

# Modelling & Simulation

## Queuing Systems

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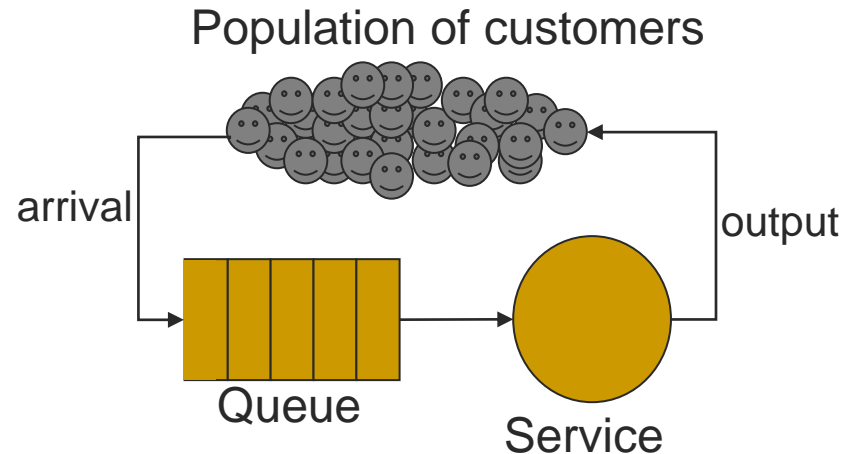
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- Queuing System
- Kendall Classification
- Performance Measures



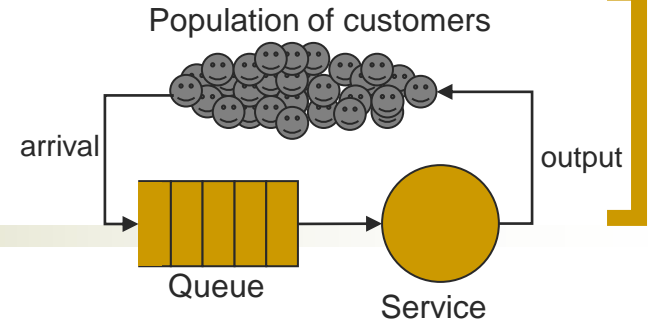
# Queuing System I

- *Systém hromadnej obsluhy*
- Single queue queuing system:



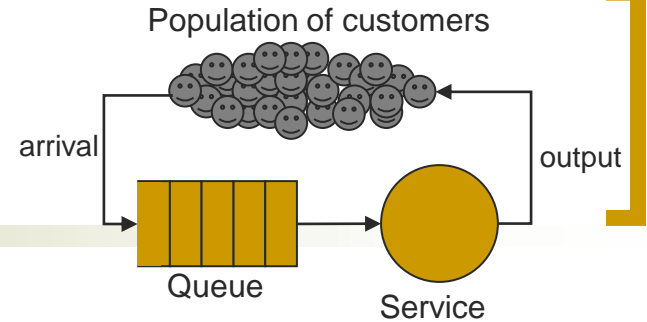
- Population of customers
  - limited (closed systems)
  - unlimited (open systems)
    - theoretical model of systems with a large number of possible customers
  - customers = people, processes, machines...

# [ Queuing System II



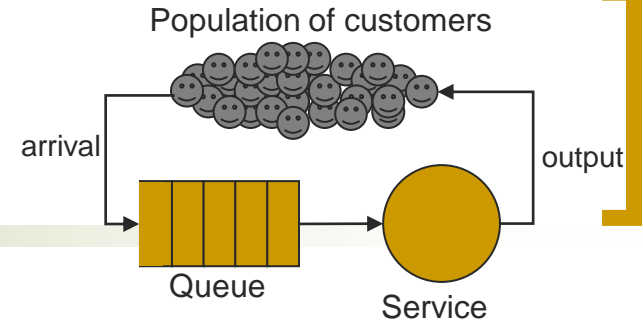
- *Arrival (vstupný prúd požiadaviek)*
  - defines the way customers enter the system
  - mostly random
    - random intervals between two adjacent arrivals.
  - *Arrival pattern (charakteristika vst. prúdu)*
    - random distribution of intervals

# Queuing System III



- Queue (*front*)
  - customers waiting for service
  - Maximum queue size
    - the maximum number of customers that may wait in the queue
    - + customers being served = system capacity
    - some theoretical models assume an unlimited length
  - Queuing Discipline
    - the way the queue is organised
    - FIFO, LIFO, SIRO (Serve In Random Order), Priority Queue, ...

# Queuing System IV



- Service (*uzol obsluhy*)
  - an activity customers are waiting for
  - has some duration
    - typically random
  - Service pattern (*charakteristika uzla obsluhy*)
    - random distribution of service duration
    - Number of servers
      - Single Channel Systems - one server
      - Multi Channel Systems - more servers
- Output (*výstupný prúd*)
  - the way customers leave the system
  - mostly ignored by theoretical models

# Kendall Classification I

- several modifications
- ***A/B/s/q/c/p***
  - ***A*** = arrival pattern
  - ***B*** = service pattern
  - ***s*** = number of servers
  - ***q*** = queuing discipline
  - ***c*** = system capacity
  - ***p*** = population size = number of possible customers



# Kendall Classification II

- ***A/B/s/q/c/p***
  - **A** = arrival pattern
  - **B** = service pattern
- **Common values for A & B**
  - M - Poisson arrival distribution (exponential interarrival distribution) or an exponential service time distribution
  - $E_m$  - Erlang distribution
  - D - deterministic or constant value
  - G - general distribution with a known mean and variance
- **M/M/1**
  - Poisson arrival distribution, exponential service time distribution, single channel, unlimited FIFO or unspecified queue, unlimited customer population



# [ Performance Measures I ]

- Performance Measures
  - average waiting time
  - expected number of customers
    - waiting
    - receiving service
  - probability of
    - empty system
    - full system
    - having an available server
    - having to wait a certain time to be served



# [ Performance Measures II ]

- How to obtain performance measures?
  - analytically
    - using Queuing theory
    - only for limited number of system types
      - M/M/1
  - by simulation