103rd Purdue Road School
Purdue University

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

Marco A. Lara Gracia, Ph.D.
University of Southern Indiana

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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
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.
MITYNice – Restaurant & Bar (Chicago, IL)

http://www.mitynicechicago.com/
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
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

Customs - Trade Partnership Against Terrorism

and to present this certificate to

Kepix Corp.
Importer

During the month of       June        2005
at Washington, D.C.

Here, Comr.  
Commissioner
GLOBAL ENTRY®
TRUSTED TRAVELER NETWORK

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

Apply Now!

http://www.cbp.gov
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.
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
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
Assumptions of waiting line analysis:
- Poison arrival rate
- Exponential service rate

Symbols:
- $\lambda = \text{the arrival rate (average number of arrivals/time period)}$
- $\mu = \text{the service rate (average number served/time period)}$
- $C = \text{Number of servers}$
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.

CBP = US Customs and Border Protection
Statement of Problem (Cont’d)

http://www.cbp.gov
Statement of Problem (Cont’d)
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, $\lambda$. 
Airport Wait Time Results for 01/01/2017 to 02/28/2017 - Airport: Chicago O'Hare International Airport

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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*μ.
### PEAK HOURS

<table>
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<tr>
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<th>Days</th>
<th>Wait Time (mins)</th>
<th>Passenger</th>
<th>Flights</th>
<th>Booth</th>
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**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
Macro-Enabled Works!
Sensitivity Analysis

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

<table>
<thead>
<tr>
<th>Current</th>
<th>Future</th>
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<tbody>
<tr>
<td>( \lambda : 733 )</td>
<td>( \lambda : 733 )</td>
</tr>
<tr>
<td>( c : 52 )</td>
<td>( c : 70 )</td>
</tr>
<tr>
<td>( \mu : 20 )</td>
<td>( \mu : 20 )</td>
</tr>
<tr>
<td>Service rate : ( \mu \times c = 1040 )</td>
<td>Service rate : ( \mu \times c = 1400 )</td>
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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.
Questions?
Queuing Theory-based Modeling & Analysis of an Airport's Customs Facility

Thanks!
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mlaragraci@usi.edu