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Strategic Application of M/M/s Queuing Model with Balking and Reneging to Alleviate OPD Congestion in Healthcare Settings

[1]Yaspal Singh,[2]Diwari Lal
[1]Research Scholar,[2]Professor
[1-2]Narain (PG) College, Shikohabad, Uttar Pradesh (India)
Affiliated to Dr. Bhimrao Ambedkar University, Agra, Uttar Pradesh (India)
Email id of corresponding Author: yaspalsingh644@gmail.com

Abstract: This exploration investigates the essential utilization of the M/M/s queuing model with balking and renege peculiarities to advance outpatient department (OPD) activities and reduce patient holding up times in emergency clinics. The review tends to the squeezing need for further developed medical care administration conveyance by zeroing in on the many-sided elements of patient stream inside the OPD setting. The M/M/s queuing model, consolidating the conduct parts of balking (patients deciding not to join the line) and renege (patients leaving the line prior to getting administration), offers a complete structure to investigate and improve OPD productivity. By getting it and coordinating these elements, emergency clinics can tailor their functional systems to limit patient holding up times, improve generally quiet fulfillment, and enhance asset usage. Empirical data analysis, mathematical modeling, and simulation are all components of the research methodology. The goal of the study is to shed light on how balking and reneging affect OPD performance metrics like wait times, queue lengths, and resource utilization. The M/M/s model is used to evaluate the efficacy of various interventions and strategies to reduce wait times and enhance the patient experience as a whole. The discoveries from this exploration can possibly contribute fundamentally to the assemblage of information in medical care activities the board. By executing the proposals got from the M/M/s queuing model with recoiling and renege contemplations, clinics can take on proactive measures to address OPD blockage, smooth out persistent stream, and improve the nature of medical services administrations. Eventually, the use of this model offers a promising road for medical clinics to accomplish functional greatness and work on the general effectiveness of outpatient services.

Keywords: *Outpatient Department (OPD) , Waiting time reduction, Balking , Reneging, Patient flow optimization*

I. INTRODUCTION

Outpatient clinics, dental offices, medical laboratories, and a plethora of other health care facilities all have waiting lines, which are commonplace and occasionally unavoidable. Combined with the rising interest for medical care administrations because of the developing populace particularly in emerging nations, the quantity of patients holding on to get administration at a given time will keep on developing, bringing about significant delays and immersion of the offices. To work on the nature of administration in wellbeing offices, it is fundamental to designate adequate assets to relieve the impacts of significant delays on the way of behaving of patients and a compromise should be made between working on the nature of administration and the ideal utilization of assets at the wellbeing office. The holding up lines in wellbeing offices can be demonstrated as lining frameworks in which patients show up, join a holding up line on the off chance that any, get administration at their divert and withdraw from that asset.
In the powerful scene of medical services, the successful administration of patient flow inside outpatient department (OPDs) is pivotal for guaranteeing quality consideration and a positive patient encounter. One of the huge difficulties looked by medical

care foundations is the improvement of assets to limit holding up times and improve generally speaking functional productivity. This study digs into the use of the M/M/s queuing model, enhanced by contemplations of balking and reneging, as an essential way to deal with address and relieve the delayed holding up times in OPD settings.

The M/M/s queuing model is a mathematical framework that is frequently used to examine the dynamics of queuing in service systems. This gives insight into the performance of the system, how resources are used, and potential areas for improvement. By stretching out this model to incorporate the peculiarities of recoiling (where patients decide not to join a line because of seen extended stand by times) and reneging (where patients forsake the line prior to getting administration), this exploration expects to offer a more practical portrayal of patient way of behaving inside the OPD climate.

Goswami (2014) introduced an examination of recoiling and reneging in limited support discrete-time single server line with single and different working get-aways. A showing up client might recoil with a likelihood or renege in the wake of joining as per a mathematical dispersion. Vass and Szabo (2015) show that most of protests from patients are generally connected with significant delays, once in a while because of deficient assets, and lacking sitting area. Obulor and Squeeze (2016) applied lining hypothesis for the assessment of a short term arrangement framework to demonstrate the arrangement planning process to decrease patients' holding up times and the inactive seasons of the wellbeing staff. Rasheed (2016) considered deterred appearance of Markovian queueing frameworks whose assistance speed is directed by the quantity of clients in the framework. They lessen the blockage in two ways. First they endeavor to lessen the clog by deterring the appearances of clients from joining the line. Furthermore they decrease the blockage by presenting the idea of administration switches. Alenany and El-Baz (2017) demonstrated the presentation of a wellbeing office utilizing a queuing network analyzer and discrete occasion reenactment. Kumar (2017) considered a Markovian multi-server lining framework with recoiling and disasters. They utilized likelihood creating capability procedure alongside the Bessel capability properties to get a transient answer for the lining model. Hu et al. (2017) analyzed the commitments of queueing hypothesis in demonstrating EDs and evaluate the qualities and restrictions of this application. They incorporated an immediate correlation with discrete-occasion reenactment when applied to comparable issues, and examine information procurement and difficulties related with every strategy. A single-server queuing model with reneging and retaining reneging customers was considered by Kumar and Sharma (2018). They have inferred the transient arrangement of the model. Kumar and Sharma (2018) acquired the transient arrangement of a M/M/c queueing model with balking, reneging, and maintenance of reneging clients. Kuban and others (2020) studied that the application of the concept of correlated reneging in a finite capacity multi-server queuing model is controversial. Medhi (2020) demonstrated a reneging peculiarity. Likewise, clients are additionally thought to be of balking type with reneging probabilities being a component of framework state. He introduced unequivocal shut structure articulations of different execution measures.

The primary goal of this study is to find out how the M/M/s queuing model, which includes balking and reneging factors, can be used to cut down on wait times and improve patient flow in hospital outpatient departments. Holding up times in OPDs influence patient fulfillment as well as have more extensive ramifications for the effectiveness of medical services conveyance, asset usage, and staff efficiency. By taking into account the subtleties of patient way of behaving through shying away and reneging, this examination looks to distinguish basic elements impacting holding up times and likely bottlenecks in the OPD framework. Through the investigation of patient appearance designs, administration times, and the effect of recoiling and reneging on line elements, the review plans to give significant bits of knowledge that can illuminate dynamic cycles for medical clinic heads and medical care experts.

II. BASIC M/M/S MODEL EQUATIONS

(i) Utilization Factor: $\rho = \frac{\lambda}{c\mu}$

Where λ is the arrival rate (patients per time unit)

μ is the Service rate (patients per time unit per server)

s is the number of servers.

ρ is the utilization factor.

(ii) Probability that there is no patient in the system

$$P_0 = \frac{1}{1+\sum_{r=1}^{s-1}\frac{(\lambda/\mu)^r}{r!}+\frac{(\lambda/\mu)^s}{s!(1-\rho)}}$$

(iii) Average Time in System: $W = \frac{1}{\mu-\lambda}$

(iv) Average Number in System : $L = \lambda W = \frac{\lambda}{\mu-\lambda}$

III. INCORPORATION OF BALKING AND RENEGING TO M/M/S MODEL OF HEALTH CARE SYSTEM

Let's incorporate balking and reneging into the M/M/s queueing model for a healthcare system. The basic M/M/s model equations are modified to account for the probability of balking (P_{balk}) and the probability of reneging (P_{reneg}).

(i) Effective Arrival Rate with Balking: $\lambda_{eff} = \lambda(1 - P_{balk})$
(ii) Effective Service Rate with Reneging: $\mu_{eff} = \mu(1 - P_{balk})$
(iii) Traffic Intensity: $\rho_{eff} = \frac{\lambda_{eff}}{s\mu_{eff}}$
(iv) Probability that there is no patient in the system

$$P_0 = \frac{1}{1+\sum_{r=1}^{s-1}\frac{\left(\lambda_{eff}/\mu_{eff}\right)^r}{r!}+\frac{\left(\lambda_{eff}/\mu_{eff}\right)^s}{s!(1-\rho)}}$$

(v) Probability of there is n patient in the system:

$$P_n = \frac{\left(\lambda_{eff}/\mu_{eff}\right)^n}{n!}P_0$$

(vi) Average time a patient spends in the system: $W_{eff} = \frac{1}{\mu_{eff}-\lambda_{eff}(1-\rho_{eff})}$

(vii) Average number of patients in the system: $L_{eff} = \lambda_{eff}W_{eff} = \frac{\lambda_{eff}}{\mu_{eff}-\lambda_{eff}(1-\rho_{eff})}$

(viii) Average number of patients in the queue : $L_q = L_{eff} - \frac{\lambda_{eff}}{\mu_{eff}}$

(ix) Average time a patients spends in the queue: $W_{eff} = \frac{L_q}{\mu_{eff}-\lambda_{eff}(1-\rho_{eff})}$

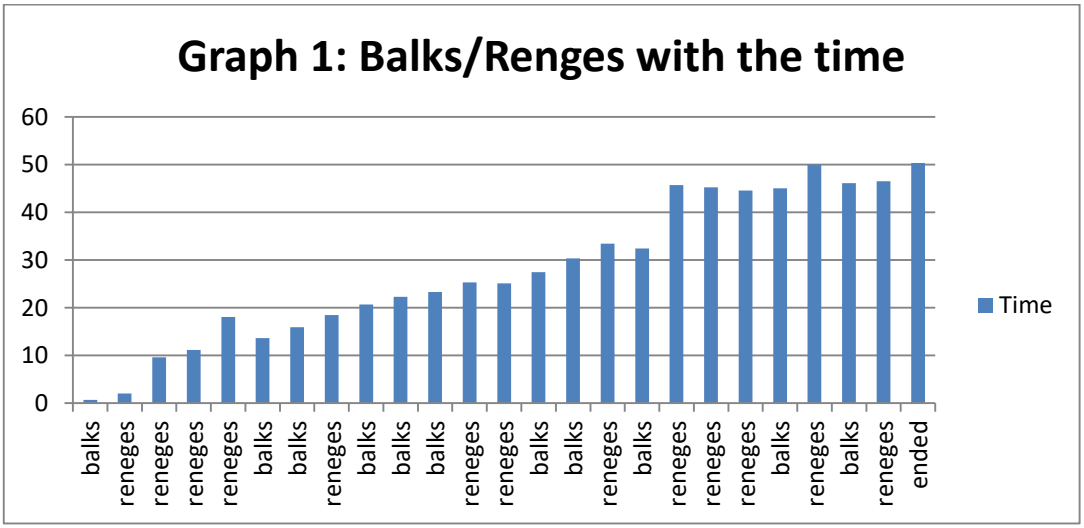
These equations provide a comprehensive framework for the M/M/s queueing model with balking and reneging in a healthcare system.

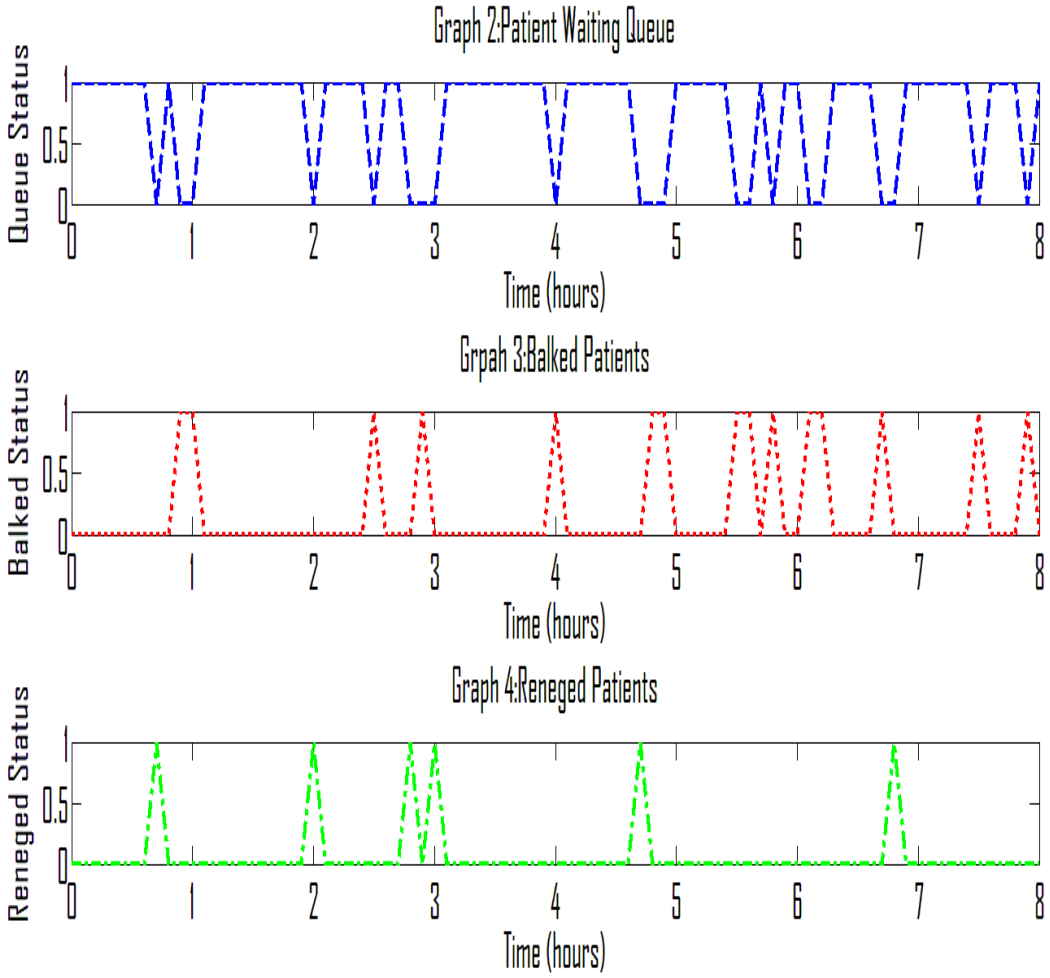
IV. Results and Discussion

$\lambda = 2.5, \mu = 4.5, s = 4, P_{balk} = 0.1, P_{renege} = 0.2$, Maximum simulation time=50

Table 1: Balking/ Reneging of the patients at the time

Time	Balks/Renege
0.666251	balks
2.0573	reneges
9.586759	reneges
11.156689	reneges
18.090941	reneges
13.665819	balks
15.899791	balks
18.474423	reneges
20.683191	balks
22.279753	balks
23.3273	balks
25.318449	reneges
25.123557	reneges
27.481682	balks
30.342191	balks
33.397806	reneges
32.40451	balks
45.710303	reneges
45.210913	reneges
44.577938	reneges
45.002088	balks
49.973947	reneges
46.123679	balks
46.504258	reneges
50.333556	ended

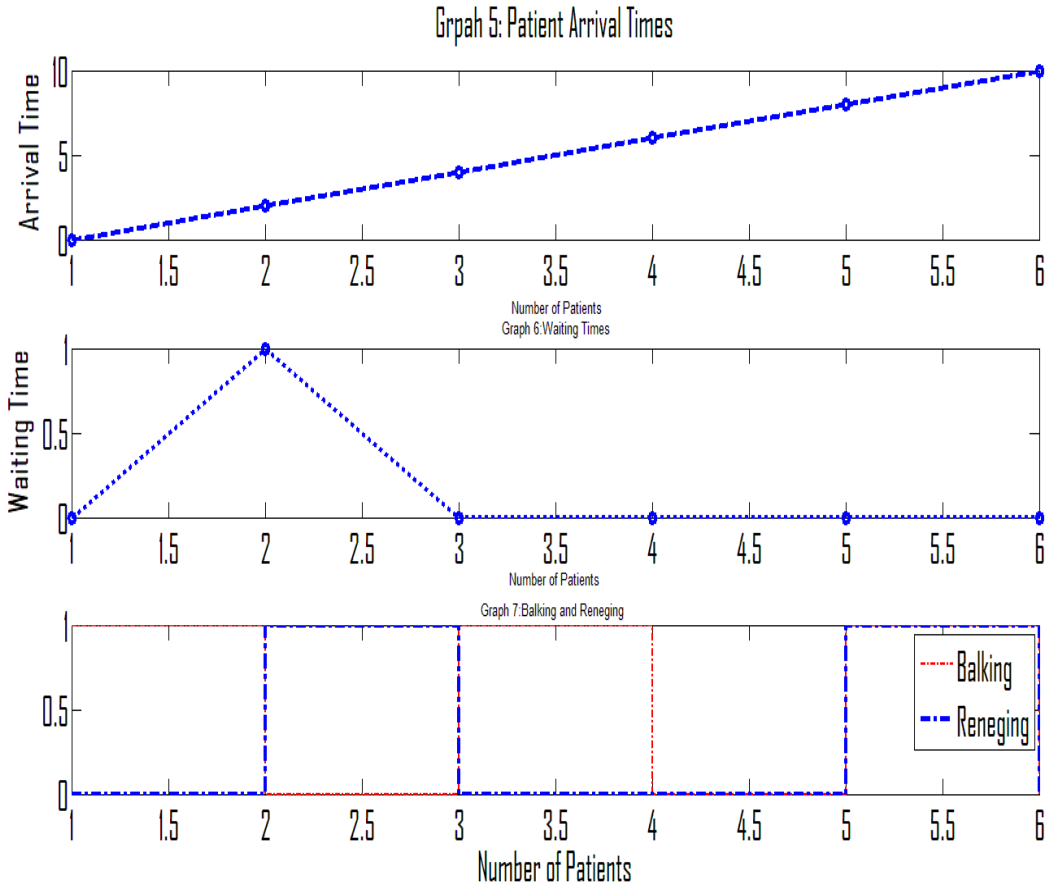




The graph (2) shows vacillations in the line status after some time. Pinnacles might demonstrate times of high blockage, while box address seasons of lower action. Tops or abrupt drops in the line status relate to occasions of recoiling or reneging. An unexpected expansion in line length demonstrates that more patients are deciding not to join the line (balking). On the other hand, an unexpected lessening could demonstrate patients leaving the line prior to getting administration (reneging).

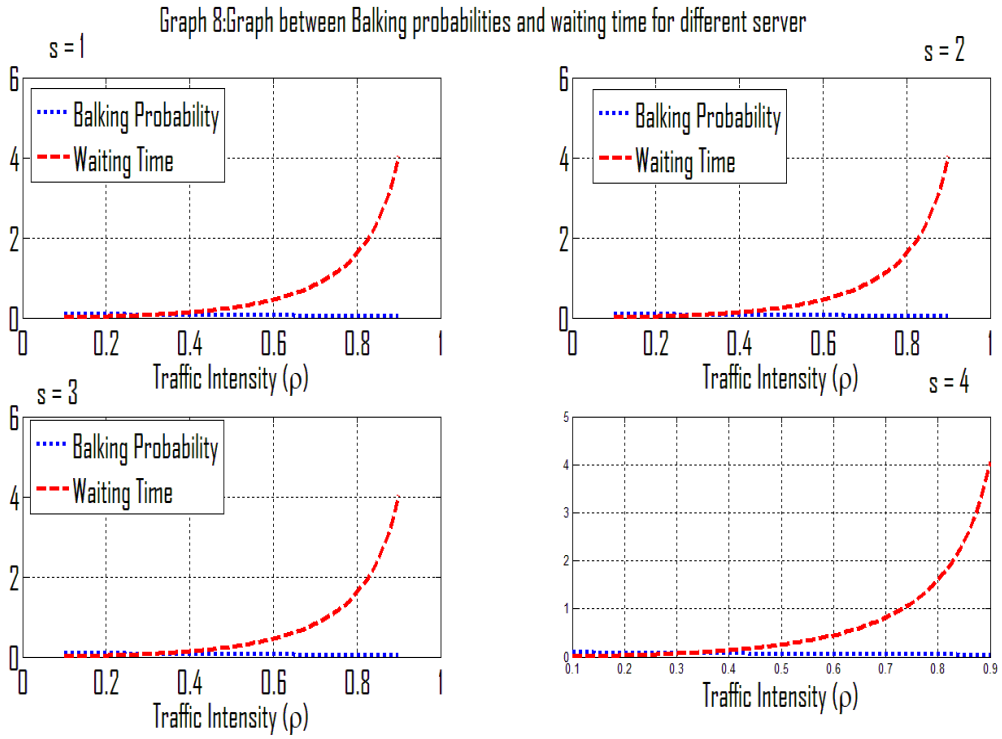
Pinnacles and box in the graph (3) address varieties in balking conduct over the long run. While lower values indicate times when patients are more willing to join the queue, high peaks indicate times when patients are more likely to balk. The graph depicts the effects of strategic efforts to lessen balking. In the event that actions are taken to further develop administration proficiency, diminish holding up times, or improve the general patient experience, it is notice that a reduction in the recoiling status over the long haul.

The graph (4)'s peaks and troughs depict variations in reneging behavior over time. While lower values indicate times when patients are more patient and willing to wait for service, high peaks indicate periods of increased reneging. A diminishing pattern in reneging over the long haul might recommend that the carried out systems are effectively tending to patient worries and working on quiet maintenance in the line.



The variations in the number of patient arrivals over time are depicted in graph (5). Tops demonstrate times of appeal, while box might address seasons of lower movement. The graph aids in the identification of patient arrival patterns and trends. There is a pinnacle appearance time during specific hours of the day or days of the week. Understanding these examples is pivotal for asset allotment and booking. Looking at the "Appearance Times versus Number of Patients" chart with the diagrams of balking and reneging situations with an all encompassing perspective on how patient ways of behaving (appearance, recoiling, and reneging) cooperate over the long run.

The graph (6) shows how holding up time fluctuates with the quantity of patients in the framework. Tops demonstrate times of high clog, prompting longer holding up times, while box address seasons of lower blockage and more limited holding up times. An expansion in the quantity of patients might prompt longer holding up times, particularly if the help limit (number of servers in the M/M/s model) is deficient to deal with the interest. Dissecting the chart gives bits of knowledge into the progress of the lining model and related methodologies in mitigating OPD clog. A diminishing pattern in holding up times during top periods might demonstrate successful mediations. Dissecting the graph (7) gives experiences into the outcome of the lining model and related techniques in mitigating OPD clog. A diminishing pattern in recoiling or reneging during top periods might show viable mediations. With considerations for balking and reneging, the graph helps determine how well the queuing model is managing patient decisions during busy times. Vital mediations to upgrade the lining framework might appear as changes in shying away and reneging designs.



The graph (8) shows how the balking likelihood and holding up time change with expanding traffic intensities for various server arrangements. Increased balking and longer waiting times may result from lower server capacities and higher traffic intensities. For various server configurations, the graph also shows how balking probability and waiting time change with increasing traffic intensities. Higher traffic powers and lower server limits prompt expanded balking and longer holding up times.

V. CONCLUDING REMARKS

All in all, the use of the M/M/s queueing model, enhanced by the thought of balking and reneging arises as an important technique for decreasing holding up times and improving Outpatient Department (OPD) tasks in clinic settings. The study's findings shed light on the intricate dynamics of patient flow in the OPD and offer healthcare administrators and professionals insights that can be put into practice to improve operational efficiency and the overall patient experience.

The fuse of balking and reneging factors into the customary M/M/s model considers a more practical and nuanced portrayal of patient way of behaving. By recognizing the effect of patients who decide not to join a line or forsake it rashly, the model gives an exhaustive comprehension of the variables adding to delayed holding up times. This understanding is vital for recognizing likely bottlenecks inside the OPD framework and carrying out designated mediations to address them.

This study has contributed to the development of practical strategies for reducing waiting times by meticulously analyzing patient arrival patterns, service times, and the impact of balking and reneging on queue dynamics. Clinic directors can utilize these methodologies to improve asset portion, refine planning processes, and upgrade offices to make a more productive and patient-driven OPD climate. As medical services establishments endeavor to meet the developing requirements of patients and upgrade the nature of care, the bits of knowledge got from this exploration offer a guide for further developing OPD tasks. The ramifications reach out past simple holding up time decrease, enveloping more extensive improvements in asset use, staff efficiency, and, eventually, the general adequacy of medical care administration conveyance. In the consistently developing scene of medical care, where patient fulfillment and functional productivity are foremost, the utilization of the M/M/s model with recoiling and reneging contemplations addresses a critical forward-moving step. This strategy contributes to the ongoing efforts to create OPD environments that are more responsive, streamlined, and patient-friendly by aligning mathematical modeling with the complexities of real-world patient behavior. Future examination and useful executions directed by these discoveries can possibly

additionally refine and raise medical care administration conveyance, eventually helping the two patients and medical care suppliers.

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