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A BRIEF LITERATURE REVIEW ON DIFFERENT VACATION POLICIES IN QUEUING SYSTEMS

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Abstract: This paper is a short communication of various policies that server adopts to resume service after vacation. Customer's waiting time may leads to loss for queueing system.Thus, we have presented these policies for optimizing queue parameters.

Key words: *Vacation,N-Policy,F-Policy,D-Policy*

Introduction: The mathematical study of waiting lines or queues is known as queuing theory. The theory allows for the derivation and calculation of a number of performance measures, such as the average wait time in the line or system, the anticipated customer volume (waiting for service or receiving it), and the likelihood of running into the system in various states, such as empty, full, with servers available, or requiring a certain amount of time to be served.

The literature on probability, operations research, management science, and industrial engineering has a wealth of useful applications for queueing theory, the most of which are well-documented. Examples include scheduling (patients in hospitals, jobs on machines, computer programmes), traffic flow (vehicles, communications, people), and facility design (banks, post offices, food courts).

Vacation refers to the scenario in queues where a server is occasionally unavailable for primary consumers. However, the server may provide service to secondary customers while the primary consumers are unavailable in many engineering systems, including computer networks, digital communication, production or manufacturing, airline scheduling, inventories, and other stochastic systems. The server working on the secondary customers is analogous to the server taking a vacation as far as the queueing systems in the applications are concerned. When servers can take breaks (such as vacation, dormant, startup, breakdown, etc.), queue models become more flexible and realistic when analysing real-world scenarios.Research studies on queues with vacations have been increased tremendously and still many researchers have been developing theory of it.

The development of vacation queueing theory was an expansion of traditional queueing theory. In a queueing system with vacations, the server is free to take time off in addition to servicing customers that show up at random. Vacations taken by servers may be caused by a lack of work, a server's failure, or other responsibilities given to them in applications like priority queues, preventive maintenance jobs in production systems, and so forth. Vacations could be servers working on side projects, doing server maintenance checks and repairs, or servers having problems that prevent them from providing customer service. Additionally, queueing models are more adaptable in determining the best service policies when servers are permitted to take vacations.Therefore, queues with vacations or simply called *vacation models* attracted great attention of queueing researchers and became an active research area.

Miller (1964) was the first to investigate the M/G/1 queueing system with a server that gets inactive and unavailable for an arbitrary period of time. Similar queueing models, such as various modifications of the traditional M/G/1 queueing system, were also examined by Levy and Yechiali in 1975.

The next sections provide a brief discussion of these policies, various service mechanisms, and uses of vacation queueing systems. Single vacation policy, multiple vacation policy, N-policy, (M,N)-policy, T-policy, (N, T)-policy, min (N, T)-policy, D-policy, (p,T)-policy, Q-policy, Bernoulli vacation policy, modified Bernoulli policy, repeated attempts, etc. are just a few of the many types of policies for controlling the vacation mechanism that have been discussed in the literature.

Broadly vacation policies are classified as follows:

Single Vacation Policy**:** The server takes only one vacation between two consecutive busy periods. If the server does not find any customer in the system upon his return from the vacation to the queue station, he stays in the system waiting for the first customer to arrive, known as dormant period. When there is a dormant period, vacation and dormant periods together are considered to be idle period.

Multiple Vacation Policy**:** In this policy the server goes on vacations until, at least one customer is present upon his return from the vacation.

Some of the literature on different vacation policies are given below:

1.N-policy: The server departs the service channel when it is empty under the N-policy vacation models, returns when the queue length reaches the desired level N (>= 1), and starts providing service with or without startup time.

Yadin and Naor were the ones who initially introduced the idea of N-policy (1963). In order to establish the appropriate queue size for a single server, they examined an M/G/1 queueing system. They assumed that the server would be turned on when the queue size above a particular threshold, N, and off when the system size was empty.

The exponential startup durations of the M/M/1 queue were examined by Baker (1973). In order to reduce the mean time cost, he discovered the ideal number of customers to be present at zero and non-zero starting times.

In addition to doing a transient analysis of the server states, queue size, and time spent in each state, Takagi (1990) built an M/G/1 queue with numerous vacations, single vacations, atypical start service timings, and a combination of N-policy and setup times.

An N-policy M/G/1 system with early setup—the server starts setup when N customers are waiting—was researched by Lee and Park in 1992. After setup, if there are less than N clients still waiting, he waits until N users have accumulated in the system.

In order to minimise the average stationary operating cost, Lee and Park (1997) proposed a linear cost model based on a technique for determining the joint optimal (m, N) value. Calculations were also made for a number of crucial factors, including likelihood and wait length.

T-policy and N-policy, two varieties of control operating policies having a random setup time, were examined by Choudhury (1998 b). He discovered the decomposition property by obtaining the queue size distribution of the M/G/1 queue at various points in time.

The best technique to manage an MX/G/1 queue with two different types of randomly distributed vacations—type 1 (long) and type 2 (short)—was examined by Ke (2001). (short). When the system is completely empty, the server is shut down and takes a type 1 vacation. The server will resume a type 1 vacation if there are less than Q customers in line when he returns from vacation. He will take a type 2 vacation if there are at least Q but no more than N clients waiting. The server is immediately activated if there are N or more clients, but the awaiting clients experience a brief interruption of service as he sets up.He has devised a number of essential system performance indicators. He also provided an ideal cost function.

Zhang and Tian (2004) examined the N threshold policy for the GI/M/1 queue method and were able to generate stable distributions of queue length and waiting time. Tadj et al. (2006) investigated an ideal management strategy for a bulk service queueing system with random setup time and server vacations based on Bernoulli schedules running under N-policy.

In a service station with sporadic breakdowns, Wu. Wenqing et al. (2015) developed an M/G/1 repairable queueing system with N-policy and single vacation. A vehicle is taken to a mechanic when it breaks down. Additionally, there is always a chance that the repair facility would

malfunction, delaying the repair process. A failing repair facility starts up again after some arbitrary interval of time. To calculate different probabilities, including those for breakdown, working, and repair, the probability decomposition method and renewal process theory are utilised. The long-run anticipated cost function per unit of time was numerically evaluated to determine the best threshold N- policy for lowering the cost function.
Ojobor and Omosigho (2016) investigated a temporary fix for a single server machine interference problem with an additional server for lengthy waits during N-Policy vacations. The number of malfunctioning machines, the number of running computers, and the duration of server vacation could all be calculated using transitory probability. For various values of N with respect to time, they obtain different values for the expected number of failed, expected number of functioning, and machine availability. In response to the repairmen's prompts, they also calculated the number of faulty equipment (N).
Zhanyou Ma et al. solved the Geo/Geo/1 repairable queue with multiple working vacations, pseudo-fault, and N-policy (2017). They assumed that a fictitious fault or malfunction that only manifested itself when the server was overwhelmed was to blame for the service interruption. When a server malfunctions, repairs are made right away, and after they are finished, the server is considered to be in perfect working order. They evaluated the queueing system under discussion, presented a number of performance indices for the system in steady-state, and calculated the steady-state queue length distribution using a two-dimensional Markov chain and a matrix-geometric solution approach.
Azhagappan et al. (2019) used an M/M/1 queueing model with N-policy to study the transient behaviour of the model as well as system disaster, repair, preventative maintenance, baulking, re-service, closedown, and setup times. Until N clients enter the queue, the server is inactive (off state), at which point it begins an exhaustive service (on state). Each customer has the choice to exit the system or ask for prompt re-service following the service. The server resumes closedown activities after the system is empty before doing preventive maintenance. It returns to being idle and waits to be called into service once N has accumulated. The server begins the setup process before launching the service when the Nth person joins the queue. The system crashes catastrophically during this period. As a result, the system failed and all customers were removed. The server is then fixed and put back to sleep after that. Customers can choose to join the queue or leave it when the system size is less than N. The generating function method is used to determine the likelihood of the proposed model in the transient example. Additionally, numerical simulations and system performance indices are shown.
An M/M/1 constant retrial queueing model with reserved idle time under N-policy was researched by Li QL et al. in 2019. The server can be promptly filled when a customer shows up when it is on and idle. The server is dormant after the final client has been handled for an arbitrary duration of time. A consumer who walks in during this time will be quickly attended to. If there are more than N waiting clients in retry orbit, the server will shut down to conserve energy ($N>1$). The generating function method is used to calculate the likelihood of the server in various states. Additionally, based on the reward-cost function and other factors, all clients will decide when they arrive whether to accept or reject the system. It's been revealed that the longer a server sits inactive, the more money it earns.

2.T-policy: The T-Policy was introduced by Heyman who suggests its use in situations where the server cannot continuously monitor the queue, but scans it T time units after the end of the last busy period. He called this operating plausible policy, the T-Policy. In corporation of the T-policy to the queueing system leads to a system when the servers discipline is as follows: At the end of a service, the server checks the number of customers in the queue. If more than r customers are present, the server picks a batch of customers to process .Otherwise; the server leaves the service area and scans the queue T time units after the previous service. He keeps scanning the queue every T units of time until r customers are available. After all the customers in the queue are served, if there is no customer waiting for service in the system, the server proceeds on to vacation. Heyman showed that the optimal N-policy always does better than the optimal T-policy. Ke (2005) studied a variant T-policy for the M/G/1 queueing system with an unreliable server.

The M/G/1 queue with a T-policy was first studied by Heyman (1977). In such a system, the server is turned off at the end of a busy period (or a customer departure leaving an empty system) and scans the queue after *T* time units. If customers are found, a busy period begins and the server is kept serving the customers until the system is empty. If no customers are found, the server remains off for another period of length *T*. This process continues so that the server is in either on (or service) or off (or absence) state. Heyman (1977) used the regeneration cycle approach to develop the average cost function of *T* for the system and compared it with the average cost function in the same M/G/1 queue with an N-policy (for the details of the N-policy model, see Heyman, 1968). He showed that the optimal average cost in the N-policy model is always lower than that in the T-policy model. Recently, we reviewed the past works on the M/G/1 queues with threshold control policies over the past almost three decades and noticed that the regeneration cycle may be defined differently in developing the average cost function. While the results for the major system performance measures such as the probability generating function (pgf) of the queue length or the Laplace–Stieltjes Transform (LST) of the waiting time are not affected, it is worth noting that some differences do exist when evaluating the average cost under a certain cost structure. The aim of this note is to clarify these differences.

The vacation strategy of an M/G/1 queueing system with an unstable server and startup was explored by Jau-ChuanKe in 2005. The server deactivates and repeatedly takes at most J vacations of a fixed length T after serving every customer in the queue to completion. This process is repeated until at least one customer is still in the queue when the server comes back from vacation. When a server returns from vacation and there is at least one customer present in the system, the server reactivates and needs some startup time before it can start offering the service. The server, on the other hand, is left idle in the system until at least one consumer shows up, even if none do by the conclusion of the Jth vacation. The policy is known as the modified T vacation policy. Additionally, it is presumptive that the server experiences a Poisson process for failure and a generic distribution for repair time. For this model, they looked at the system features.

The T policy M/G/1 queue with server failures and startup times was studied by Tsung-Yin Wang et al. (2009). The system receives customers via a Poisson process. The distribution of service times, repair times, and startup times is considered to be uniform. Until there is at least one customer in the waiting queue, the server is continually turned on after a specified amount of time T. Before initiating the service, the server needs a startup period. The total expected cost function per unit of time, in which T is a decision variable, was developed after they examined several system performance metrics. They established the ideal threshold T and generated analytical findings for sensitivity studies. When assessing potential future conditions, the system analyst finds the sensitivity analysis to be especially helpful. For instance, they also provided a comprehensive numerical computation.

The average operational cost of the M/G/1 queue with T-policy studied in the 1970s was evaluated using the idea of regeneration cycle, which Zhe George Zhang (2011) clarified in a note. The benefits and drawbacks of each of the two definitions of the regeneration cycle are contrasted. They also defined the cost function's convexity based on the service cycle.

In a work published in 2015, XueluZhang et al. looked at a single server queueing system with a threshold control policy and its use to manage a computing server's energy usage. The service rate is set at a low value if there are less users than a certain threshold, and it can also be changed to a high value once there are enough users. The key performance measures of the system, such as the steady-state probability distribution, the anticipated number of customers in the system and in the queue, the anticipated sojourn time in the system, and the anticipated waiting time in the queue, were examined for monotonicity, convexity, and concavity properties with respect to the threshold. They further investigated a real-world issue involving the energy usage of a computing server based on these attributes. The state-dependent service policy is a promising method to balance the energy consumption and the quality of service of a computer server, according to numerical data.

3. D-policy: Under this policy the server is turned on when the cumulative service times of the customers in the system exceed the value D and turned off when the system empties. The classical D-policy was studied by Chae and Park and simplified the result of Dshalalow. Feinberg and Kella (2002) showed that the D-policy is optimal for an M/G/1 queue with removable server under the criterion of the average cost per unit time. The server is turned on when the cumulative quantity of work first surpasses some set number D and is turned off at the end of a busy period, according to an M/G/1 queue that was described in detail by Artalejo (2001). Their initial focus was on computing the steady-state probabilities. Investigated are the initial moments and connections between the busiest time, the number of clients served, and other performance indicators. Additionally studied are the main model variations and the M/M/1 special instance.
New research on the queueing process in D-policy models with Poisson bulk input, general service time, and repeated vacations is presented by R. P. AGARWAL (2003). The D-policy is in effect when the system, having run out of resources, suspends operation until the total workload crosses D (_> 0), accruing a certain number of users. The "first service cycle," which comprises the first vacation period when all clients line up waiting for the server to return and a period when those customers are handled, is the focus of the inquiry. In accordance with the departure epochs, neither the servicing process nor the queueing process in this model are semi-regenerative. The research investigated a novel fluctuation method of multivariate marked counting processes to solve the issue. It also produces their stationary distributions in closed analytical forms. It contains the time-dependent analysis of queueing and busy period processes, which were designed specifically for this procedure.
BaraKim(2013) took into account the queueing model under the D-policy with erroneous service time information. The operator is aware of the correlated portion of the service time but not the actual service time of an arriving customer at each arrival epoch. We first calculate the incomplete work's mean and variance before deriving its Laplace-Stieltjes transform. In numerical examples, the Laplace-Stieltjes transform is numerically inverted to calculate the distribution function of the unfinished job. The unfinished work's mean and variance are shown.

A paper by Priyanka Kalita et al. (2019) that discusses a single server queue with a modified vacation strategy was presented. The operation of a close down period, a type 1 vacation period, a type 2 vacation period, a start-up period, and a dormant period are all covered by the modified vacation policy. Here, type 1 vacations last for a brief, arbitrary period of time, whereas type 2 vacations last for a lengthy, arbitrary period of time. For the steady state queue size distribution at the service completion point and the steady state system size probabilities, explicit formulations have been found. For the system, the waiting time's Laplace-Stieltjes transform and associated mean value have been determined.

4. F-policy: An interesting concept introduced by Gupta (1995) in regard to finite queues is the concept of F-policy. The intention of the F-policy is to control the arrival process when service control is not possible through N-policy. Consider a queueing system of finite capacity. If the system reaches its capacity K, no further customers are allowed to enter the system until enough customers who are already in the system have been served so that the number of customers in the

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system drops down to a threshold value F ($0 \leq F \leq K.1$). There is a duality relationship between N-policy and F-policy that allows obtaining the stationary queue length distribution for the two systems at once. The duality relationship has been proved by Gupta (1995).
A limited capacity G/M/1 queueing system with the F-policy and an exponential starting time was the subject of Kuo-Hsiung Wang's (2008) study on the best way to control it. The most frequent challenge of regulating arrival to a queueing system is examined in the F-policy queueing problem. We offer a recursive method for developing the steady-state probability distribution of the number of consumers in the system, utilising the supplementary variable methodology and treating the supplementary variable as the remaining interarrival time. By providing three straightforward examples for the respective exponential, 3-stage Erlang, and deterministic interarrival time distributions, they demonstrated a recursive technique. In order to establish the best management F-policy at the lowest possible cost, a cost model is created. They calculated the ideal operational F-policy and various system performance metrics using an effective Maple computer programme. Analysis of sensitivity is also studied.
Dong-Yuh Yang(2015) et al investigated the F-policy queue using fuzzy parameters, in which the arrival rate, service rate, and start-up rate are all fuzzy numbers. The F-policy deals with the control of arrivals in a queueing system, in which the server requires a start-up time before allowing customers to enter. A crisp F-policy queueing system generalised to a fuzzy environment would be widely applicable; therefore, we apply the α-cuts approach and Zadeh's extension principle to transform fuzzy F-policy queues into a family of crisp F-policy queues. This study presents a mathematical programming approach applicable to the construction of membership functions for the expected number of customers in the system. Furthermore, they proposed an efficient solution procedure to compute the membership function of the expected number of customers in the system under different levels of α. Finally, they gave an example of the proposed system as applied to a case in the automotive industry to demonstrate its practicality.

A multi-server finite queueing model with blocking under F-policy-based customer admission management was studied by Madhu Jain et al. (2019). By deploying just one server, clients' rush-hour backlogs are reduced and their baulking behaviour is lessened. The proposed Markov model's noble realistic characteristic is that it controls client admission depending on the queue size threshold level "F." Customers cannot be accepted until the wait size drops below the predetermined "F" threshold level after the system is full, in accordance with the "F" policy. To determine the steady-state queue size probability distribution of the system's consumers, Chapman-Kolmogorov equations were generated and solved using the recursive method. The optimal control parameters, which include the threshold value 'F,' system capacity, server count, and service rate, are calculated using the cost function.
A study on F-policy for single-server finite capacity was conducted by Madhu Jain et al. in 2019. Investigated is a Markovian queueing model with retry attempts. Customers can join the system up until the system is fully utilised, at which point they are prohibited from doing so until the queue size drops below the "F" level. The concepts of state-dependent arrivals and service process are taken into consideration when creating a Markov model in order to deal with more realistic situations. Chapman-Kolmogorov equations governing the model are derived based on the birth-death process to analyse the queueing characteristics of the system. To determine the best service rate and related minimum cost, a cost function is applied. A numerical example, a sensitivity analysis of the system, and descriptors for several indices are included in order to analyse the system's behaviour.

Some of the other policies are

(M, N)-policy: When the queue is exhausted, the server goes on multiple vacations until the queue replenishes to *M* or more customers. On his return, if the queue crosses an *N* as well, the server resumes his service. Otherwise, he waits until the queue to reach or exceed *N*.
Bohm et al (1993) presented that it has been demonstrated by several authors, that combinatorial methods can be successfully applied to derive certain probability distributions in queuing theory. Recently the authors have obtained the transient solution of (0,N)-policy M/M/1 queues with an arbitrary number of initial customers, by considering their discrete-time analogue and by using combinatorial arguments. In this note, they derived the transient solution of M/M/1 queues under (M,N)-policy by an alternative combinatorial method in which lattice paths with diagonal steps are counted. As a special case the result for ordinary M/M/1 queues is checked.
***(N, T)-policy*:** Starting from an empty queue, the service of arriving customers is postponed until either of two thresholds is reached. Specifically, exhaustive service of customers is initiated only if either N customers have accumulated (Space threshold) of if more than T slots have passed since the arrival of the first customer. In this policy, the server terminates its vacation as soon as the number of arrivals reaches N or the time units after the end of the last completion period reach predetermined T units. Doganta (1990) first considered the (N, T) - policy M/G/1 queueing system with a reliable server. Ke (2006) studied the optimal (N, T)-policies for M/G/1 system with a startup and unreliable server.
***Min (N, T)-policy*:** In this policy, the server's vacation is finished if either N ($\geq$ 1) customers have accumulated in the system or T time units have elapsed since the end of a busy period or the end of the previous T time units and at least one customer in the system waits for service, whichever occurs first. Gakis et. al. (1995) first introduced this policy.
(p, T)-policy: The (T, p)-policy for T > 0 and 0 < p < 1 is to control the server randomly at the service completion epoch when the system becomes empty and is characterized by the following requirements: (i) switch the server off with probability p when the system becomes empty and the server takes a vacation of time T. If customers are found, the server is activated and works until the system is empty otherwise, the server takes another vacation for the same period. (ii) Leave the server on with probability (1-p) when the system becomes empty, then the server is still in an active position waiting for a customer to arrive and keeps serving customers until the system becomes empty. (iii) Do not switch the server on at other epochs. (T, 1)-Policy coincides with the T-policy introduced by Heyman [3], and the (T, 0)-policy is identical to the 2T-policy.
Q-policy: Bulk service queues have been used as models of a shuttle transport system, in which vehicles move between two terminals, say T1 and T2. When the vehicle is dispatched, it transports all the passengers waiting at T1 to T2, immediately picks up the passengers waiting at T2, and returns to T1. Assume that a fixed startup cost c_s is incurred in each round trip and the waiting cost per customer is h per unit of time. The vehicle will wait until there are Q customers available, the capacity of the vehicle being assumed to be infinite. Then this is a bulk service queue under general bulk service rule (Q, ∞). In the literature, this is also known as Q-policy. Kosten (1967) was first to consider such a model for a loop shuttle system with constant duration of trip.
***Bernoulli Vacation Policy*:** On completion of service to a customer, even though the queue is not empty, sometimes the server goes on vacation with probability p ($0 \leq p \leq 1$) and resumes service with probability (1 – p). The classical vacation scheme with Bernoulli schedule discipline was introduced by Keilson and Servi (1986, 1987). Servi (1987), Doshi (1986, 1987) and Takagi (1990) are among several others who have studied this type of queueing system.
Modified Bernoulli: Madan and Abu Al-Rub (2004) analyzed a single server queue with modified Bernoulli server vacations based on exhaustive service. Unlike other vacation policies, they assume that it is only at the completion of service of the last customer in the system that the server has the option to take a vacation or to remain idle in the system waiting for the next customer to arrive. The service times of the customers have been assumed to be exponential and vacations are

phase type exponential. Besides the Bernoulli vacation schedules, the queueing system of interest to us exhibits other features that we briefly mention here, without surveying any relevant literature since they are all well-known.

Conclusion: We presented several threshold approaches to estimate threshold strategies in queuing and machining systems. These variations include a variety of congested conditions that arise in both regular settings and industrial settings. Over time, a number of academics have created several queuing/machine models that incorporate different thresholds such N-policy, F-policy, and D-policy. In today's world, the idea of a threshold has a completely different meaning. The scope of the work, the methodology, and several fundamental aspects of threshold queuing systems have all been investigated. Beginning with the advent of threshold queuing systems and finishing with current additions, a survey of relevant research work has been offered. The primary purpose of this research is to offer enough data for queuing theorists and machine analysts to locate similar events in their own research.

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