Analysis of Finite Buffer Markovian Queue with Balking, Reneging and Working Vacations

P. Vijaya Laxmi, Department of Applied Mathematics, Andhra University, Visakhapatnam, Andra Pradesh, India
V. Goswami, School of Computer Application, KIIT University, Bhubaneswar, Orissa, India
K. Jyothsna, Department of Applied Mathematics, Andhra University, Visakhapatnam, Andra Pradesh, India

ABSTRACT

This article presents the analysis of a finite buffer M/M/1 queue with multiple and single working vacations. The arriving customers balk (that is do not join the queue) with a probability and renge (that is leave the queue after joining) according to exponential distribution. The inter-arrival times, service times during a regular service period, service times during a vacation period and vacation times are independent and exponentially distributed random variables. Steady-state behavior of the model is considered and various performance measures, some special cases of the model and cost analysis are discussed.

Keywords: Balking, Cost, Finite Buffer, Reneging, Working Vacations

INTRODUCTION

In recent years, there is an emerging trend to study queueing systems from an economic view point. Traditional models of queueing systems do not consider the economic costs and therefore, these models have been criticized as being inappropriate for service providers. Many queueing situations arise in real life wherein the customers are discouraged by a longer queue resulting in a long wait anticipated by him upon arrival. As a result, the customers either decide not to join the queue or depart after joining the queue without receiving service due to impatience. Balking means the phenomenon of customers arriving for service into a non-empty queue and leaving without joining the queue. On the other hand, a customer is said to have reneged if after joining the queue he gets impatient and leave the system without receiving service. The losses in revenues in various industries due to balking and reneging are enormous and thus need to be studied in suitable context.

When customers have to wait for long more dissatisfaction is likely to arise. Perhaps, service providers may be interested in allowing certain amount of balking if it leads to a higher level
of customer satisfaction. It is more important to reduce reneging as renegers make the line seem longer for those contemplating joining and may prompt some to balk. At the same time customers become dissatisfied because of the total length of time they have to spend before being served. If customer’s decision making can be predicted, a powerful set of tools will be available to customer service managers.

Models with customers’ impatience in queues have been studied extensively due to their versatility and applicability. An $M/M/1$ queue with customers balking and reneging has been discussed in Haight (1957) and (1959), respectively. The combined effects of balking and reneging in an $M/M/1/N$ queue has been reported in Ancker and Gafarian (1963a, 1963b). Analytical solutions of the single-server Markovian overflow queue with balking, reneging and an additional server for longer queue have been discussed in Abou-El-Ata and Shawky (1992). Al-Seedy and Kotb (1991) studied the transient solution of the state-dependent $M/M/1$ queue with balking. Drekic and Woolford (2005) discussed a preemptive priority Markovian queue with state-dependent service and lower priority balking customers. Abou-EI-Ata and Hariri (1992) discussed the finite buffer multiple server queueing system with balking and reneging. Choudhury (2004) considered a single server finite buffer queueing system assuming reneging customers. Some of its variations have been studied by several authors including Abou-EI-Ata (1991), Altman and Yechiali (2008), Baccelli et al. (1984), Kok and Tijms (1985) and Shawky (1997).

Queueing systems with server vacations have been studied extensively due to their wide applications in several areas including computer and communication systems, manufacturing and production systems. More details have been reported in Doshi (1986), Takagi (1991) and Tian and Zhang (2006) and Tadj and Abid (2009). In the study of vacation models, the server is generally assumed to stop service completely during vacation period. However, there are numerous situations where the server remains active during the vacation period and serves the customers generally at a slower rate. At the end of a vacation if the queue is nonempty a service period begins with normal service rate; otherwise the server takes another vacation. This policy is called multiple working vacations (MWV). Under the single working vacation (SWV) policy, the server takes only one working vacation when the system becomes empty. When the server returns from a SWV, it stays in the system waiting for customers to arrive instead of taking another working vacation. Otherwise, it changes the service rate back to the normal service rate as under the MWV policy. Servi and Finn (2002) introduced the concept of multiple working vacations with the study of $M/M/1/WV$ queue. Wu and Takagi (2006) generalized the $M/M/1/WV$ queue to an $M/G/1/WV$ queue. SWV queues have been studied by Tian et al. (2008, 2010). The study of the queueing systems with balking, reneging and vacations seems to be a recent endeavor. Zhang et.al (2005) considered an $M/M/1/N$ queue with balking, reneging and multiple server vacations. However, queueing models with server working vacations accommodate the real world situations more closely. This motivated us to study an $M/M/1/N$ queueing system with balking, reneging and multiple and single working vacations.

Performance modeling of Markovian queue with balking has attracted many researchers due to its applications in real life congestion problems. Even if a customer does not balk and joins a queueing system, customers may become impatient in the queue while waiting for service, and depart from the system after some time. Such impatient behavior is known as reneging. Many practical queueing systems with balking and reneging have been widely applied to many real-life problems such as impatient telephone switchboard customers, the hospital emergency rooms handling critical patients, and perishable goods storage in inventory systems. Balking and reneging are not only common phenomena in queues arising in routine activities, but also in telecommunication networks and in several machine repair models. This paper deals with a Markovian multiple and single working vaca-
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