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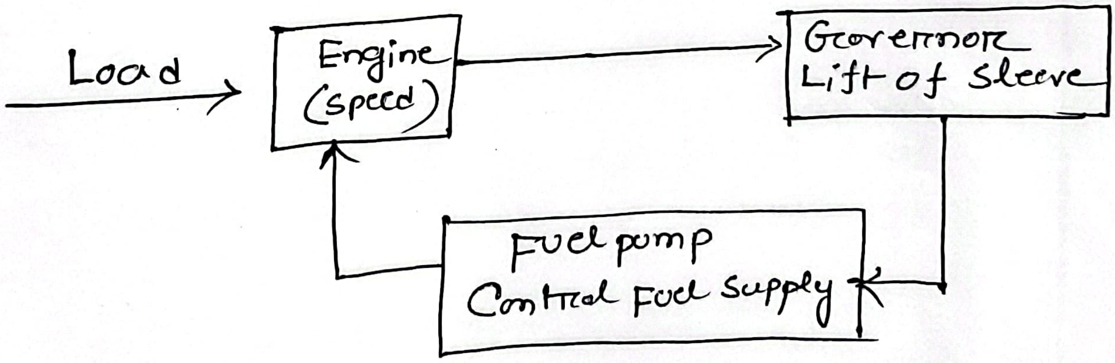
Simulation: Simulation is the imitation of the reality.

Simulation is the representation of a real life system by another system, which depicts the important characteristics of the real system and allows experiment on it.

System: A system is a collection of components where individual components are connected each other by interrelationships such that the system as a whole perform some specific function to solve the problem.



Activities which occur within the system are called endogenous activities.

Activities which occur in environment are called exogeneous activities.

Continuous	Discrete
1) State changes continuously with time.	1) State changes suddenly at discrete points with time
2) Ex: The pure pursuit problem. Since target and pursuer locations changes continuously	2) Ex: Inventory system Queuing system demand of items of the stock occur at discrete point or customers arrive and leave the system at discrete point.

In a factory system though the start and finish of a machine are discrete points but the machine process is continuous.

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Real time Simulation → is

A ~~system~~ system that mimics real world system in real-time

Example

1) Aircraft cockpit simulator for the training pilots
2) Simulated zero gravity chambers
3) Windy weather app.

3b)

Simulation model → Simplified representation of real world system.

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Steps in Simulation study →

PMD MVD RDI

- P → problem formulation
- M → Model construction
- D → Data collection
- M → model programming
- V → validation
- D → Design of experiment
- R → Run and analysis
- D → Documentation
- I → Integration

Problem formulation
Model construction
Data collection
Model programming
Validation
Design of experiment
Run and analysis
Documentation
Integration

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Phase of a Simulation Study → PMRI

1) problem formulation
2) Model Building
3) Running the model
4) Implementation

Advantges →

1) রিয়েল সিস্টেম না থাকার পরেও, রিয়েল সিস্টেম সম্পর্কে জানা যায়

এক্সপেরিমেন্ট করা সত্যিকারভাবেই সম্ভব না।

2) কিছু রিয়েল সিস্টেম নিয়ে আচরণ কেমন হবে তা করবে।

যেমন: চাঁদের মাটিতে মানুষের দরকার হয় না বললেই চলে।

3) সিমুলেশন এর জন্য কোন ম্যাথমেটিক্স বুঝতে পারে।

তাই কোন নন টেকনিক্যাল মানুষ সহজেই

4) ফ্লেক্সিবল হওয়ার কারণে যে কোন সিদ্ধান্তের জন্য পরিবর্তন করে নেওয়া যায়।

5) ট্রেনিং দেওয়ার জন্য সিমুলেশন বেশ উপকারী।

যেমন: Aircraft Cockpit
Military Squad

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Disadvantages →

1) খুব অসাধারণ সমাধান দেয় না।
2) প্রোগ্রামের দক্ষতার উপরই নির্ভরশীল হয়।
3) বড় অ্যাপ্লিকেশন যেগুলো অনেক প্যারামিটার আছে এমন হয়— যেগুলো নিখুঁত সমাধান হয় না।
4) সিমুলেশন সহজ হলেও অনেক সময় ব্যয় হতে পারে।
5) অনেক সময় সিমুলেশন শেষ হতে সময় লাগে। কিছু ক্ষেত্রে কিছু প্যারামিটারের মধ্যে বিশ্লেষণের সিমুলেশন সঠিক উত্তর দেয় না।

Application →

1) Manufacturing,
2) Business
3) Military
4) Health care application
5) Communication Application
6) Computer application
7) Economic Application
8) Transportation Application
9) Biological Application

Computer Science

- Network design
- Network reliability evaluation
- Sizing system buffer
- Designing hardware
- Software simulation, test under different condition
- Game development
- Robotics
- Algorithm analysis.

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Analytical Solution	Simulation
1) Deriving exact mathematical formula	2) Numerically approximate the Solution
2) ~~Need~~ used Algebric manipulation method	2) Computer based modelling method
3) Result are closed form equation	3) Result are Numerical values or graph
4) Give exact accuracy	4) Depends on simulation parameters and steps.
5) Suitable for simple system	5) Suitable for complex System
6) Example: Find area of a circle	6) Traffic flow Analysis through a city

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Disadvantages of Analogue Simula

1) Accuracy
2) Security
3) Scalability
4) Time Consuming
5) Flexibility
6) Cost
7) Data Collection

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Effective Random number generator → 7

1) Independent
2) Unpredictable
3) Efficient
4) Statistical Sound
5) portable
6) Fast and cost effective
7) Sufficiently Long cycle

7 GT & RSF

System Study ways →

1 Experiment with actual system

2 Experiment with a model of the system

i) physical model

ii) mathmatical model

A. Analytical Solution

B. Simulation

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Monte Carlo method

methodol tcian mym

(It is a technique of experimental sampling with random numbers or the method of trials which can be used to solve many problems, which are otherwise difficult or impossible to solve

Normally Distributed Random numbers →

A set of random values that follow a normal (Gaussian) distribution meaning they have a bell-shaped curve

properties:

* Symmetry
* Bell shaped curve
* mean = median = mode
* Unbounded

Application →

* Statistical analysis
* machine learning
* Financial modeling
* Quality Control

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Define Auto correlation →

The uniformity test of random numbers is only a necessary test for randomness, not a sufficient one. A sequence of numbers may be perfectly uniform and still not random. For example the

.1, .2, .3, .4, .5, .6, .7, .8, .9, .1, .2, .3 ... would give a perfectly uniform distribution with the Chi-square value as zero. But the sequence can by no means be regarded as random.

The numbers are not independent as the occurance of one number say .3 decides the next, which is to be .4 etc. This defect is called serial auto correlation of adjacent pairs of numbers.

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Random Numbers →

A number that is drawn from a uniformly distributed random variable between some specified intervals and they have equal probability of occurrence

pseudo Random Numbers → A random numbers that is generated by using some arithmatic operations.

Disadvantages:

* may not be uniformly distributed
* May not be continuous.
* mean may be too high or too low.
* variance may be too high or too low.
* They are may be cyclick pattern.

Method:

* Congruence or Residue

3 type → additive ⇒ $r_{i+1} = (r_i + b)$ modulo m

multiplicative ⇒ $r_{i+1} = a r_i$ modulo m

mix ⇒ $r_{i+1} = (a r_i + b)$ modulo m.

* Arithmatic congruential ⇒ $r_{i+1} = (r_{i-1} + r_i)$ mod m

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Disadvantages of Congruence method →

1) Not possible to generate a non repeating sequence

2) Numbers obtained are not truly random. Because the number can be predicted. Rather the number is computed from r_i and whole string is reproduceable.

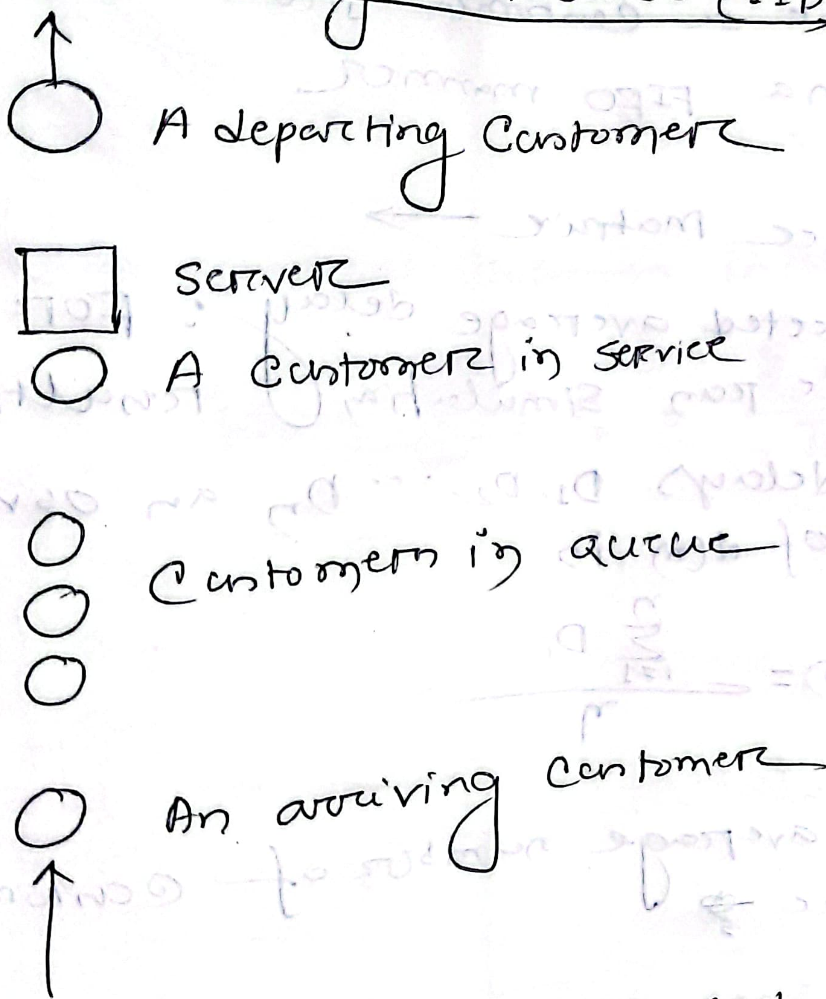
why Testing ~~and~~ uniformity and Independence are necessary →

1) Ensure values are evenly distributed
2) prevent biases that could affect security
3) value is not dependent on previous value
4) prevents patterns that could lead to predictability

ensure evenly distributed
prevent biases
prevent patterns

problem statement →

Consider a single server queueing system for which the interarrival times A_1, A_2 --- are independent and identically distributed (IID) random variables.



IID
independent and identically distributed

A customer who arrives and finds the server idle enters service immediately, and the service times $S_1, S_2, \ldots$ of the successive customers are IID random variables that are independent of the interarrival times.

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A customer who arrives and find the server busy joins the end of a single queue.

Upon completing service for a customer the server chose a customer from the queue (if any) in a FIFO manner.

performance matrix →

1) Expected average delay: For a single run simulation resulting in customer delays $D_1, D_2, \cdots D_n$ an obvious estimator of $d(n)$ is

$$\hat{d}(n) = \frac{\sum_{i=1}^{n} D_i}{n}$$

2) Expected average number of customer in the queue →

P_i → This is the portion of time during the simulation when there were exactly i customers in the queue

Ex: If simulation time 100 min, and for 20 min there were 2 people in the queue

then $P_2 = \frac{20}{100} = 0.2$

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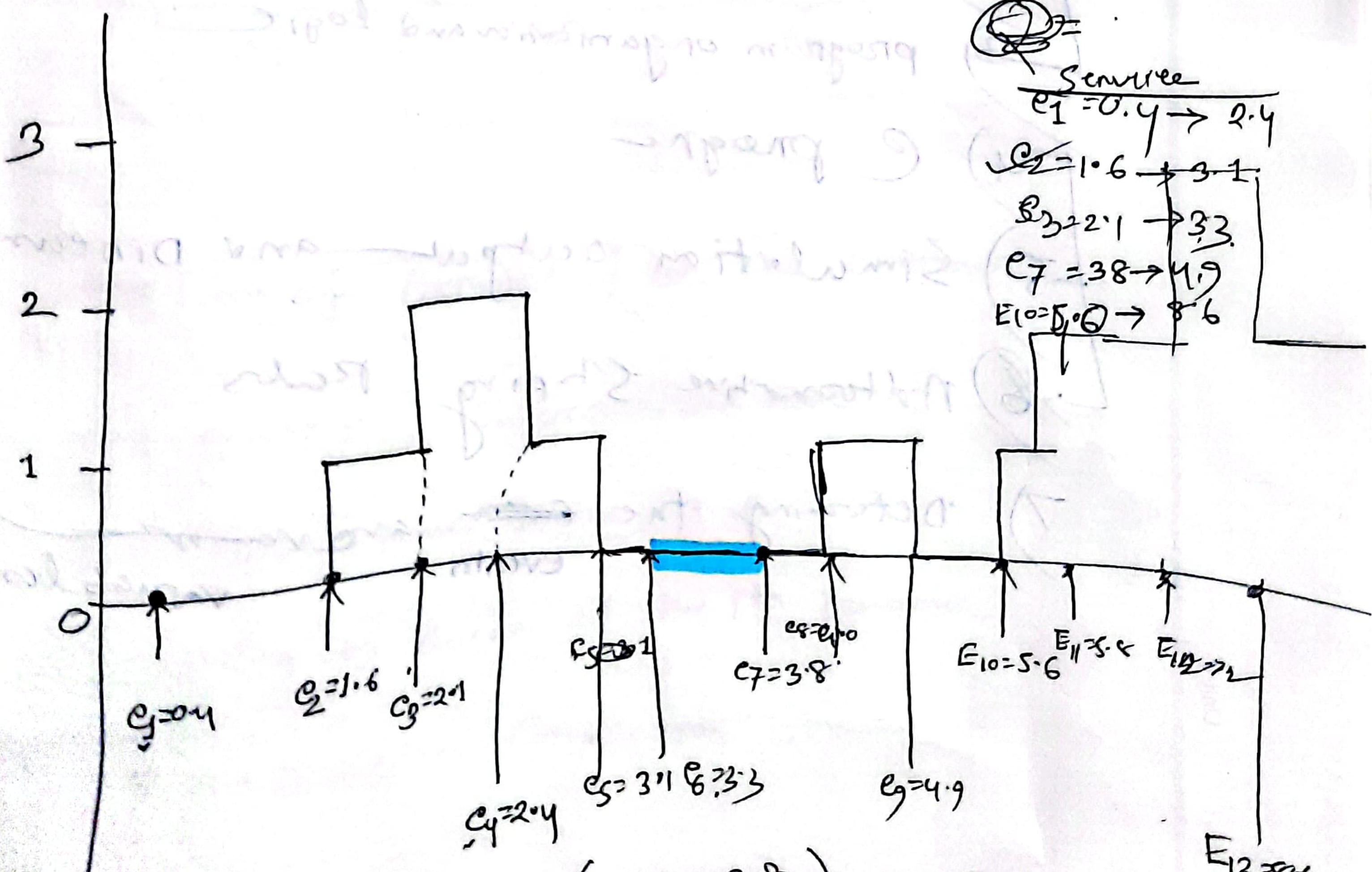
T_i : This is the total time the Queue had exactly i customers (20)

$T(n)$: Total simulation time (100min)

$$P_i = \frac{T_i}{T(n)}$$

Average number of customers in the queue

$$\hat{q}(n) = \sum_{i=0}^{\infty} i \cdot P_i = \frac{\sum_{i=0}^{\infty} i T_i}{T(n)}$$



$$\hat{U}(n) = \frac{(3.3 - 0.4) + (8.6 - 3.8)}{8.6} = \frac{7.7}{8.6} = 0.90$$

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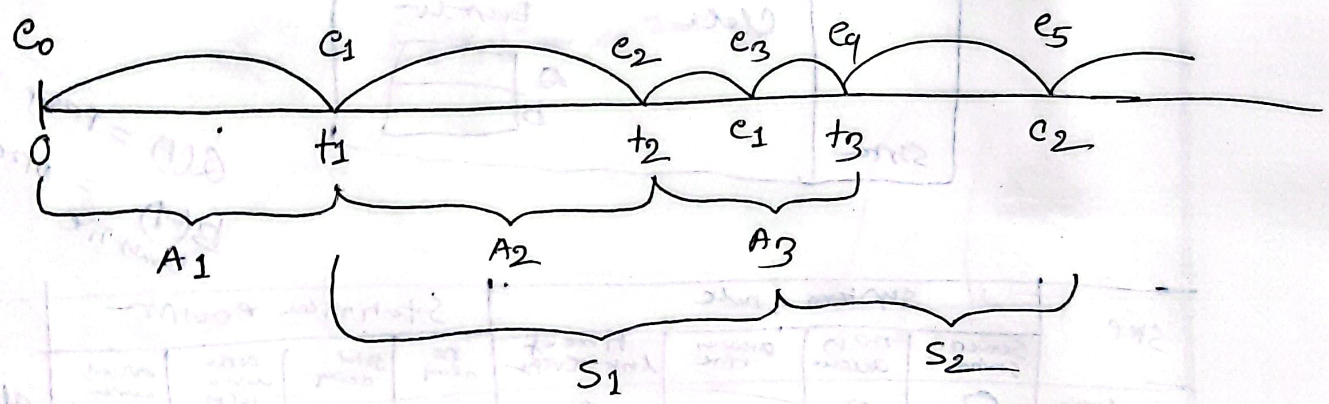
This indicating that the server was busy about 90 percent of time during this simulation

Steps of simulation for a single Server queueing system → 7

1) problem statement
2) Intuitive explanation
3) program organization and logic
4) C program
5) Simulation output and Discussion
6) Alternative stopping rules
7) Determining the ~~event~~ events and ~~variables~~ variables

Explain the next event time advance approach illustrated for the single server queueing system

Time at which customer departs after getting service = arrival time + service time + delay time



t_i = Time of Arrival of the ith customer

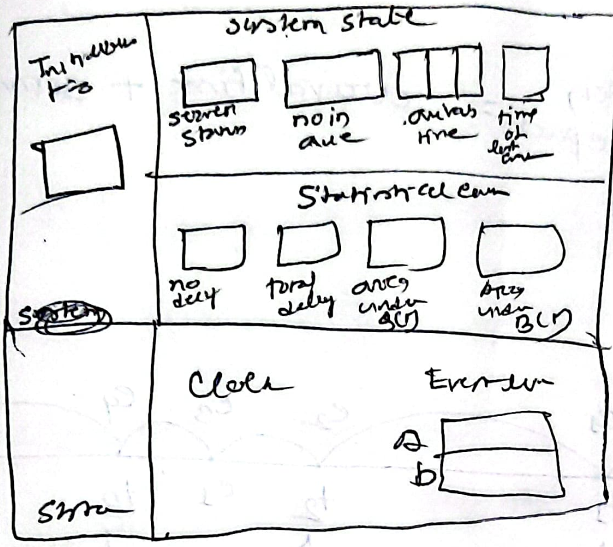
$A_i = t_i - t_{i-1}$ Interarrival time

S_i = Service time of the ith customer

D_i = Delay in Queue of the ith customer

$C_i = t_i + D_i + S_i$ = Completion time

Intuitive Explanation



Q(t) = prev t no in queue

B(t) = prev t server stat
Busy time

Step	System state: Server status	System state: no in queue	System state: arrival time	System state: time of last event	Statistical counts: no delay	Statistical counts: total delay	Statistical counts: area under Q(t)	Statistical counts: area under B(t)	Clock	Event list: A	Event list: D
Initialization	0	0		0	0	0	0	0	0	0.4	∞
Arrival time 0.4	1	0		0.4	1	0	prev t no in queue (0)	0	0.4	1.6	2.4
Arrival 1.6	1	1	1.6	1.6	1	0	0 0+0(1.6-0.4)	1.2 0+1 (1.6-0.4)	1.6	2.1	2.4
Arrival 2.1	1	2	1.6 2.1	2.1	1	0	0.5	1.7	2.1	3.8	2.4
Departure 2.4	1	1	2.1	2.4	2	1.8	0.5+2 0.3 2.1		2.4	3.8	3.1

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Variance:

The variance is a measure of the dispersion of a random variable about its mean, as seen below figure the larger the variance, the more likely the random variable is to taken on values far from its mean.

$$\sigma_i^2 = E(x_i)^2 - \mu_i^2$$

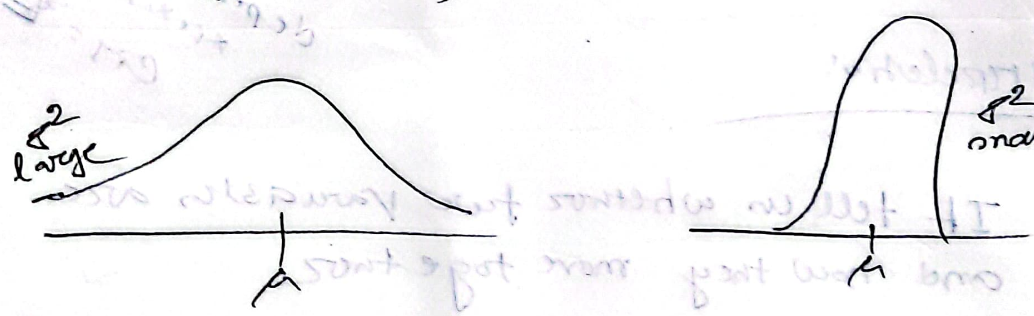

FIG: Desity functions for continuous random variables with large and small variance.

Covariance:

The Covariance between the random variables X_i and X_j which is measure of their (linear) dependencies, will be denoted by $C_{ij} = E(X_i X_j) - \mu_i \mu_j$

measure of the dependence of the 2 variables $X_i X_j$:
$C_{ij} = E(X_i X_j) - \mu_i \mu_j$

Correlation:

It tell us whether two variables are related and how they move together

Why stochastic process

A stochastic process is used to simulate situations where outcomes are $\boxed{\text{uncertain}}$ or random. It helps predict possible results when we can't know for sure what will happen, but we can estimate based on probabilities

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Example

Imagine you are trying to guess how many customers visit a shop each day.
Some days there are 20, other days 50, and it changes randomly. A stochastic process helps simulate these changes, giving you a range of possible outcomes instead of just one fixed number.

M/M/1 model:

The MM1 model is a queueing process in which customers arrive at one server and wait in a queue (if necessary) until the server is available. Customers are serviced in the order in which they arrive. The server services at most one customer at a time. There is no limit to the number of customers who can wait in the queue.

M	M	1
↓	↓	↓
Markovian arrival process	Markovian Service process	1 server

In the MM1 queue the delays D_1, D_2 --- are positively correlated because the service times of earlier customers affect the wait times of later customers. When one customer experiences a long delay, the next customer is likely to experience a longer delay as well