶ Waiting lines form because customers arrive at a service station faster than they can be served.
- ▶ Customers however, do not arrive at a constant rate nor are they served in an equal amount of time.
- ▶ Waiting lines are continually increasing and decreasing in length and in the long run approach an average customer arrival rate and an average service time.

Intro to Queuing Theory (Cont'd)

- ▶ Customer arrival rate and service time are used to compute the operating characteristics of the system.
- ▶ Operating characteristics of waiting line systems:
 - Average number of customers in the waiting line
 - Average number of customers in the system
 - Average time customers spend in the waiting line
 - Average time customers spend in the system
 - Probability of zero customers in the system
 - Probability of exactly n customers in the system

Intro to Queuing Theory (Cont'd)

- ▶ Components of a waiting line system include arrival of customers and servers.
- ▶ Factors to consider in analysis of waiting line systems:
 - The queue discipline (FIFO, etc.)
 - The nature of the calling population (Finite or infinite)
 - Size of waiting line (Finite or infinite)
 - Number of servers
 - The arrival and service rates
 - Physical arrangement of waiting line

Intro to Queuing Theory (Cont'd)

- ▶ Common models of queuing systems:
 - Single-server waiting line system
 - Multiple-server waiting line system
 - Undefined and constant service times
 - Finite queue length
 - Finite calling population

Intro to Queuing Theory (Cont'd)

▶ Assumptions of waiting line analysis:

- Poisson arrival rate
- Exponential service rate

▶ Symbols:

λ = the arrival rate (average number of arrivals/time period)

μ = the service rate (average number served/time period)

C = Number of servers

Statement of Problem

- Management of the waiting line system of the CBP facility at the Chicago O'Hare airport is a complex process.....
 - Numerous international flights arrive throughout the day
 - Arrival rate of customers (travelers) varies constantly during the day
 - More than 250 passengers can arrive in a single flight
 - CBP officers added as needed to better serve arriving travelers
 - Arrangement of waiting lines modified (randomly – for the most part) as needed to accommodate more travelers in the waiting area
- No evidence of application of Queuing Theory in management of waiting line system.

Statement of Problem (Cont'd)



<http://www.cbp.gov>

Statement of Problem (Cont'd)

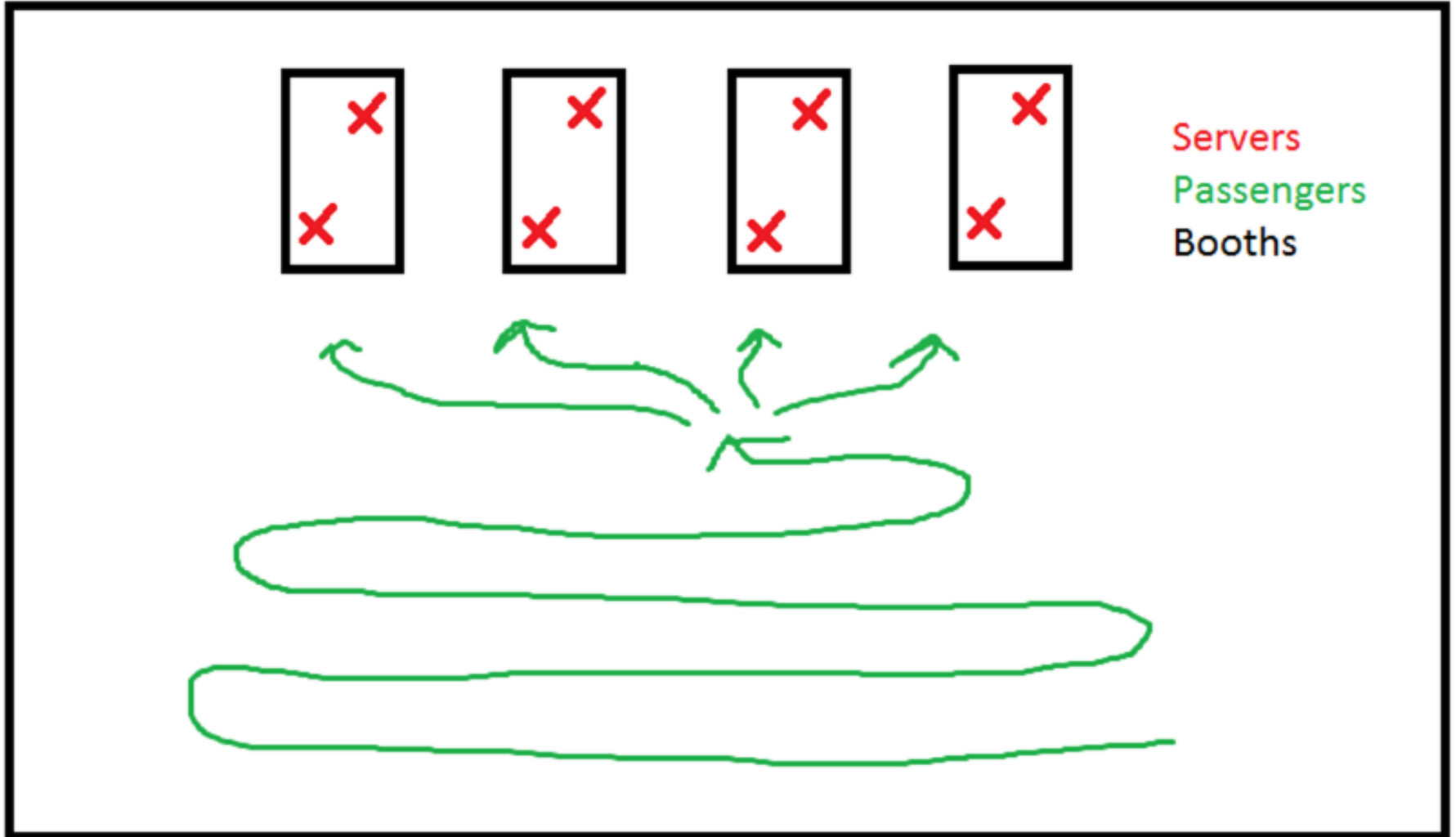


<http://www.easysentry.com>

Purpose of Work

- ▶ Modeling and analysis, using Queuing Theory, of the CBP waiting area of the Chicago O'Hare International airport in order to evaluate, in terms of waiting time, the level of service provided by CBP officers.
- ▶ Develop recommendations to configure and operate the CBP area of the Chicago O'Hare International airport in order to maximize the flow of travelers, reduce waiting time, and enforce security procedures.

Physical Arrangement of Waiting Line



MS Excel-based Computer Simulation

- MS Excel used to build and run simulation model.
- 2015 actual O'Hare international flight data (<http://awt.cbp.gov/>) , which refers to CBP's Airport Wait Times (AWT).
- Based on the AWT data, a random hour of flight arrivals is simulated.
- Peak hours were the main focus of the study.
- A probability distribution is used to determine the number of flights arriving during that hour.
- A probability distribution and the AWT data are used to determine the number of passengers on each of the arriving flights, which determines an arrival rate, λ .



[Definitions](#)

Airport Wait Time Results for 01/01/2017 to 02/28/2017 - Airport: Chicago O'Hare International Airport

[Export to Excel](#)

Airport	Terminal	Date	Hour	Wait Times		Number of Passengers Time Interval							Excluded	Total	Flights	Booths
				Average	Max	0-15	16-30	31-45	46-60	61-90	91-120	121Plus				
ORD	Terminal 5	1/1/2017	0300 - 0400	0	0	0	0	0	0	0	0	0	7	7	1	0
ORD	Terminal 5	1/1/2017	0400 - 0500	21	51	121	160	60	8	0	0	0	13	362	3	10
ORD	Terminal 5	1/1/2017	0600 - 0700	20	49	154	81	64	19	0	0	0	10	328	1	10
ORD	Terminal 5	1/1/2017	0700 - 0800	11	26	272	88	0	0	0	0	0	10	370	2	12
ORD	Terminal 5	1/1/2017	0800 - 0900	11	37	298	121	16	0	0	0	0	11	446	2	12
ORD	Terminal 5	1/1/2017	0900 - 1000	20	53	178	69	79	37	0	0	0	12	375	2	12
ORD	Terminal 5	1/1/2017	1000 - 1100	9	20	328	40	0	0	0	0	0	15	383	3	10
ORD	Terminal 5	1/1/2017	1100 - 1200	34	89	233	182	188	152	119	0	0	32	906	5	19
ORD	Terminal 5	1/1/2017	1200 - 1300	28	92	329	279	136	139	85	1	0	32	1001	5	24
ORD	Terminal 5	1/1/2017	1300 - 1400	14	55	787	375	41	16	0	0	0	47	1266	6	25
ORD	Terminal 5	1/1/2017	1400 - 1500	15	70	1367	486	176	65	12	0	0	88	2194	8	30
ORD	Terminal 5	1/1/2017	1500 - 1600	19	69	897	328	266	108	21	0	0	72	1692	8	27
ORD	Terminal 5	1/1/2017	1600 - 1700	17	47	479	218	173	12	0	0	0	40	922	4	24
ORD	Terminal 5	1/1/2017	1700 - 1800	15	42	755	285	191	0	0	0	0	56	1287	9	15
ORD	Terminal 5	1/1/2017	1800 - 1900	13	51	1399	572	156	25	0	0	0	79	2231	11	17

MS Excel-based Computer Simulation (Cont'd)

- Number of servers (C), is determined according to available booths, reported in the AWT data.
- A standard service rate (μ) is assumed.
- Based on arrival and service rates, the MS Excel-based simulation process checks if travelers waiting in line will be served within an hour.
- Mean effective rate is $C * \mu$.

MS Excel-based Computer Simulation (Cont'd)

		Average				
PEAK HOURS	Hours	Days	Wait Time (mins)	Passenger	Flights	Booth
	1400 - 1500	365	20.14	1670.8	7.89	28.9
	1300 - 1400	365	15.14	1588.8	7.92	29.3
	1500 - 1600	365	19.23	1498.4	7.6	28.43
	1800 - 1900	365	11.9	1113.5	6.8	23.11
	1700 - 1800	365	11.87	944.6	6.04	24.2
	1600 - 1700	364	15.96	1159.9	6.08	28.17
	1200 - 1300	363	10.29	906.2	4.72	26.2
	1900 - 2000	361	11.15	806.7	4.22	21.52

BASED ON US CUSTOMS AND BORDER PROTECTION AWT DATA:

Average passengers arriving in Peak Hours

- 1211 To be used as a point of reference only - the model calculates arrival rate in passengers / hour

Average booths open during Peak Hours. Each booth has 2 servers.

- 26 The model assumes that 26 booths are available, with 2 servers at each booth.

Average Flights per hour during peak hours

- 6.41 This is used as a target for the probability of flights that land in a randomly simulated hour

Average Passengers per flight

- 189 This is used with probabilities to determine how many passengers are arriving / arrival rate

MS Excel-based Computer Simulation (Cont'd)

Demo



Microsoft Excel
Microsoft Office 2010

Sensitivity Analysis

Variables that can be modified are the number of servers and the service rate

Current	Future
λ : <u>733</u>	λ : <u>733</u>
c : <u>52</u>	c : <u>70</u>
μ : <u>20</u>	μ : <u>20</u>
Service rate : $\mu * c = 1040$	Service rate : $\mu * c = 1400$

The processing time will still be 3 mins / passengers in the future state , increasing the number of servers will improve the overall service rate by 360 passengers / hr., reduce time spend in waiting line, and size of waiting line.

Future Work

- ▶ Fully incorporate Queuing Theory – based formulas into the MS Excel – based computer simulation worksheet.
- ▶ Run simulation & compare results with CBP's AWT data.
- ▶ Expand model as needed.
- ▶ Publish results.

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Questions ?

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Thanks !

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