Introduction to Queueing Theory

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OR 647

Lecture 1

Psychology of Waiting

- OR 647 deals mostly with *objective* measures of waiting
- What about the *experience* of waiting?
  - Less work done in this area

Maister, D. 1984. The psychology of waiting lines. Harvard Business Review Case Study. 9-684-064

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Propositions of Waiting

1. Unoccupied time feels longer than occupied time

2. Pre-process wait feels longer than in-process wait

Maister, D. 1984. The psychology of waiting lines. Harvard Business Review Case Study. 9-684-064

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Propositions of Waiting

3. Anxiety makes waiting seem longer

4. Uncertain waits are longer than known, finite waits

Maister, D. 1984. The psychology of waiting lines. Harvard Business Review Case Study. 9-684-064

Propositions of Waiting

5. Unexplained waits are longer than explained waits

6. Unfair waits are longer than equitable waits

Maister, D. 1984. The psychology of waiting lines. Harvard Business Review Case Study. 9-684-064

Propositions of Waiting

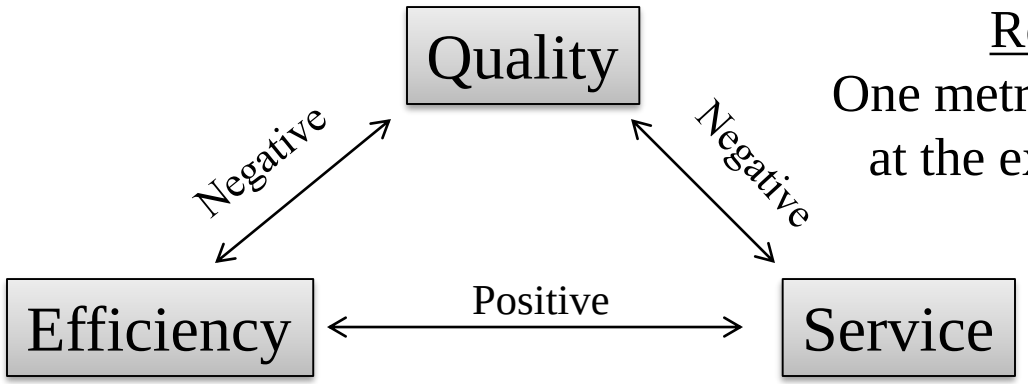
7. Longer waits are tolerable for more valuable service

8. Solo waits feel longer than group waits

Maister, D. 1984. The psychology of waiting lines. Harvard Business Review Case Study. 9-684-064

Queueing Metrics

- Perspective: Customer or management?



Relationships

One metric can be improved at the expense of another

Service Metrics

- Associated with delays experienced by customers
- Wait in queue
  - Average wait
  - Probability of waiting more than a threshold
  - Probability of zero wait (call centers)
  - Standard deviation of wait
- Length of queue
  - Decision to join queue may depend on line length
  - Physical layout may limit line length

Service Metrics

- Fraction of customers who leave
  - Blocked
  - Abandoned
- Total time in system
  - Total time versus waiting time

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Efficiency Metrics

- Metrics associated with server performance
- Average service time
- Server utilization (100% - percent idle time)
  - Possible to have queues when utilization is low
  - Possible to have no queues when utilization near 100%
  - 100% utilization is usually not the best decision
    - Solution: Have employees work on non-essential tasks during idle time
- # servers
- Schedule efficiency
- Schedule adherence

Quality Metrics

- Associated with quality of customer interaction
- Customer satisfaction
- Adherence to procedures
- First-call resolution rate
- Transfer rate

Throughput

- Throughput (customers served per time)
  - Throughput = arrival rate assuming no customer losses

Metrics and Random Variables

- Moment-based measures
  - Average
  - Standard deviation
  - Variance
  - Coefficient of variation
- Distribution-based measures
  - Probability $X > x$
  - Probability $X \leq x$
  - Median
  - x% quantile

Types of Queues

- Multiple servers, each with single queue
  - McDonald's, grocery store
- Multiple servers / single queue
  - Airports, banks
- Multiple-stage system
  - Potbelly's
- Combination (airport security)
- Network
  - Disneyland

Some Types of Queues

- Physical waiting area
  - "Typical" line
  - "Take a number"
- Virtual line
  - Call center
  - Packets / routers
  - Appointments, reservations
- Traffic congestion
  - Hard to define boundary of "queue" and "service"
  - Driving
  - Air traffic

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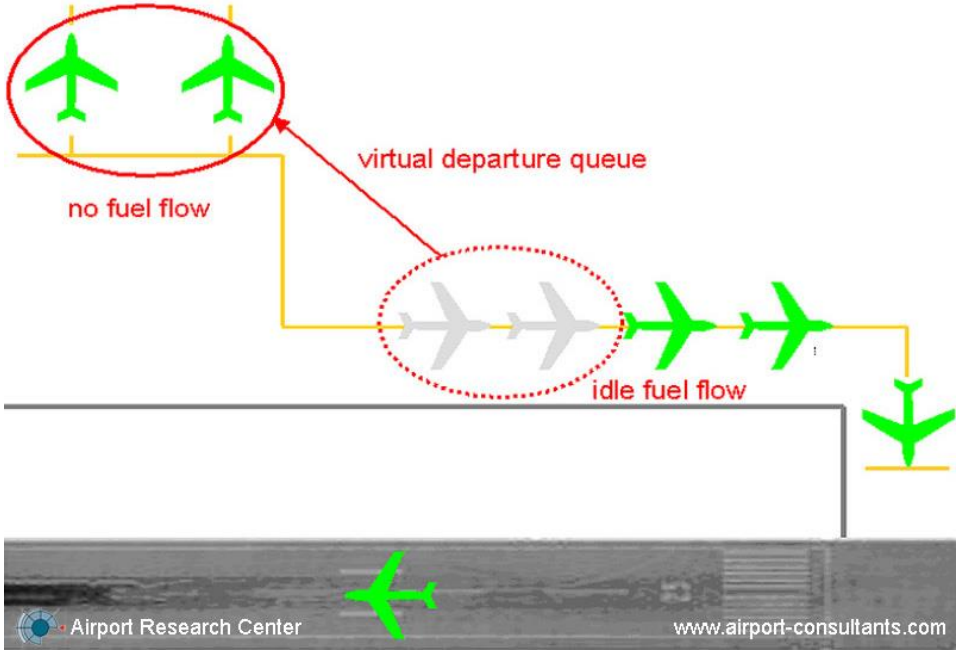
Virtual Queue Example

- DMAN, Departure Manager
  - Maintain a virtual departure queue
  - Reduces fuel burn and emissions (aircraft not waiting in a physical queue)



Source: http://www.airport-consultants.com/consulting-services/aeronautical-studies/33-projects/63-dman-validation-study-departure-manager

Queueing Disciplines

- Queueing discipline: rule for choosing which customer is served next
- First-come-first-served
- Last-come-first-served
- Priority system
  - Interruptions possible
- Shortest processing time first
- Class-based system
- Round-robin
  - Traffic light (weighted round robin)
- Weighted fair queueing

Management Decisions

- Number of servers
  - Staffing as function of time
- Service rate
- Queueing discipline
- Influence arrival patterns
  - Peak pricing
  - Appointments
- Waiting experience (psychology of waiting)