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CHAPTER ONE

DEFINITIONS AND SOME CONCEPTS FOR THE QUEQUEING SYSTEMS

١,١. INTRODUCTION

In general we do not like to wait. But reduction of the waiting time usually requires extra investments. To decide whether or not to invert, it is important to know the effect of the investment on the waiting time. Queues help facilities or business provide service in or dearly fashion. Forming a queue being a social phenomenon, it is beneficial to the society if it can be managed so that both the unit that waits and the one that serves get the most benefit. For instance, there was a time when in airline terminals passengers formed separate queues in front of check-in counters. But now we see invariably only one line feeding into several counters. This is being cause of the realization that a single line policy serves better for the passengers as well as the airline management. Such a conclusion has come from analyzing the mode by which a queue is formed and the service is provided.

The analysis is based on building a mathematical model representing the process of arrival of customers who join the queue, the rules by which they are allowed into service, and the time it takes to serve the customers. The unit providing service is known as the server. Queueing theory is mainly seen as a branch of applied probability theory. Its applications are in different fields, e.g. communication networks, computer systems, machine plants and so forth. For this area exist a huge body of publications, a list of introductory or more advanced texts on queueing theory is found in the bibliography.

The subject of queueing theory can be described as follows: consider a service center and a population of customers, which at some times enter the service center in order to obtain service. It is often the case that the service center can only serve a limited number of customers. If a new customer arrives and the service is exhausted, he enters a waiting line and waits until the service facility becomes available. So we can identify three main elements of a service center: a population of customers, the service facility and the waiting line. Also within the scope of queueing theory is the case where several service centers are arranged in a network and a single customer can walk through this network at a specific path, visiting several service centers. Since queueing theory is applied in different fields, also the terms client and task are often used instead customer. The service center is often named processor or machine**.** Queueing theory tries to answer questions like e.g. the mean waiting time in the queue, the mean system response time, mean utilization of the service facility, distribution of the number of customers in the queue, distribution of the number of customers in the system (**[٥]Bhat,٢٠٠٨**).

These questions are mainly investigated in a stochastic, where e.g. interarrival times of the customers or the service times are assumed to be random**.** A basic model of a service center is the customers arrive to the service center in a random fashion. The service facility can have one or several servers, each server capable of serving one customer at a time; the service times needed for every customer are also modeled as random variables. Queueing systems may not only differ in their distributions of the inter arrival and service times, but also in the number of servers, the size of the waiting line (infinite or finite), the service discipline and so forth. Some common service disciplines are:

FIFO: (First Input, First Output): a customer that finds the service center busy goes to the end of the queue. **LIFO:** (Last Input, First Output): a customer that finds the service center busy proceeds immediately to the head of the queue. It will be served next, given that no further customers arrives. Service in random order **(SIRO):** the customers in the queue are served in random order.

Priority Disciplines**:** every customer has a (static or dynamic) priority; the server selects always the customers with the highest priority. This scheme can use preemption or not. The Kendall notation is used for a short characterization of queueing systems. A queueing system description looks as follows:

$$a/b/c/d/e/f \ ,$$

where a denotes the distribution of the interarrival time, b denotes the distribution of the service times, c denotes the number of servers, d denotes the maximum size of the waiting line in the finite case and the optional e denotes the service discipline used (FIFO, LCFS) and f : Size of the source feeding the system with customers or size of calling source.

If S is omitted the service discipline is always FIFO. For A and B the following abbreviations are very common:

- M (Markov): this denotes the exponential distribution with

$$A(t) = 1 - \exp(-\lambda t), \quad a(t) = \lambda \exp(-\lambda t),$$

where $\lambda > 0$ is a parameter of interarrival time . The name M stems from the fact that the exponential distribution is the only continuous distribution with the Markov property, i.e. it is memoryless.

- D (Deterministic): all values from a deterministic "distribution" are constant, i.e. have the same value.
- E_k (Erlang-k): Erlangian distribution with k phases $k \geq 1$. For the Erlang-k distribution we have

$$\text{A(t)=1-exp(-k}\mu\text{t)}\sum_{\text{j=1}}^{\text{k}} \frac{(k\,\mu t)^j}{\text{j!}},$$

where $\mu > o$ is a parameter of service time. This distribution is popular for modeling telephone call arrivals at a central office.

- G (General): general distribution, not further specified. In most cases at least the mean and the variance are known. The most simple queueing system, the $M/M/1$ system (with FIFO) can then be described as follows: we have a single server, an infinite waiting line, the customer interarrival times are independent and identically (iid) and exponentially distributed with some parameter $\lambda > 0$ and the customer service times are also (iid) and exponentially distributed with some parameter $\mu > 0$.We are mainly interested in steady state solutions, i.e. where the system after a long running time tends to reach a stable state, e.g. where the distribution of customers in the system does not change (**[١٦]Gross, D., Harris ,١٩٩٨**).

A queueing system is described by its calling population, the nature of the arrivals and services, the system capacity, shown in **Figure (١.١.١)** and the queueing discipline.

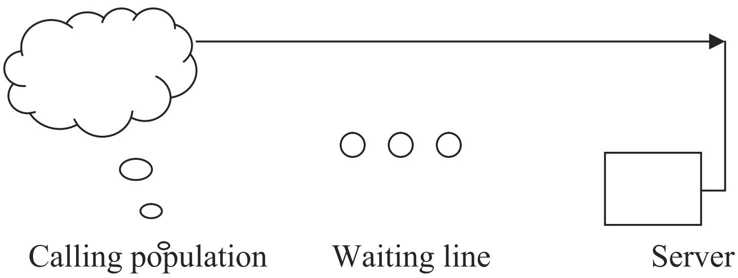

Figure (١.١.١): Queueing system

In this system the calling population is infinite; that is, if a unit leaves the calling population and joins the waiting line or enters service, also the system capacity is unlimited. (The system includes the unit in service plus those waiting in line).Finally, callers are served in the order of their arrival (often called FIFO, for first input, first output) by a single server, or channel. Arrivals and services are described by the distributions of the time between arrivals and service, or the waiting line will grow without bound. Exceptional situation would be arrival rates that are greater than service rates for short periods of time. However, such a situation is $\lambda < \mu$ to reach to steady state ($t \to \infty$) more complex. As shown as in **Figure (١.١.٢)**. If the server is busy, then the arriving unit entries the queue. If the server is idle and the queue is empty, while the unit entries the server. It is impossible for the server to be idle and the queue to be not empty.

		Queue system	
		Not empty	Empty
Server status	Busy	Enter queue	Enter queue
	Idle	Impossible	Enter Service

Figure (١.١,٢): Potential unit actions upon arrivals.